

Towards a Global Strategy for the conservation and use of yam

In 2010, the Global Crop Diversity Trust (GCDT) commissioned the International Institute of Tropical Agriculture (IITA) to lead the development of a global strategy for the conservation and use of yam, with a focus on the edible species. The goal is to share the responsibility of maintaining in perpetuity and in *ex situ* conditions a representative sample of the existing yam diversity and to facilitate the use of this diversity for food security today and tomorrow. The development of the strategy involved a survey via a questionnaire sent to the holders and users of yam germplasm worldwide. Out of the 100 countries contacted (Fig. 1), 26 holders of germplasm returned completed questionnaires (Table 1, Fig. 2). Based on the survey outcome, invitations to attend a two-day expert consultation meeting were sent to 11 countries (Bénin, Colombia, Côte d'Ivoire, Cuba, Ghana, Japan, Mali, Nigeria, Tanzania, Thailand, Togo, and Vanuatu). A working group of 19 yam experts (9 country representatives, 9 IITA scientists, and 2 Trust representatives) met in November 2010 at IITA, Ibadan, Nigeria. During the meeting, experts shared their knowledge and vision for the conservation and use of yam genetic resources.

Part I of the present document *Shaping the global strategy for the conservation and use of yam* reports on yam conservation and use and highlights 5 themes identified as priority, based on the data captured during the survey and the expert meeting. For each theme, recommendations were made to address the main challenges faced by the conservation and use of yam genetic resources. It predominantly reflects and focuses on the African situation as inputs were mainly provided by African partners. Part II presents IITA's own conservation and use strategy for the international collection of yam. As IITA holds the largest collection and the only one that is international, the institute is likely to further guide the yam community in the development of global and concerted initiatives.

Figure 1: Countries contacted for the global survey on the conservation and use of yam.

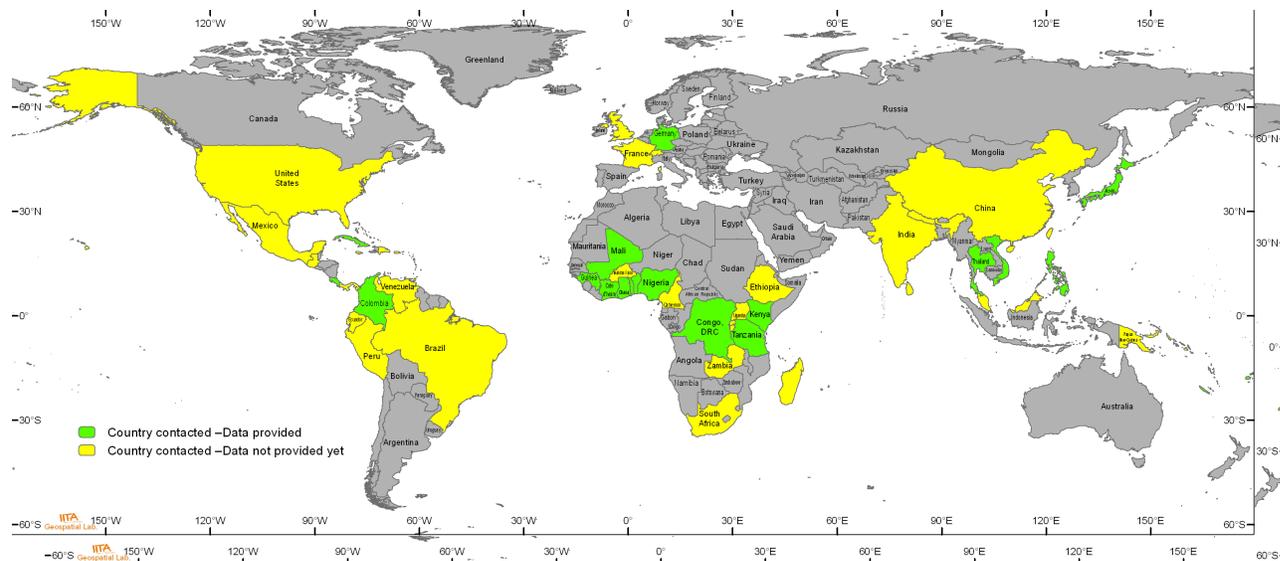


Table 1: Countries and institutes that provided input via the survey questionnaire.

Countries	Institutes
Bénin	University of Abomey Calavi
Colombia	University of Cordoba and CORPOICA
Costa Rica	University of Costa Rica
Côte d'Ivoire	Centre National de Recherche Agronomique (CNRA)
Cuba	Research Institute of Tropical Root and Tuber Crops (INIVIT)
DRC	Centre de Recherches sur l'Amélioration Génétiques des Plantes (CERAG)
Fiji Islands	Koronivia Research Station
Germany	Leibniz Institute of Plant Genetic and Crop Plant Research (IPK)
Ghana	Plant Genetic Resources Research Institute (PGRRI)
Guinea	Institut de Recherche Agronomiques de Guinée (IRAG)
Japan	Tokyo University of Agriculture; National Institute of Agrobiological Sciences; Ibusuki Botanical Garden
Kenya	National Genebank of Kenya
Mali	Institut d'Economie Rurale
New Caledonia	AICA Centre des Tubercules Tropicaux
Nigeria	National Root Crop Research Institute (NRCRI); IITA
Philippines	PhilRootcrops
Tanzania	Kizimbani Agricultural Research Station, Zanzibar
Thailand	Khon Kaen Field Crop Research Center
Togo	Institut Togolais de Recherche Agronomique (ITRA)
Vanuatu	Centre Technique de Recherches Agronomiques du Vanouatou
Viet Nam	Plant Resources Center

Towards a global strategy for the conservation and use of edible yam

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PART I

Shaping the global strategy for the conservation and use of edible yam

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1. Introduction

Yam (*Dioscorea* genus; family: Dioscoreaceae) is important for food, income, and socio-cultural events. West and Central Africa account for approximately 93% of the world's annual production of an estimated 51 million tonnes (t). The dominant production zone stretches from Côte d'Ivoire through Ghana, Togo, Bénin, Nigeria, Cameroon, Gabon, Central African Republic, and the western part of the Democratic Republic of Congo. The crop is also grown to a limited extent in several countries in East and Southern Africa and is important in Asia, northern countries of South America, as well as the Caribbean and the South Pacific islands. Yam is a multi-species, clonally-propagated crop that is cultivated for its starchy tubers. Most of the cultivated species are dioecious, with separate male and female plants, although a few species are monoecious. Of the ten cultivated species, *D. rotundata*, *D. cayenensis*, *D. alata*, and *D. trifida* are the most important. The major edible yam species from Africa are *D. rotundata* Poir. (white yam, white Guinea yam), *D. cayenensis* Lam. (yellow yam, yellow Guinea yam), and *D. dumetorum* (Kunth) (trifoliolate yam, bitter yam). Edible species from Asia include *D. alata* L. (water yam, greater yam), *D. bulbifera* L. (aerial yam), and *D. esculenta* (Lour.) Burk. (Chinese yam, lesser yam). *D. trifida* L. (cush-cush yam) is from the Americas and *D. nummularia* Lam. is from the South Pacific.

D. rotundata is indigenous to West Africa; *D. alata* is indigenous to Asia and was introduced to Africa during the sixteenth century. *D. rotundata* (2n = 40 chromosomes) and *D. cayenensis* (2n = 60 and 80 chromosomes) (also referred to as the *D. cayenensis-rotundata* complex) represent

an estimated 95% of global production. They have the highest market value owing to the superior suitability of their tubers for the preferred food uses for the crop in West Africa. *D. alata* is the most widely distributed species throughout the tropics (Asia, Pacific islands, the Caribbean, and Latin America). It includes accessions with $2n = 40, 60,$ and 80 chromosomes. Its advantages include high yield potential, ease of propagation (through the production of bulbils and reliability of sprouting), early vigor for weed suppression, and long storability of tubers. These are valuable characteristics for sustainable production but the species has a major limitation in the field; most varieties are highly susceptible to a devastating foliar disease, anthracnose, caused by *Colletotrichum gloeosporioides* Penz.

Yam (*Dioscorea* spp.) is particularly important for the millions of producers, processors, and consumers in West Africa. About 51 million t are produced on 4 million ha annually in this sub-region, mainly in five countries—Bénin, Côte d'Ivoire, Ghana, Nigeria, and Togo (Table 2). Annual increases in production, however, are due to increases in the area of land used for production, and not to improved productivity. Nigeria alone accounts for 68% of the global production (35 million t on 3 million ha). Although Nigeria is the largest producer in the region (because of the size of its population of yam farmers), more yam is produced per capita in Côte d'Ivoire, indicating that the crop is a more important contributor to farmers' incomes in that country.

Table 2: Basic statistics on the production of yam in West Africa, 2008–2009.

Region/Country	Area harvested (million ha)	Yield (t/ha)	Production (million t)	Percentage of world production	Population (million)	Production per capita (kg)
West Africa	4.44	10.83	48.1	92.99	291.27	165.1
Bénin	0.2	8.81	1.8	3.49	8.66	208.1
Côte d'Ivoire	0.82	8.45	6.93	13.4	20.59	336.7
Ghana	0.3	11.87	3.55	6.86	23.35	152
Nigeria	3.05	11.5	35.02	67.69	151.21	231.6
Togo	0.06	10.2	0.64	1.23	6.46	98.8
World	4.93	10.5	51.73	100		

Source: FAOSTAT, Updated December 2009 -Adapted from YIISWA project document.

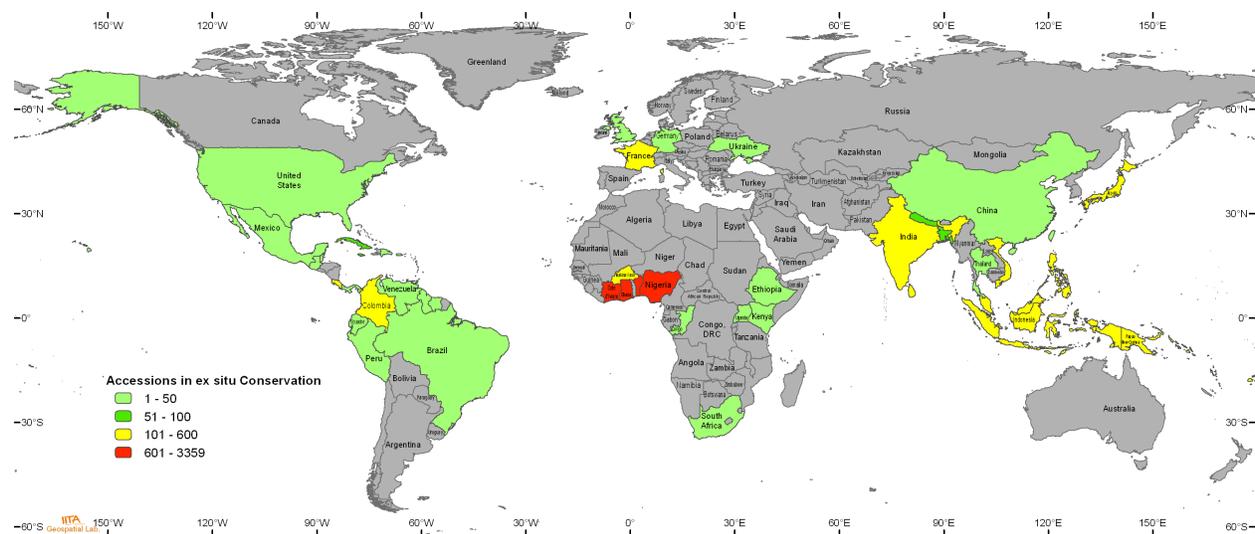
2. Priority themes

Theme 1: Yam conservation

Ex situ collections

The *Dioscorea* genus comprises over 600 species, the vast majority of which are tropical, with only a few species extending into temperate climates. According to the 2010 report on the state of the world's plant genetic resources (FAO 2010), 15,903 accessions of yam are presently maintained in *ex situ* conditions in 57 countries (Fig. 2).

Figure 2: Yam germplasm holders worldwide and number of accessions reported to be maintained in *ex situ* conditions (FAO 2010).



The questionnaire developed and sent to 100 partners for our own (IITA) survey captured information for 7516 yam accessions, i.e., approximately half of the accessions surveyed by the FAO report (Table 2). However, it complements the FAO data as some collections were not captured in the FAO records (Togo, Tanzania, and Mali). Worldwide, the most represented species in *ex situ* collections are *D. alata* and *D. rotundata* (Table 3). As these two species are those most cultivated worldwide, their predominance is expected. However, it clearly identifies the need to collect and store under-represented species/diversity. Other species reported in *ex situ* collections during the survey are *abyssinica*, *burkilliana*, *cirrhusa*, *doryphora*, *dumetorum*, *guineensis*, *hispidia*, *liebrechtsiana*, *manganotiana*, *persimilis*, *prehensilis*, *preusii*, *quartiniana*, *sansibarensis*, *shimperiana*, *togoensis*.

Table 3: Number of accessions and percentage of the collection maintained in *ex situ* conditions per species. Data extracted from FAO 2010 or from the yam global strategy survey.

Species	FAO data 2010		Survey data	
	No. of accessions	Percentage of the collection	No. of accessions	Percentage of the collection
<i>D. alata</i>	3904	24.5	2763	35.9
<i>D. bulbifera</i>	334	2.1	164	2.1
<i>D. cayenensis</i>	843	5.3	393	5.1
<i>D. esculenta</i>	662	4.2	215	2.8
<i>D. nummularia</i>	43	0.3	81	1.1
<i>D. opposita-japonica/japonica</i>	118	0.7	20	0.3
<i>D. pentaphylla</i>	68	0.4	65	0.8
<i>D. rotundata/rotundata-cayenensis</i>	4208	26.5	3631	47.2
<i>D. transversa</i>	2	0.0	10	0.1
<i>D. trifida</i>	154	1.0	35	0.5
Others/Unknown	5567	35.0	320	4.2

Details related to the collections surveyed within the development of the strategy are presented in Table 4. The largest collection is held by IITA with 3170 accessions of 8 species (Table 5). Most of the germplasm maintained in IITA is of West African origin (Fig. 3). This clearly shows the need to enrich the international collection with germplasm from other regions, at least from Africa.

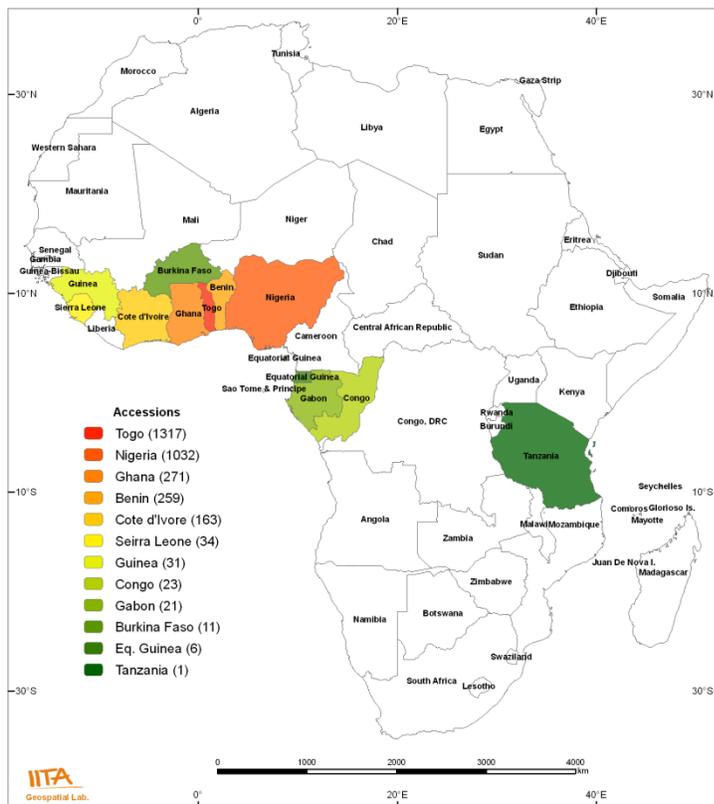
Table 4: Number of accessions per surveyed country of the 10 most cultivated species. Da =alata ; Db=bulbifera, Dc=cayenensis, De=esculenta, Do=opposite/japonica or japonica, Dn=nummularia, Dp=pentaphylla, Dr=rotundata, Dt=transversa, Dtr=trifida, Oth=Others or unspecified.

Countries	Da	Dbu	Dca	Des	Do	Dn	Dp	Dr	Dt	Dtr	Oth	Total
Bénin	101	0	51	0	0	0	0	860	0	0	0	1012
Colombia	64	8	16	16	0	0	0	32	0	16	8	160
Costa Rica	8	1	2	0	0	0	1	2	0	1	1	15
Côte d'Ivoire	233	5	16	5	0	0	0	212	0	0	58	530
Cuba	100	2	7	2	0	0	0	4	0	1	0	116
DRC	2	0	0	21	0	0	0	1	0	0	4	28
Fiji Islands	20	0	0	9	0	0	0	0	0	0	16	45
Germany	3	4	1	0	0	0	0	0	0	1	20	29
Ghana	105	15	20	15	0	0	0	159	0	0	78	392
Japan	290	17	1	7	19	73	3	1	0	1	44	456
Kenya	4	0	150	0	0	0	0	18	0	0	6	177
Mali	45	15	45	0	0	0	45	0	0	0	0	150
New Caledonia	230	2	0	5	0	0	1	5	1	0	0	244
Nigeria	46	0	13	7	0	0	0	66	0	0	0	132
Philippines	28	3	0	11	0	0	3	3	0	3	3	54
Tanzania	18	0	1	0	0	0	0	7	0	0	0	25
Thailand	23	1	0	1	1	0	3	0	1	0	3	33
Togo	30	6	2	2	0	0	0	107	0	0	5	150
Vanuatu	320	8	8	24	0	8	8	8	8	8	0	400
Viet Nam	125	1	1	68	0	0	1	1	0	0	1	198
IITA	811	68	59	19	0	0	0	2139	0	0	74	3170

Table 5: Yam species and number of accessions maintained at IITA in the international collection.

Species	Number of accessions
<i>D. alata</i>	811
<i>D. bulbifera</i>	68
<i>D. cayenensis</i>	59
<i>D. dumentorum</i>	53
<i>D. esculenta</i>	19
<i>D. manganotiana</i>	8
<i>D. preusii</i>	10
<i>D. rotundata</i>	2139

Figure 3: Geographic origin of the international collection of yam maintained at IITA.



***Ex situ* conservation**

Today's optimal conservation approach for yam is the *in vitro* slow growth of meristem-derived seedlings which allows medium-term conservation with minimum input (controlled light and temperature and one to two subcultures/year) (Dumet et al. 2007). However, yam meristem culture remains an obstacle in this *in vitro* conservation system as some accessions are recalcitrant to existing procedures. IITA, in association with JIRCAS, are presently further

investigating yam meristem for use as a conservation method.

At present, 39% of the curators maintain their germplasm in field-banks, versus 30% who maintain in both *in vitro* and field genebanks (survey data). Cryobanking (conservation at very low temperature, generally in liquid nitrogen) is not yet deployed for yam, although this conservation approach may soon be a reality. Indeed, various successful processes have already been described (Maurie and Trouslot 1996; Maurie et al. 1998; Leunufna and Keller 2003). Recent upscale trials performed at IITA showed a high level of cryo-tolerance for yam accessions (Dumet et al., in preparation). Once domesticated, cryobanking would require just a regular supply of liquid nitrogen and an occasional sample regeneration, i.e., it will become the most economically efficient option for the long-term storage of yam. IITA is further exploring yam cryopreservation in collaboration with Institut de Recherche et de Développement (IRD) and with support from GCDT.

***Ex situ* collection erosion**

One of the major concerns of germplasm holders is the erosion of their own collection, whether maintained in field or *in vitro* conditions. This is often due to low conservation standards, for example, inadequate light and temperature conditions of *in vitro* facilities from an erratic electricity supply, or the biotic and abiotic stresses (nematodes, fungi, drought, viruses, etc.) encountered in the field. When engaging in long-term conservation, financial support mechanisms are necessary to secure the maintenance and safety of this germplasm. For that reason, national holders are encouraged to transfer their germplasm to genebanks of international standard for the safe long-term conservation of their diversity. In West Africa, yam germplasm from Ghana, Togo, and Bénin is currently being duplicated for safety at IITA (through the projects on regeneration funded by GCDT). For other regions of the world, duplication hubs need to be identified. It was suggested that CATIE (Costa Rica) and/or EMBRAPA (Brazil) could play this role in Latin America as well the Secretariat of the Pacific Community for Oceania.

The varietal erosion taking place in field genebanks can be decreased when they are established in multiple sites in the agro-ecological zones of adaptation. Where reliable funds are limited and *in vitro* conservation is not an option, such a zonal genebank approach is encouraged. It is successfully used in Bénin and Japan. In the case of Bénin, the genebanks were developed at the community level and have the added advantage of facilitating the farmers' direct access to and use of germplasm.

Varietal erosion can also take place due to mislabeling during storage. Such errors were observed in the IITA collection in both *in vitro* storage and in the field bank. To reduce this recurrent problem, a bar code system avoiding hand transcription has now been implemented in IITA. Moreover, the identity of each accession is being verified. This involves re-characterizing individual accessions and matching their agro-morphological profile to the historical characterization data. Once validated, DNA or dry leaves of true-to-type samples will be banked with the appropriate accession reference.

As mentioned above, the heavy pressures on germplasm maintained in the field from pests and diseases also result in erosion from collections. Basic cultural techniques, such as propagation by vine cuttings or the use of targeted pesticide applications can help to maintain low levels of pests and diseases and their dispersion. Such technical practices are often neglected in field banking (see Theme 3).

***In situ* genetic erosion**

On-going genetic/variatal erosion of yam is difficult to evaluate as there is no baseline information on the existing diversity and only limited knowledge on the diversity presently held in farmers' fields or in *ex situ* collections. The most significant factors of genetic/variatal erosion reported by most germplasm holders are linked to agricultural development, i.e., the replacement of yam landraces by elite varieties or other crops, loss of farms, changes in farmers' practices and market demands. Climate change (drought, floods) and biotic stresses (new diseases) were also indicated as major eroding factors. Dr Alexandre Dansi (Bénin) has recently carried out a systematic inventory of landraces maintained by farmers in the zonal genebanks. Such initiatives could be deployed in other countries/regions to monitor future variatal/genetic erosion to guide the prioritizing of future collection missions.

In Africa, yam is mainly used as a food crop while elsewhere in the world, such as in Asia and Latin America, it is used as an additive ingredient for food processing (as starch in ice cream, for example), in snacks, and increasingly for pharmaceutical and other industrial applications. Generally there is a growing interest in yam (survey data) which may further endanger diversity, especially the diversity of wild yam. In Bénin, a unique population of *D. burkiliania* is being destroyed (Dansi, personal communication). In Thailand, wild yam diversity was reported endangered by the uncontrolled harvesting of the natural environment (the forest) and the expansion of communities into natural habitats (extensive housing plans, replacement of yam by other crops in the new communities). To prevent an irreversible erosion of the genepool, the collection of botanic seeds of wild species should be undertaken as soon as possible.

Recommendations for Theme 1

- 1:** Further collect and store yam diversity. If possible priority should be given to regions/countries from where samples have not yet been collected, and transferred to an international collection (e.g. ,Madagascar, Ethiopia, and Cameroon, in particular)
- 2:** Duplicate all unique accessions in genebanks with high-standard *in vitro* conservation to prevent irreversible loss
- 3:** Identify international hubs for *in vitro* safe duplication and the sanitation of yam germplasm at the regional level worldwide
- 4:** Pursue the research on cryopreservation (especially germplasm stability following cryopreservation) and implement cryobanking for yam

- 5: Raise awareness on phytosanitary issues for stored germplasm and promote best cultural practices to reduce pathogen pressures in the field genebank (see Theme 3)
- 6: Identify sustainable locations for the establishment of the yam cryobank
- 7: Validate the identity of accessions in all collections and develop DNA or dry leaves banks for appropriate reference and back-up information
- 8: Prepare inventories of the varietal diversity maintained by farmers at the national level and include information related to farmers' preferences and agro-ecological knowledge in the analysis
- 9: Collect and store botanical seeds of endangered wild yam. The IUCN Red List may help to prioritize species, at least at the global level. Collaborate with institutes, such as Kew Royal Botanical Garden, to benefit from their knowledge on yam seed storage behavior and the yam genepool
- 10: Develop conservation strategies at the national level to avoid duplication of efforts within the same country and to have a common vision at the country level

Theme 2: Yam diversity

Generally the quality of the passport data of the germplasm maintained in *ex situ* conditions is poor (survey data). Moreover, the vernacular names of landraces are often a source of confusion as some genotypes may have different names across different cultural or national boundaries, while different genotypes may have similar names from one region to another. The majority of the germplasm holders have reported using the International Plant Genetic Resources Institute (IPGRI)/IITA phenotypic descriptor list (survey data) to characterize their collections. However, there is a great disparity in the number and type of actual descriptors used per accession (only 30% use more than 20 descriptors). Further germplasm characterization is needed for most *ex situ* collections. In this regard, the use of the recently published key descriptors for yam genetic resources is encouraged (Hunter and Bhattacharjee 2009). Poor passport and characterization data impede an improved understanding of the diversity maintained in the various collections.

Except in Bénin (Dansi, personal communication), the phenotypic diversity maintained by farmers has yet to be analyzed. In the same vein, the phenotypic characterization of yam in *ex situ* collections has rarely involved farmers. Participatory characterization of yam should be encouraged for a better understanding of yam diversity in both *ex situ* collections and farmers' fields. Farmers' knowledge will provide insight to validate yam descriptors generated from scientific knowledge. It is also important to learn more about the diversity presently maintained by farmers in the different agro-ecological production zones and to understand why such diversity is maintained (farmers' preferences). This will help in re-designing breeding programs

oriented towards the needs of farmers or other users.

Molecular tools are generating highly valuable information for a better understanding of yam diversity and to reveal accessions' uniqueness and traits, i.e., to further rationalize yam *ex situ* conservation. Various molecular markers (EST-SSRs for *D. alata*, genomic SSRs for *D. cayenensis* and *D. alata*, *D. prahensis*, and *D. abyssinica*) have already been developed by IITA/VSU, JIRCAS, and IRD, and are used by various institutes (Tostain et al. 2006; Narina et al. 2010; Muluneh et al. unpublished). The sequencing of the whole genome of *D. rotundata* is underway in a collaborative project between JIRCAS and IITA with the objective of developing new generation markers, such as SNPs, for the construction of linkage maps, the identification of trait-specific QTL(s), and association mapping for marker-assisted selection in yam improvement programs. IITA is also involved in another collaborative project with Australia to develop DArT markers using *D. alata* accessions. The development of additional tools, such as EST-SSRs, SNPs, and DArTs along with species-specific genomic SSRs, will soon allow the efficient assessment of accession uniqueness and collection diversity.

IITA, in collaboration with 12 national programs (Bénin, Costa Rica, Côte d'Ivoire, Fiji, Ghana, New Caledonia, Papua New Guinea, Philippines, Solomon Islands, Togo, Vanuatu, and Vietnam) and with financial support from the GCDT, is engaged in a molecular fingerprinting project aiming at identifying unique/duplicate accessions within and across national and international collections. At that stage, molecular profiles are analyzed using both genomic and EST-SSRs.

Molecular, phenotypic, and farmers' indigenous knowledge are equally important. Their integration will reveal yam diversity and allow the definition of core or trait-based subsets at global, regional, or national level. In the case of the international collection, a core collection of 350 accessions was developed based on morpho-agronomic traits and passport data (Mahalakshmi et al. 2007). This core will need regular revision as new germplasm is acquired and included in the international collection (presently 500 entries are pending). Uniqueness, core, and sub-set information will facilitate the stratification of the global *ex situ* collection, i.e., the level of security required for the maintenance of each accession. For example, a truly rare accession with many beneficial traits of interest may be maintained in several locations using different approaches (field, *in vitro*-, cryo- or seed-bank), while only one accession of a duplicate batch will be considered for conservation in conditions of maximum safety.

Recommendations for Theme 2

11: Implement participatory phenotypic characterization trials and integrate farmers' knowledge in germplasm description. (*Note:* The model developed by Alexandre Dansi could be applied to other countries)

12: Further develop molecular tools to explore and better understand yam diversity

13: Define core and trait based subsets at national, regional, or global level to increase germplasm use

14: Develop a stratification strategy for clonal crops in collaboration with other clonal collection holders

15: Document/define primary, secondary, and tertiary gene pools for edible yam species

16: Engage taxonomists from RBG Kew (Royal Botanic Gardens, Kew, UK) or other relevant institutes in the conservation strategy to provide advice/information related to yam taxonomy and the gene pool

Theme 3: Germplasm health

Germplasm health issues are often neglected in conservation systems despite their importance in the conservation and use of the germplasm. Yam tubers are known to carry and accumulate many pests and pathogens (viruses, fungi, nematodes, insects, bacteria, etc.). As a result, collections maintained in the field can readily turn into a reservoir of pests and diseases, with damaging consequences on the viability of material, future germplasm production, dispersion of pathogens and erosion of germplasm.

Pathogens are as diverse as the germplasm they infect and pathotypes vary greatly from one region to another. As mentioned above, cultural practices can drastically reduce the pathogen load. For example, propagation by vine cuttings will eliminate tuber infection by nematodes and help to eradicate other tuber-borne pests and diseases (provided newly produced cuttings are planted in nematode-free fields), while pesticide treatments will also reduce the occurrence of insects and fungi. However, elimination of viruses is difficult to achieve. Production of planting material using meristematic tissue in several host-virus systems resulted in generation of virus-free plants. However, recent meristeming performed on the IITA field collection could not eradicate the virus load from the plant tissues. Thermo-treatments, in particular cryopreservation, are under investigation for improving yam sanitation and hold promise.

Pathogen identification and distribution as well as reliable diagnostics are essential components for the sustainable conservation and use of yam genetic resources. There is no doubt that new pests and diseases of yam are yet to be documented as diagnostic capabilities improve and activities on yam broaden. The spectrum of viruses infecting yam, for example, is broad, with but a few accurately characterized (Kenyon et al., 2003). In Uganda in East Africa, only recently the causal agent of dry rot on yam was identified as a nematode species (*Pratylenchus sudanensis*) different from the nematode pest that causes the same symptoms in West Africa (*Scutellonema bradys*) and the Americas (*Pratylenchus coffeae* and *S. bradys*) (Coyne et al. 2003; Mudiope et al. 2008). The importance to productivity and quarantine status of newly identified biotic constraints then needs to be determined. As yam becomes popular in, or is introduced to new geographic areas, so the possibility of new biotic constraints occurs. The documentation of pests of quarantine importance is also the key to rationalize germplasm distribution (to avoid unnecessary tests and guarantee those that are necessary).

More than 82% of the germplasm holders surveyed declared that they used an import permit to bring foreign germplasm into their country (survey data). However, the general national capacity for indexing and phytosanitation is low, i.e., less than 50% have indexing procedures in place and only 50% regularly receive support from their national plant quarantine service. Indexing, as well as germplasm phytosanitation is a costly process. Moreover, germplasm health expertise is often lacking in national programs. The development of plant health units specialized in monitoring germplasm for pests and pathogens, protection of genetic resources and production of clean planting material should be encouraged at a regional level. The Germplasm Health Unit (GHU) at IITA is already acting as a service for such health issues within Africa. There is an urgent need to identify other hubs in other yam growing regions. National programs where indexing and cleaning capacity already exists (e.g., Colombia, Cuba, Costa Rica, and Brazil) should be encouraged to provide such a regional service.

Recommendations for Theme 3

17: Assess pest risk to classify yam pathogens (viruses) as regulated or non-regulated quarantine pests

18: Develop protocols for the production of virus-free planting materials, using cryotherapy in particular

19: Develop simple and cost-effective diagnostic tools for the rapid assessment of *in vitro* seedlings and safe germplasm exchange

20: Create awareness about the need for safe conservation and distribution of yam germplasm, and build capacity to safeguard valuable germplasm from pests and pathogens

21: Promote the development of regional hubs for virus indexing and germplasm sanitation

Theme 4: Promoting the use of yam germplasm, and the generation and diffusion of information

Germplasm attractiveness

To date, only a small proportion of the international collection maintained at IITA has been used in yam improvement programs, and this is evident from the distribution of just 1077 accessions (from a total collection of 3170 accessions) in the last 10 years (survey data). Little information was captured about the distribution patterns in national collections during the survey but the situation is likely to be similar, if not worse. This may not be surprising, given that yam production in West Africa largely remains with farmers' varieties/landraces, with little yam breeding activity underway. In terms of access to and the use of germplasm, the participatory zonal genebanks established in Bénin are the most efficient system. In this particular case, farmers are involved in the collection process for assemblage, thus having

direct access to yam.

The regulations on germplasm sanitation and import currently limit the movement and use of yam germplasm (non-clean material) in the international collection. To date, efforts have mainly focused on describing diversity based on “academic” agro-morphological descriptors, which have somewhat neglected traits of more interest to users such as breeders. Collections need urgent screening for traits such as pest and disease resistance, as well as drought and flood tolerance. Other traits, including taste, cooking properties, techno-functional characteristics and postharvest behavior, are also missing from the existing characterization data. As described above, germplasm characterization should involve farmers or community-based germplasm holders. Moreover, for industrial and pharmaceutical applications, the private sector should be encouraged to engage in collection characterization (starch quality, secondary metabolite content, etc.).

Germplasm visibility

Another factor limiting germplasm use is the visibility and accessibility of information related to the collections. In the case of the international collection maintained at IITA, passport and characterization data are available on line (<http://www.iita.org/genetic-resources-center>) in addition to other systems, such as SINGER (<http://sgrp.cgiar.org>) and soon GENESYS (<http://www.genesys-pgr.org/>). Information related to accessions entering the international collection for safe duplication purposes will be uploaded on these CGIAR and global information systems. The acknowledgement to the data provider and the responsibility for the information so provided were discussed during the consultation. Arrangements should be made in the database to acknowledge data providers and identify the responsibility for updating the data.

Germplasm diffusion

Ninety percent of national germplasm holders distribute germplasm directly to farmers (Survey data), compared with less than 1% from the international collection. That reflects the critical role of national programs in diffusing germplasm to farmers, and is probably a much higher figure than for most seed crops. According to Alexandre Dansi, a lot of diversity available in genebanks does not reach farmers. Efforts should be made to transfer the diversity to farmers. This could be achieved by the distribution of the core collection or trait-based subsets (once developed) to national programs and/or farmers. This implies the regular characterization of newly acquired germplasm following a minimum set of descriptors under standard environmental conditions. Another approach to increase farmers’ access to diversity would be to invite farmers to research institutes to enable them to have direct access and improved awareness of new technologies, varieties, or crops and to promote the diffusion of germplasm through events such as field days. Such field days that also involve the private sector (e.g., agro-input producers or suppliers) as sponsors have proved very successful in Thailand. Similarly, farmers could be invited to visit field conservation plots maintained as international collections at IITA. This latter option has not been welcomed by all experts participating in the meeting, however, as some believed that communication problems might reduce the expected impact.

Only a few national programs are fully functional with regard to indexing and sanitation but many of them have *in vitro* facilities that can punctually mass-produce yam seedlings (even when facing difficulties in running a long-term, reliable conservation facility). Systems allowing the movement of clean germplasm from a germplasm health hub to national plant tissue culture facilities should be developed to facilitate users' access to clean germplasm. Where the plant tissue culture technology is not available, the deployment of the vine cutting technique may help in increasing the distribution of clean material. Indeed, vine cutting performed on meristem-derived *in vitro* plants showed higher rates of multiplication and can be maintained free of pathogens if multiplied under controlled conditions in the screen house (Kikuno et al. 2007; Coyne et al. 2010).

Recommendations for Theme 4

22: Evaluate accessions for traits of immediate interest for farmers/breeders and new uses (industrial, pharmaceutical)

23: Promote and implement farmer-participatory evaluation to enrich information on an international/regional/national database

24: Upgrade online documentation tools to acknowledge and identify data provider

25: Promote appropriate techniques for yam propagation such as *in vitro* propagation or vine cuttings to address health issues and increase safe germplasm distribution

26: Organize field days at national institutes to promote new technologies and varieties

27: Provide farmers with the opportunity to visit the international collections or assess their diversity

Theme 5: Capacity building and awareness

Very few scientists are dedicated to yam research worldwide. There is a need to train young staff in the field of conservation and the use of yam genetic resources. IITA is regularly involved in such trainings but preferably targets candidates who are already employed by a national institute and able to apply their newly acquired knowledge directly. Field and *in vitro* conservation manuals were recently developed and are available at <http://www.iita.org/genetic-resources-center> as well as <http://croptgenebank.sgrp.cgiar.org/http://croptgenebank.sgrp.cgiar.org/>.

Several African countries are concerned with regard to capacity building and the replacement of scientists involved in yam research. The risk of losing newly trained staff is high. Working on other crops is often more attractive because of greater funding opportunities. Joint international projects in the fields of breeding, conservation, and the value chain are needed to raise the profile of yam and attract more funds. Involving the private sector should also be

considered. Pleading for the recognition of yam research at higher decision-making levels, such as at ECOWAS for West Africa, is also to be considered. However, such advocacy is difficult to tackle.

Recommendations for Theme 5

28: Postgraduate training grants (MSc or PhD) should be secured to train future yam scientists. Such studentships should also be bonded to the national program to avoid the “brain drain”, at least for a few years

29: Whenever possible, the potential value of yam should be brought to the attention of policy-makers and other high-powered groups at national, regional, and international levels

3. Conclusions

The success of the conservation and use strategy for yam will depend on the diversity and commitment of the partners engaged, including donors, and the demands from the private sector. So far, 26 countries have provided input to the present document, i.e., at least 26 partners are engaged in the strategy. It is important to keep a nucleus of active partners to further engage others. This will happen only if the demand for yam increases, the private sector is involved in setting priorities and implementing yam conservation and use, common (regional) projects are developed, and the different working groups have pathways for communicating their respective progress. At that stage, 29 action priorities were identified by the group to shape the global strategy. The group realized that some crucial points were yet to be identified and thus further feedback is welcomed (contact ddumet@cgiar.org or toll.jane@cropptrust.org). Action is already ongoing to address some of the recommendations with the support of the GCDT, national programs, and IITA. Others priorities need the initiation of new projects, i.e., new sources of funding and more private sector-oriented participation. As observed during the expert meeting, the critical mass of scientists working on yam is limited and those engaged in some yam research activities are not dedicated to these full-time. For this reason, and depending on initiatives, yam partners should be linked with other communities working on similar issues. For example, the implementation of regional platforms will be viable only if developed with a ‘multiple crops’ focus, i.e., if partners working on other clonal crops are engaged in the strategy. IITA is presently the only institute holding an international collection, and as such plays a critical role in the long-term conservation of yam biodiversity and the sustainable use of yam genetic resources. IITA’s own strategy, described in part two of the present document, can provide guidance for the global system. However, national and regional strategies, defined more broadly for clonal crops, are needed to match and be integrated to the present document for global action to start.

The present document will be circulated to users and holders of yam germplasm worldwide. We encourage partners willing to provide feedback and/or engaged in the strategy to contact IITA (ddumet@cgiar.org; a.lopez-montes@cgiar.org) or GCDT (jane.toll@cropptrust.org). In particular, we welcome information related to *ex situ* collections of yam (those not reported in

the present document), examples of yam genetic erosion, as well as strategy documents developed at country or regional level.

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5. Annexes (Survey data in power point added)

PART II

IITA's Yam Strategy, 2011 to 2020

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1. Introduction

The new IITA strategy 2011–2020 states: “in addition to its fundamental role of collection and conservation, the Institute will expand its role in utilization of these genetic resources to support its own breeding programs and those of its partners. It will explore the genetic wealth of these precious genebank holdings to help nations respond to new food needs and biological threats, as well as adapting to climatic and environmental changes (drought tolerance, pests, soil erosion, human preferences, etc.). Many tropical countries stand to benefit from the genetic resources of other tropical nations, if these resources can be effectively managed and shared; such intra-tropical interdependence will undoubtedly increase under climate change and with it the necessity of improved collaboration, conservation, and the use of crop genetic diversity. IITA can play a central role in facilitating this collaboration and providing a stable base for ongoing efforts”.

At present, IITA's Genetic Resources Center is the only genebank maintaining an international collection of yam. As such, it is playing a key role in the conservation and use of yam genetic resources. This international collection, maintained in trust under the auspices of the United Nations, is the largest *ex situ* collection worldwide, with over 3000 accessions. However, there is broad agreement, as depicted in the IITA 2011–2020 strategy above, that more benefit could be derived from this collection and from IITA as a whole. To this end, and as a complement to the global conservation and use strategy, the IITA yam strategy was developed.

2. Guiding Principle

Explore the wealth of IITA's genebank holdings to help nations respond to increasing food needs and biological and abiotic threats, as well as adapting to climate and cultural change

3. Vision and Mission

Consistent with IITA's mission, the yam strategy for the period 2011–2020 seeks to find solutions to hunger and poverty via the increased access for farmers, processors, researchers, and the extension services to the genetic diversity of yam species

4. Objectives

1: Increase the diversity of the international collection

- The international collection of yam maintained by IITA has its limitations, i.e., the germplasm is exclusively from West Africa and one species, *D. rotundata*, is over represented (67%). A fraction of the existing yam diversity is captured in the international collection.

The IITA yam strategy calls for efforts to enrich the collection with African yam diversity, including wild relatives. This will be achieved in association with national programs via collection missions and/or transfers from national collections. Institutes, such as Kew Royal Botanical Garden, will be solicited to share their knowledge of the yam genepool and help in drafting a priority list for the acquisition of wild species. IITA supports the idea of developing at least two other international platforms dedicated to clonal crop conservation and diffusion in two other regions of the world (Asia and America) to serve the yam community.

2: Further improve conservation approaches

- Today's optimal conservation approach for cultivated yam is the *in vitro* slow growth of meristem-derived seedlings which allows medium-term conservation (12–24 months) of germplasm. Some accessions are recalcitrant to the standard meristeming process. The estimate annual cost of maintaining the international collection is US\$28/accession. Ultimately, cryopreservation will provide a longer-term conservation method and the cheapest option for yam germplasm. For *Dioscorea* wild species, long-term conservation in the form of botanical seeds is also foreseen.

*IITA will further investigate yam meristeming as well as cryopreservation via the droplet vitrification process. The sustainability of cryobanking yam in the IITA-Ibadan environment will also be analyzed. Germplasm stability following *in vitro* storage (including cryopreservation) will be investigated. Botanical seed storage will be initiated for wild species of yam.*

- At present all accessions of the international collection are maintained in the field (3 tubers/accession) and 35% of them are duplicated *in vitro* (5 seedlings/accession). In addition, approximately 40% of the *in vitro* collection is yearly transferred to Bénin for safe duplication.

*IITA will start stratifying the international collection, i.e., reviewing the conservation option for each accession: field- and/or *in vitro*- and/or possibly soon cryo- and/or seed-banking. The stratification will be based mainly on the comparative rarity of an accession (see below), cryotolerance, *in vitro* growth rate, and health status, as well as users' preferences. IITA will further investigate mass production for the faster delivery of robust *in vitro* seedlings.*

- Ongoing *in situ* conservation strategies with yam and other crops are considering as a complementary strategy involving farmers' knowledge and agro-ecosystem evolution to contribute in the conservation process.

IITA will encourage the backstopping of institutions of the national science and technology systems to implement community based conservation and use projects, linking farmers' diversity, the IITA genebank, and breeding programs.

3: Identify and trace international germplasm

- Accession passport data are often limited. As a result, duplicates have accumulated in the international collection. In the same way, sample mislabeling has led to the loss of valuable germplasm. Duplicates and mislabeled accessions undermine the conservation effort, i.e., low priority samples are maintained to the detriment of those not yet represented and/or more valuable.

IITA will further work on molecular tool development to optimize germplasm management, i.e, accession identification, rarity, and traceability. These tools will also help to set a priority for collecting missions/acquisitions. JIRCAS, which is an institution already collaborating with IITA on yam genome sequencing, is foreseen as a major partner. It is expected that close collaboration with other institutes, such as IRD, will be developed, to share and benefit from respective knowledge. After sequencing the yam genome, IITA will be conserving genes as well as accessions.

4: Improve germplasm use

- Agro-morphological and passport data are available for most yam accessions maintained in the international collection. In contrast, evaluation data which are of immediate interest for users are often missing. The diversity of the international collection has been estimated using passport and agro-morphological data only.

IITA will further engage in germplasm evaluation to better fit users' needs. IITA will lead participatory evaluation trials and the techno-functional characterization of the international collections. This work, linked with Objective 3, will generate information for genetic improvement via linkage mapping, the identification of QTLs, association mapping, and marker-assisted selection. Farmers and national programs, institutions in the science and technology system, and industry will play key roles in this mission as partners or as co-financers.

- Passport and characterization are the main data presently available to users. This information is accessible on line on IITA web site (<http://www.iita.org/genetic-resources-center>) as well as on other systems such as SINGER (<http://sgrp.cgiar.org>) and will be soon in GENESYS (<http://www.genesys-pgr.org/>).

IITA will carry on its effort on centralizing and making available newly generated data and dispatching information to global information systems for the benefit of the yam international community. An on-line catalog of elite new clones will be available too.

5: Clean germplasm for safe movement and use

- The distribution of yam from the international collection is limited because of the accumulation of viruses of quarantine importance in the germplasm. This is a major phytosanitary barrier to the international exchange of yam germplasm. Available *in vitro* tissue culture procedures are not effective in generating virus-free germplasm.

IITA will further invest in yam germplasm sanitation research. Cryo-therapy, in particular will be tested for clean seedling production. Efforts will also be focused on developing efficient virus indexing techniques to guarantee the safe conservation and distribution of germplasm.

6: Exchange knowledge with our partners

- National institutions for science and technology, advanced research institutes, farmers, and IITA have different amounts of knowledge related to the conservation and use of clonal crops. Whether academic or ancestral, all knowledge is valuable and needs to be accessible and exchanged. Private sector and industry have the potential to contribute to evaluation.

IITA will continue to build capacity in the field of biotechnology applied to the conservation and use of yam. Efforts will be augmented to increase knowledge exchange among partners to better serve the yam community. Food, feed, medicinal, and other industries will be engaged in the evaluation of yam genetic diversity to increase knowledge and, demand and so make the potential of yam a reality.

5. Conclusion

The conservation strategy 2011–2020 for yam at IITA aims at maintaining in perpetuity the international collection in harmony with worldwide partners involved in yam conservation, and promotes its use as an international public good. The strategy will be built on IITA's experience and exchange with partners.

This strategy provides elements to integrate biotechnology and natural resource management strategies in a complementary effort to raise the profile of yam at the national and international levels.

6. Acronyms and abbreviations

CATIE	Tropical Agricultural Research and Higher Education Center
CGIAR	Consultative Group for International Agricultural Research
CORPOICA	Corporacion Colombiana de Investigacion Agropecuaria
ECOWAS	Economic community of West African States
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria
GCDT	Global Crop Diversity Trust
GHU	Germplasm health Unit (IITA)
IITA	International Institute of Tropical Agriculture
IPGRI	International Plant Genetic resources Institute
JIRCAS	Japan International Research Center for Agricultural Sciences
IRD	Institut de Recherche et de Développement
VSU	Virginia State University