

CROP GENETIC RESOURCES OF AFRICA



VOLUME I

Proceedings of an International Conference
on Crop Genetic Resources of Africa

26-30 September 1988

Nairobi, Kenya

F. ATTERE, H. ZEDAN, N. Q. NG and P. PERRINO

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Proceedings of an international conference organized by the International Board for Plant Genetic Resources (IBPGR) and the United Nations Environment Programme (UNEP), in association with the International Institute of Tropical Agriculture (IITA) and the Consiglio Nazionale delle Ricerche (CNR), and held in Nairobi, Kenya, 26-30 September 1988

Edited by F. Attere, H. Zedan, N. Q. Ng and P. Perrino

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IBPGR

International Board for Plant Genetic Resources



UNEP

United Nations Environment Programme



IITA

International Institute of Tropical Agriculture



CNR

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Preface

Worldwide, food crops are increasing their yields but from ever fewer varieties. The genetic base of the world's food supply is shrinking, at an ever faster rate. The dangers in this situation are the particular concern of plant geneticists, who act as the conservators of the world's genepool of agricultural species. The genetic resources saved from extinction today may provide the solutions for tomorrow's unexpected pests or calamities. Hence germplasm conservation is an imperative for society, having an inestimable but unquestioned value.

Many changes have occurred since the first meeting on Crop Genetic Resources of Africa was held in January 1978 in Ibadan, Nigeria. This meeting was organized by the International Institute of Tropical Agriculture (IITA) and the Association for the Advancement of Agricultural Sciences in Africa (AAASA) and brought together many research scientists from Africa and other parts of the world.

In order to review past achievements and develop future strategies for African plant genetic resources conservation and utilization, the International Board for Plant Genetic Resources (IBPGR), IITA and the United Nations Environment Programme (UNEP), in association with the Consiglio Nazionale delle Ricerche (CNR) of Italy, jointly organized two workshops.

The first workshop, held at UNEP in Nairobi, Kenya, was organized from 26 to 30 September 1988 by IBPGR and UNEP, in association with IITA and the CNR, and brought together representatives and scientists from national research programs in Africa to discuss recent developments in the field of plant genetic resources. In addition, participants discussed ways to further work on conserving, collecting, evaluating and using the wide range of plant diversity in Africa. The workshop was sponsored by the following donor agencies: Finnish International Development Agency (FINNIDA), Finland; Norwegian Agency for International Development (NORAD), Norway; Swedish International Development Authority (SIDA), Sweden; and Directorate General for International Cooperation (DGIS), Netherlands.

The second workshop was held at IITA in Ibadan, Nigeria, from 17 to 20 October 1988, to address and discuss those activities and strategies as they related to the crops of special interest to IITA: cassava, cowpea, maize, plantain, rice, soybean, yams and bambara groundnut. In addition, the issues of plant quarantine regulation and safe movement of germplasm were addressed. This workshop was organized by IITA and CNR in association with IBPGR and UNEP and was sponsored by the Ministry of Foreign Affairs of the Government of Italy.

The two meetings drew a combined participation of over 200 experts and observers who represented 38 African countries and 20 international and scientific institutions in Europe and the Americas. It is hoped that through the subsequent deliberations of many officials of African countries, representatives of international organizations and experts in plant genetic resources, the recommendations of the two workshops will promote the goals of effective use of plant genetic resources and preserve the fruits of evolution of African species for posterity.

Volumes I and II of this publication constitute the proceedings of the Nairobi and Ibadan workshops, respectively. The various chapters bring together the contributions of research workers in plant genetic resources collection, evaluation, conservation, management and survey, taxonomy, cytogenetics, plant breeding and plant health. They give a picture of current activities of the international and regional institutions that are involved in plant genetic resources in Africa. The recommendations from each workshop for future action by participants and country delegates are also reported. The status reports presented by country delegates at the two workshops are to be published in volume III.

Grateful acknowledgement is made of the generous contributions of the sponsors of the workshops, for financial support in organizing the workshops and for publishing the proceedings in the two volumes. The contribution of the Organization of African Unity (OAU) in preparing volume III for publication is also gratefully acknowledged.

IBPGR	International Board for Plant Genetic Resources
UNEP	United Nations Environment Programme
IITA	International Institute of Tropical Agriculture
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Summaries of Chapters

1.1 Status and diversity of African germplasm collections maintained by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

Germplasm samples from 47 African countries have been assembled at ICRISAT. The present collections include 19,815 accessions of sorghum, 7,776 of pearl millet, 1,301 of chickpea, 906 of pigeonpea, 3,328 of groundnut and 1,788 of minor millets. Considerable diversity is found in characters studied in all crops. Descriptors for all crops, except minor millets, were jointly published with IBPGR to facilitate systematic evaluation and international exchange of information. Passport and evaluation data are maintained in the computerized database. Catalogues containing passport and evaluation data have been published for pigeonpea, are in press for chickpea and are in production for the other crops. Seeds and information are available on request to any researcher.

Le statut et la diversité des collections génétiques africaines conservées à l'institut international de recherche sur les cultures des zones tropicales semi-arides (ICRISAT)

L'ICRISAT conserve des échantillons de matériel phytogénétique provenant de 47 pays africains. Les collections comprennent actuellement 19,815 obtentions de sorgho, 7,776 de millet, 1,301 de pois chiche, 906 de pois cajan, 3,328 d'arachide et 1,788 d'espèces mineures de mil. Les caractères étudiés sur ces cultures présentent une diversité considérable. Des descripteurs concernant toutes ces cultures, à l'exception des espèces mineures de mil, ont été publiés en collaboration avec le CIRPG pour faciliter leur évaluation systématique et l'échange international d'informations les concernant. Les fiches d'identité et les données d'évaluation sont enregistrées dans un ordinateur. Des catalogues contenant la fiche signalétique et les données d'évaluation ont été publiés pour les pois cajan, et ceux concernant les pois chiche sont en cours de publication. Des catalogues consacrés aux autres plantes sont en préparation. Des semences et des informations sont fournies aux chercheurs sur demande.

1.2 The diversity of under-utilized African plant species

Africa's intertropical flora includes many useful species. In addition to timber and export wood, the mainstay of some African countries, many other resources could contribute to the development of the rural economy. These resources include a large community of plant species used as medicinal plants, fiber plants, food crops, etc.

Unfortunately, following the political independence of former African colonies, edible wild plants that were previously in high demand are now almost forgotten and have been replaced by species only recently introduced.

Fortunately, some of these species can still be found on the market, for example: *Blighia sapida* (Sapindaceae), *Brassica integrifolia* (Brassicaceae), *Chrysophyllum albidum* (Sapotaceae), *Dioscorea praehensilis* (Dioscoreaceae), *Gnetum* spp. (Gnetaceae) and *Vernonia amygdalina* (Asteraceae).

In an effort to create awareness in the international scientific community of the genetic importance of this category of under-utilized plant resources, and in the light of the recommendation of the International Conference on Food and Nutrition in Tropical Africa held in Dschang, Cameroon, 3-9 October 1949, this report describes 44 (randomly chosen) species of edible wild plants that have been split into 38 genera and 26 families.

La diversité des espèces végétales sous-exploitées d'Afrique

La flore intertropicale de l'Afrique compte de nombreuses espèces utiles. Outre le bois de transformation et les bois d'exportation qui confortent l'économie de certains Etats africains, il existe de nombreuses autres sources de revenu pouvant utilement concourir au développement de l'économie rurale de ces pays. Ces ressources consistent en une large variété d'espèces végétales classées en plantes médicinales, en plantes textiles, en plantes alimentaires, etc.

Malheureusement, après l'accession à l'indépendance politique des anciennes colonies d'Afrique, les plantes alimentaires sauvages, autrefois si recherchées, ont presque été abandonnées, au profit d'espèces d'introduction récente.

Heureusement, on trouve encore sur les marchés quelques-unes de ces espèces, par exemple: *Blighia sapida* (Sapindaceae), *Brassica integrifolia* (Brassicaceae), *Chrysophyllum albidum* (Sapotaceae), *Dioscorea praehensilis* (Dioscoreaceae), *Gnetum* spp. (Gnetaceae) et *Vernonia amygdalina* (Asteraceae).

Afin d'attirer l'attention de la communauté scientifique internationale sur l'intérêt génétique de cette catégorie de ressources végétales sous-utilisées et conformément à la recommandation de la Conférence internationale sur l'alimentation et la nutrition en Afrique tropicale, tenue à Dschang (Cameroun, 3-9 octobre 1949), nous décrivons, dans ce rapport, quarante-quatre espèces de plantes alimentaires sauvages (choisies au hasard), réparties en trente-huit genres et vingt-six familles.

1.3 Potentially valuable crop plants in a Vavilovian center of diversity: Ethiopia

The richness of Ethiopia's biological resources is well documented. Some 6,500-7,000 species of plants have been recorded in the country, of which 12% are endemic. Ethiopia is known as an important Vavilovian center of crop domestication and diversity for several important plants. More than 35 species of plants have their primary or secondary gene centers in Ethiopia.

The Plant Genetic Resources Centre/Ethiopia (PGRC/E) has collected crop plant species since its establishment in 1976; the less well-known but potentially useful plants account for about 15% of the species collected.

This paper provides a brief account of diversity in 12 potentially valuable crop plants in Ethiopia, and an outline of their usage, distribution and botanical relationships with other related genera.

Les cultures à valeur potentielle en Ethiopie, un centre de diversité de Vavilov

La richesse de l'Ethiopie en ressources génétiques est bien documentée. Des études récentes ont permis d'établir qu'il existe de 6,500 à 7,000 espèces de plantes, 12% de celles-ci étant particulièrement répandues. Depuis la théorie de Vavilov, on considère l'Ethiopie comme un important centre de domestication et de diversification pour plusieurs cultures importantes. Plus de 35 espèces se rattachent à l'Ethiopie qui constitue leur centre génétique primaire ou secondaire.

Depuis sa création en 1976, le Centre des ressources phytogénétiques de l'Ethiopie (PGRC/E) a collecté différentes espèces végétales, les plantes peu connues mais prometteuses représentant environ 15% des espèces recueillies.

Un examen succinct de la diversité de 12 espèces de cultures potentielles de l'Ethiopie est présenté ainsi que l'utilisation, la répartition, la diversité de ces plantes et leurs relations avec des variétés apparentées.

1.4 Forage species diversity in Africa: An overview of the genetic resources

There is a high level of diversity among forage plants in Africa. The phanerogamic flora of Africa comprises a minimum of 60,000 species, about 20,000 of which are consumed by livestock and large wild herbivores. African plants used in routine farming around the world amount to little more than 100 species of grasses, 100 legume species and some 20 other species. However, the contribution of African species to the tropical pasture and fodder genepool of the world is very important for grasses (70-75%) and moderate for legumes (25-35%).

Judging from the few species that have been subject to manipulation, genetic variability seems to be high. The only agroforestry tree used widely throughout inter-tropical Africa, *Faidherbia albida*, seems to include a wide array of populations within which individual variability is also high and, seemingly, genetically controlled. High degrees of variability are also found in species in which vegetative propagation is the usual method of multiplication under cultivation: *Panicum maximum*, *Pennisetum purpureum*, *P. clandestinum* and *Opuntia ficus-indica*. Other species, such as *Digitaria decumbens*, *Paspalum commersonii* and the *Brachiaria*, seem much less variable. Browse potential for agroforestry is high but largely under-utilized.

La diversité des espèces fourragères africaines: Un aperçu des ressources génétiques

L'Afrique recèle une très grande diversité d'espèces fourragères. La flore phanérogamique comprend au moins 60,000 espèces, dont environ 20,000 sont consommées par le bétail et les grands herbivores sauvages. Les plantes africaines exploitées par l'agriculture courante dans le monde ne dépassent guère 100 espèces de graminées, 100 de légumineuses et quelque 20 autres espèces diverses. Mais la contribution des espèces africaines aux pâturages et au pool génétique des espèces fourragères au niveau mondial est très importante pour les graminées (70-75%) et modeste pour les légumineuses (25-35%).

La variabilité génétique est élevée, si l'on en juge par les quelques espèces qui ont été soumises à des manipulations. Le seul arbre largement utilisé en agro-sylviculture dans l'ensemble de l'Afrique tropicale, *Faidherbia albida*, semble comprendre un grand échantillon de populations dans lesquelles la variabilité individuelle est également élevée et apparemment régularisée génétiquement. On trouve aussi de hauts niveaux de variabilité pour les espèces dont le mode habituel de reproduction est la propagation végétative quand elles sont cultivées: *Panicum maximum*, *Pennisetum purpureum*, *P. clandestinum* et *Opuntia ficus-indica*. D'autres, telles que *Digitaria decumbens*, *Paspalum commersonii* et *Brachiaria*, semblent présenter une variabilité bien moindre.

2.1 Ecogeographical survey of African species

Plants native to harsh environments are generally believed to be better adapted to their environments, and therefore less diverse, than those growing under more favorable conditions. In parts of Africa, notably the Sahel, considerable genetic diversity may already have been lost to desertification. It is

especially important, therefore, to conserve the remaining sources of germplasm for crop and forage breeding.

IBPGR plans to survey the genetic diversity of selected Sahelian species to determine variation on an ecogeographical basis. Field studies will be supplemented by laboratory investigations of genetic diversity. The collaboration of interested agencies is invited.

Etude éco-geographique des espèces africaines

On estime que les plantes provenant de régions où l'environnement est difficile sont d'ordinaire particulièrement bien adaptées à leur environnement et présentent, de ce fait, moins de variétés que celles qui poussent dans des conditions plus favorables. Dans certaines parties d'Afrique, en particulier au Sahel, la diversité génétique a sans doute sensiblement diminué en raison de la désertification. Il est donc particulièrement important de conserver les collections génétiques restantes pour améliorer les cultures et les fourrages.

Le CIRPG a l'intention d'étudier la diversité génétique de certaines espèces sahéliennes pour déterminer les variations techniques écogéographiques. Les études sur le terrain seront complétées par des études sur la diversité génétique effectuées en laboratoire. Les organismes intéressés sont invités à participer aux travaux.

2.2 The potential use of the Global Resources Information Database (GRID) in plant genetic resources activities

Work in plant genetics involves consideration of a variety of environmental and geographical parameters. Geographic information systems (GIS), which are powerful tools for integrating and analyzing diverse spatial data, could fulfill an important function. UNEP's Global Resources Information Database (GRID) section has considerable experience in helping organizations such as IBPGR to realize the potential of GIS technology.

Le potentiel d'utilisation de la base de données sur les ressources mondiales (GRID) dans le cadre des activités sur les ressources phytogénétiques

Les phytogénéticiens doivent tenir compte de différents paramètres écologiques et géographiques. Les systèmes d'informations géographiques, extrêmement utiles pour intégrer et analyser des données disparates, pourraient jouer un rôle important. La base des données sur les ressources mondiales (GRID) administrée par le PNUE a acquis une expérience considérable en aidant des organisations telles que le CIRPG à tirer parti des techniques dont disposent ces systèmes.

3.1 Long-term seed conservation

The improvement of seed longevity and the prediction of seed viability under storage are discussed. The standards for long-term seed conservation are reviewed. The paper demonstrates that the seeds of some crops, particularly cowpea, can probably be stored for 50-100 years in conditions which are relatively simple to establish. It is suggested that the standards for storing base collections be relaxed to encourage more national programs to preserve germplasm. Nevertheless, because there are genotypic differences in seed longevity within species, the author urges that the viability of seeds under storage should be

monitored to prevent the loss of germplasm during storage. The system of seed conservation at IITA, Ibadan, Nigeria, is described.

La conservation à long terme des semences

La présente étude traite des techniques qui permettent d'améliorer la longévité des semences et de prédire la viabilité des semences stockées. En outre, elle examine les normes appliquées en matière de conservation à long terme. Enfin, elle démontre que certaines semences, notamment celles du niébé, sont probablement conservables de 50 à 100 ans dans des conditions faciles à réunir. Il est proposé d'assouplir les normes concernant le stockage des collections de base afin d'inciter les pays à inclure la conservation du plasma germinatif dans les programmes. Toutefois, comme au sein d'une même espèce les génotypes manifestent des caractères de longévité différents, il est recommandé de contrôler la viabilité des semences stockées pour éviter les pertes. Enfin, le système utilisé pour la conservation des semences à l'IITA d'Ibadan, Nigéria, est décrit.

3.2 Conservation of forest species in Africa

Over the past few years, cooperative international efforts, in which United Nations agencies have been prominent, have generated extensive soil vegetation and ecological syntheses on Africa. This has consolidated over 50 years of data assembly on Africa's forest trees and their environments and offers Africa the world's most comprehensive framework for developing tropical forest genetic resource programs. The technical advances coincide with the consolidation of political processes. At national level throughout Africa there is government recognition of the need to sustain resource potential through informed conservation strategies. At international level a promising development has been the creation of better-defined funding channels for assistance in implementing conservation programs.

The task for the immediate future is to take advantage of the present favorable climate of opinion by translating enlightened policy into practical action at field level. A two-stage process is applicable. First, information existing at national level must be integrated to provide national frameworks to complement those now available for the continent. Second, new field programs devised with current resource analysis objectives in mind should be undertaken to clarify resource status and promote genepool conservation and utilization. For forest trees, approaches that can contribute to these processes may be species oriented, locality oriented or national in scope.

La conservation des espèces forestières en Afrique

Au cours de ces dernières années, la coopération internationale, dans laquelle les organismes des Nations-unies jouent un rôle de tout premier plan, a permis de réaliser, à l'échelle de l'Afrique toute entière, des synthèses sur les sols, la végétation et l'écologie. Ces études, qui sont l'aboutissement de plus de 50 années de travaux axés sur la collecte des données relatives aux espèces forestières africaines et à leur environnement, fournissent à l'Afrique une base unique au monde pour assurer la mise en oeuvre de programmes de conservation des ressources génétiques des forêts tropicales. Les progrès enregistrés sur le plan technique sont accompagnés d'une évolution favorable des politiques. Partout en Afrique, les gouvernements se rendent compte qu'il est nécessaire de préserver les ressources à l'aide de stratégies de conservation bien pensées. Sur le plan international, on constate également une évolution prometteuse du fait que les circuits de financement des programmes de conservation tendent à s'améliorer.

Dans l'avenir immédiat, il faudra profiter davantage du courant d'opinion actuellement favorable en s'assurant que les politiques judicieuses proposées se traduisent dans les faits, ce qui pourrait se faire en deux temps. Dans un premier temps, les pays intégreraient les informations dont ils disposent de

façon à compléter les connaissances disponibles à l'échelle de l'Afrique. Dans un second temps, ils élaboreraient de nouveaux programmes en tenant compte des objectifs actuels en matière d'analyse des ressources de façon à déterminer l'état de ces dernières et à encourager la conservation et l'utilisation des collections des gènes. Des études des forêts par espèce, région ou pays contribueraient à ces activités.

3.3 *In vitro* conservation

The use of *in vitro* techniques for the conservation of crop germplasm is a valuable tool for those species that do not produce seeds, species whose seed cannot be stored for long periods and vegetatively propagated species whose seeds are formed by outbreeding and cannot be used to preserve clonal genotypes. The techniques, principles and value of *in vitro* conservation are discussed and examples from appropriate crops given.

La conservation *in vitro*

L'utilisation de techniques *in vitro* pour la conservation des ressources génétiques est particulièrement utile pour la conservation des espèces qui ne produisent pas de graines, les espèces dont les graines ne peuvent être stockées pendant de longues périodes, ou des espèces à reproduction végétative dont les graines se forment par hybridation et ne permettent pas la conservation des génotypes. Les techniques et les principes de la conservation *in vitro* des plantes sont examinés en se référant à des exemples appropriés.

4.1 *In situ* conservation of plant genetic resources: United Nations Educational, Scientific and Cultural Organization (UNESCO) program in Africa

The UNESCO Man and Biosphere Programme (MAB), launched in 1971, is a worldwide program of international scientific cooperation dealing with people-environment interactions in the whole range of bioclimatic and geographic situations of the biosphere, from polar to tropical zones, from islands and coastal areas to high mountain regions, from sparsely populated regions to dense human settlements.

Research under MAB is designed to provide the information needed to solve practical problems of resource management. It also aims to fill the still significant gaps in the understanding of the structure and function of ecosystems, and of the impact of different types of human intervention. Under MAB, a system of biosphere reserves has been established. These are representatives of ecological systems which are protected for their intrinsic ecological value; they form the core of UNESCO's conservation program through the protection of indigenous plant and animal communities.

Africa contains six biosphere reserves in 30 countries. These reserves form a network of cooperation in the exchange of scientific information on plant resources and their management and provide a basis for further research and training of conservation personnel.

La conservation *in situ* des ressources phytogénétiques: Le programme de l'Organisation des nations unies pour l'éducation, la science et la culture (UNESCO) en Afrique

La conservation *in situ* Le programme 'l'homme et la biosphère', lancé en 1971 par l'UNESCO, est un programme mondial de coopération scientifique qui s'intéresse à l'interaction des hommes et de

l'environnement dans tout l'éventail des conditions bioclimatiques et géographiques que présente la biosphère, des pôles aux tropiques, des formations insulaires aux régions de hautes montagnes, des zones faiblement peuplées aux régions à forte densité de population.

Par ses recherches, ce programme vise à réunir les renseignements qui permettraient de résoudre certains problèmes pratiques de gestion des ressources. Il vise en outre à combler les lacunes encore importantes dans notre connaissance de la structure et du fonctionnement des écosystèmes et de l'impact des interventions de l'homme sous toutes leurs formes. Des réserves de la biosphère ont été établies au titre du programme. Elles sont représentatives de systèmes écologiques protégés en raison de leur valeur écologique et elles occupent une place des plus importantes dans le programme de conservation de l'UNESCO, car elles assurent la protection de plantes indigènes et de certaines espèces animales.

L'Afrique compte quelque 36 réserves de la biosphère situées dans une trentaine de pays. Ces réserves forment un réseau d'échanges d'informations scientifiques sur les ressources phytogénétiques et leur gestion. Elles sont en outre le cadre d'activités de recherche et de formation complémentaires pour les spécialistes de la conservation.

4.2 The role of indigenous vegetation in the conservation and maintenance of ecological stability

The philosophy of conservation for sustainable development is discussed in the 'World Conservation Strategy', a conservation approach developed by IUCN. The three main concepts of the strategy are: maintenance of essential ecological processes, preservation of genetic diversity and the sustainable utilization of species and ecosystems. Another philosophical approach recognizes that the extinction of species and ecosystems by human intervention is undesirable. People have come to recognize that, in the long term, the natural heritage is as important as the cultural heritage.

Most natural vegetation communities found on Earth are in some stage of succession. Either they are moving toward climax conditions which are relatively stable or they are moving away from the climax stage to a more unstable secondary stage. What we observe in the real world are vegetation communities which are fragmented, harvested and polluted. All these are different types of stresses which are caused by man and his technology. It is important that as conservationists we try to understand how we should protect plant communities from these stresses.

Le rôle de la végétation indigène dans la conservation et le maintien de la stabilité écologique

Les principes de la conservation orientée vers un développement durable sont expliqués dans la 'Stratégie mondiale pour la conservation,' texte publié par l'UICN, qui est un classique en la matière. La Stratégie mondiale est articulée sur trois grandes idées: préserver les processus écologiques essentiels, maintenir la diversité génétique, et s'assurer que les espèces et les écosystèmes sont exploités de façon viable. Parallèlement, on condamne la destruction par l'intervention humaine d'espèces et de certains écosystèmes naturels. Les hommes ont fini par comprendre qu'à long terme il est aussi important de protéger le patrimoine naturel que de sauvegarder le patrimoine culturel.

La plupart des communautés végétales naturelles de notre planète sont en état de transition: soit elles progressent vers un état optimal caractérisé par une relative stabilité, soit elles régressent vers un état de moindre stabilité. C'est pourquoi la planète offre le spectacle de communautés végétales fragmentées, exsangues et polluées. Ceci est le résultat des agressions exercées par l'homme et ses techniques. Il importe qu'en tant que spécialistes de la conservation nous essayions de déterminer les moyens de protéger les communautés végétales contre ces agressions.

4.3 *In situ* conservation and monitoring of rangeland genetic resources

In situ conservation, which is usually applied to wild species, conserves the genetic resources in their natural habitat and allows interaction among different species. Multispecies communities evolve which have high plant diversity. However, the *in situ* conservation method is not always politically acceptable. Conflict often arises between conservation and modern agriculture, the latter offering more obvious economic gain.

In this paper, several methods of *in situ* conservation and monitoring are discussed at length, with special reference to Kenya. Genetic resources can be conserved by establishing national parks, controlling livestock numbers, proper grazing management, controlling fires, rehabilitating rangelands and carrying out enough research on medicinal plants to minimize wasteful harvesting.

Monitoring the rangelands for the changes taking place can be effected through: assessment of range condition and range trend; aerial and satellite surveys; and storage of the data collected using modern GIS technology. More than 70% of Kenya is made up of rangeland.

La conservation *in situ* et la surveillance des ressources génétiques des parcours

La conservation *in situ* généralement appliquée aux espèces sauvages permet de conserver les ressources génétiques dans leur habitat naturel. Elle permet des interactions entre espèces différentes, ce qui favorise l'apparition de communautés constituées d'espèces multifformes. Cependant, la méthode de conservation *in situ* n'est pas toujours acceptable sur le plan politique. La conservation se heurte souvent à l'agriculture moderne qui présente des avantages plus évidents sur le plan économique.

La présente étude explique de façon détaillée plusieurs méthodes de conservation et de surveillance *in situ*. Il est possible de conserver les ressources génétiques en créant des parcs nationaux, en contrôlant l'accroissement de l'élevage, en assurant la gestion des pâturages, en luttant contre les feux de brousse, en remettant en état les terrains de parcours et en effectuant davantage de recherches sur les plantes médicinales pour réduire au minimum les pertes à la récolte.

La surveillance des terrains de parcours permet de déceler les changements qui apparaissent en évaluant l'état du terrain de parcours, les tendances qui s'y manifestent, en réalisant des levés aériens, en utilisant les images obtenues par satellite et en stockant les données recueillies dans un système d'informations géographiques utilisant des techniques modernes (GIS). Plus de 70% de la superficie du Kenya est constituée de terrains de parcours.

5.1 Rice evaluation in Africa

Rice evaluation is a continuous process in Africa. New collections and introductions are continuously assessed to find new desirable traits for breeding programs or for direct use as a commercial variety. The evaluation is on two levels: evaluation of indigenous unimproved cultivars; and evaluation of improved cultivars, whether developed in the region or exotic.

The international centers are at the forefront of systematic germplasm evaluation in Africa, but they work in collaboration with national programs. For example, IRAT, ORSTOM, IITA and WARDA have evaluated hundreds of African collections over the years, several of which (such as LAC 23, Morobekan and GISSI 27) have been identified as possessing useful traits such as resistance to blast, yellow mottle virus, upland soil acidity, acid sulfate soil and iron toxicity. In the evaluation of improved cultivars, several varieties have been released and are currently being grown in different parts of Africa. These include Iguape Cateo, OS6, Jaya, Ikong Pao, Taichung Native No. 1, Suakoko 8, IITA cultivars and several IRRI cultivars.

L'évaluation du riz en Afrique

En Afrique, l'évaluation du riz est un processus permanent. Les nouvelles collections et introductions sont continuellement évaluées dans le but d'identifier de nouveaux caractères souhaitables pour les programmes de sélection ou pour l'introduction directe de variétés commerciales. L'évaluation porte sur deux niveaux: les collections des cultivars indigènes non améliorés et les cultivars améliorés, à la fois cultivés dans la région et exotiques.

Les centres internationaux jouent un rôle de premier plan dans l'évaluation systématique du matériel génétique en Afrique, mais travaillent en collaboration avec les programmes nationaux. Ainsi, l'IRAT, l'ORSTOM, l'IITA et l'ADRAO ont évalué au fil des ans des centaines de collections africaines, dont plusieurs (par exemple LAC23, Morobekan et GISSI 27) ont été identifiées comme possédant des caractères utiles, tels que la résistance aux brunissures, au virus de la mosaïque jaune, à l'acidité des sols des hautes-terres, aux sols acido-sulfateux ou à la toxicité du fer. Lors de l'évaluation de cultivars améliorés, plusieurs variétés ont été diffusées et sont actuellement cultivées dans diverses régions d'Afrique, notamment Iguape Cateo, OS6, Jaya, Ikong Pao, Taichung Native No. 1, Suakoko 8, des cultivars de l'IITA et plusieurs de l'IRRI.

5.2 Bean evaluation in Africa

The system of evaluating beans, *Phaseolus vulgaris*, in Africa is largely the same as elsewhere. Much emphasis has been placed on yield, drought tolerance, disease and pest resistance and nitrogen fixation. A number of promising varieties have been identified in each of these areas.

The continent continues to receive more bean genetic resources from other sources, which increase the bean gene pool, offering valuable opportunities for evaluating the crop.

Future bean evaluation should aim at supporting the current objectives, but additional effort should be spent on evaluating bean mixtures and bean performance in mixed cropping. More emphasis should also be put on evaluating other cultivated species of *Phaseolus* and the wild gene pool.

L'évaluation du haricot en Afrique

Les méthodes d'évaluation du haricot, *Phaseolus vulgaris*, utilisées en Afrique ne diffèrent guère de celles des autres pays. L'accent a été surtout mis sur le rendement, la résistance à la sécheresse, aux maladies et aux parasites, et sur la fixation de l'azote. Un certain nombre de variétés prometteuses ont été identifiées pour chacune de ces caractéristiques.

Le continent africain continue de recevoir des ressources génétiques du haricot venues d'ailleurs. Ce développement du pool génétique du haricot offre d'importantes possibilités en ce qui concerne l'évaluation de cette espèce.

L'évaluation du haricot devrait à l'avenir viser à soutenir les objectifs actuels. Cependant, des efforts supplémentaires doivent être faits pour évaluer les mélanges de haricot et le comportement du haricot en cultures mixtes. On devrait également mettre davantage l'accent sur l'évaluation des autres espèces de *Phaseolus* cultivées et sur le pool génétique de ses espèces sauvages.

5.3 The regional program on beans, *Phaseolus vulgaris* L., in southern Africa: Strategy and progress in plant improvement

This paper traces the origin, production and cropping systems of beans in Africa, drawing upon examples mainly from the SADCC region of Southern Africa, and describes the objectives, organiza-

tion and philosophy of the CIAT Bean Program in Africa. The authors review the status of bean breeding on the continent, focusing on the existing cultivars, and recent developments in plant improvement, drawing on achievements in Tanzania, Malawi and Zambia.

Attention is drawn to the immediate substantial benefits from access to the large genetic resources and new breeding materials available from CIAT and other centers. Ecological classification of bean-producing areas in Africa is helping to identify similarities between locations. Sites in Colombia, where selection and evaluation are conducted by CIAT, have been characterized in the same way. It is suggested that these environment analyses should enable us to interpret and perhaps predict genotypic behavior, so that the flow and deployment of materials from Colombia to Africa, as well as within Africa, may be more effective and efficient. Such a strategy should provide a basis for future bean improvement.

Le programme régional sur le haricot, *Phaseolus vulgaris* L., en Afrique australe: Stratégie et progrès en amélioration génétique

Ce document retrace l'origine, la production et le système de culture du haricot en Afrique à l'aide d'exemples concernant particulièrement la région de la SADCC de l'Afrique australe et décrit les objectifs, l'organisation et la philosophie du programme sur le haricot que mène le CIAT en Afrique. Il comporte un examen de l'état des travaux de sélection du haricot sur le continent, centré sur les cultivars disponibles et les récents progrès réalisés dans l'amélioration des espèces, comme en témoignent les résultats obtenus en Tanzanie, au Malawi et en Zambie.

On attire l'attention sur l'importance des avantages immédiats que procure l'accès aux vastes ressources génétiques et aux nouveaux matériels de sélection dont disposent le CIAT et d'autres centres. La classification écologique des zones de production du haricot en Afrique aide à identifier les similitudes entre régions. En Colombie, des sites, où le CIAT procède à des travaux de sélection et d'évaluation, ont été caractérisés de la même façon. On indique que ces analyses de l'environnement permettraient d'interpréter et peut-être de prédire les comportements génotypiques de façon à rendre plus efficaces et plus précis les apports et la diffusion de matériel provenant de Colombie en Afrique, ainsi qu'à l'intérieur de l'Afrique. Une telle stratégie pourrait être à l'origine de futures améliorations du haricot alimentaire.

5.4 Food legume germplasm evaluation and utilization, with special reference to Moroccan chickpea landraces

Food legumes are grown on 650,000 ha of North Africa, the principal producer being Morocco, which plants 66% of the total food legume area in the Maghreb countries.

ICARDA gives special attention to food legume research in West and North Africa. Its Genetic Resources Unit, set up after the Food Legume Improvement Program evaluated diverse germplasm collections, works jointly with relevant commodity programs, focusing on descriptive characterization.

This paper gives a brief account of the history of food legume development work in Morocco and Tunisia. Chickpea improvement projects in Morocco, where high-yield, winter-sowing cultivars are being developed, are also discussed.

L'évaluation et l'utilisation du germoplasme des légumineuses alimentaires avec mention spéciale des races de terroir marocaines de pois chiche

En Afrique du Nord, les légumineuses alimentaires occupent 650,000 ha, le principal producteur étant le Maroc, qui détient 68% de la superficie totale plantée en légumineuses alimentaires dans les pays du Maghreb.

L'ICARDA, qui accorde une attention particulière à la recherche sur les légumineuses alimentaires en Afrique du Nord et de l'Ouest, a créé son unité de ressources génétiques après que le Programme d'amélioration des légumineuses alimentaires ait évalué diverses collections de matériel génétique. L'unité travaille conjointement avec les programmes portant sur les produits concernés et se consacre principalement à la caractérisation descriptive.

Ce chapitre résume l'historique des travaux d'amélioration des légumineuses alimentaires menés au Maroc et en Tunisie. Les projets d'amélioration du pois chiche réalisés au Maroc, où des cultivars à hauts rendements en semis d'hiver sont actuellement mis au point, sont aussi présentés.

5.5 Preliminary investigations into the diversity of wild finger millets in West Africa

Evaluation work on wild millet, *Pennisetum glaucum* subsp. *monodii*, collected by ORSTOM, IBPGR and ICRISAT since 1985 in Niger, Burkina Faso, Mali, Senegal and Mauritania, has begun. Morphological and agronomic traits are being observed and isoenzyme studies are being carried out. Wild millet seems to fall into two major and distinct geographical families: the Mauritanian family, found in Mauritania, Senegal and western Mali, north of latitude 14°N; and the Niger family, found in the Air and Adrar des Iforas mountains, the great Tilemsi and Azaouak valleys, the Gourma plateau, the Ader Deutchi hills and the Tiguidit cliff.

The Mauritanian family differs from the Niger family in that it flowers later, is taller and has a different isozyme. In each family there is a contrast between the wild millet of the pastoral zone and that of the agricultural zone where the two, wild and cultivated varieties coexist. The 'pastoral' wild millet is distinguishable from the 'agricultural' variety by the absence of intermediate botanic forms in their lineage. This distinction is illustrated by a less hardy vegetation, less enzymatic diversity and high sensitivity to mildew, as observed at the research station. Even in agricultural zones, both the Mauritanian varieties and the Niger varieties of wild millet are enzymatically different from their cultivated counterparts. The enzymatic diversity of wild millet is less than that of cultivated Sahelian varieties.

Premières investigations sur la diversité des mils pénicillaires sauvages de l'Ouest africain

L'évaluation des mils sauvages, *Pennisetum glaucum* subsp. *monodii*, collectés depuis 1985 par l'ORSTOM, le CIRPG et l'ICRISAT, au Niger, au Burkina Faso, au Mali, au Sénégal et en Mauritanie a commencé. On procède à des études morphologiques, enzymatiques et agronomiques. Ces mils sauvages semblent former deux grandes familles géographiques distinctes: la famille mauritanienne qui occupe la Mauritanie, le Sénégal et l'Ouest malien au nord du 14° parallèle, et la famille nigérienne qui occupe les monts de l'Aïr et de l'Adras des Iforas, les grandes vallées du Tilemsi et de l'Azaouk, le plateau du Gourma, les collines de l'Ader Deutchi et la falaise de Tiguidit.

La famille mauritanienne se distingue de la famille nigérienne par des floraisons plus tardives, une taille plus élevée et des compositions enzymatiques différentes. Au sein de chaque famille existe un contraste entre les mils sauvages de la zone pastorale et ceux de la zone agricole dans laquelle coexistent les deux formes sauvage et cultivée. Les mils sauvages 'pastoraux' se distinguent des mils sauvages 'agricoles' par l'absence de formes botaniques intermédiaires dans leurs descendance. Ceci se manifeste par une végétation moins vigoureuse, une diversité enzymatique moindre et une forte sensibilité au mildiou, comme en témoignent les observations en station. Les mils sauvages, tant mauritaniens que nigériens, même en zone agricole, sont enzymatiquement distincts des mils cultivés voisins. La diversité enzymatique des mils sauvages est inférieure à celle des mils cultivés sahéliens.

5.6 Conservation and utilization of wild coffee

This paper reviews the taxonomy of wild *Coffea* species. A brief description of the vegetation types, where the wild Mauritian *Coffea* grows, is given. The conservation work undertaken on the wild *Coffea* species in the Mascarenes region, particularly in Mauritius, is discussed. Although no utilization work has been undertaken on the Mascarene species, the potential of the species in producing hybrids is discussed and a few possible lines of research are suggested. A proposal is made for the production of a regional and world monograph for the genus *Coffea*.

La conservation et l'utilisation du caféier sauvage

Ce chapitre qui est consacré à un examen succinct de la taxonomie des espèces sauvages du café décrit brièvement les types de végétation où poussent les espèces sauvages du café mauricien. Il traite des travaux de conservation dont font l'objet les espèces sauvages du café des Mascareignes, en particulier celles de l'Ile Maurice. Aucun travail en vue d'exploiter les espèces des Mascareignes n'est actuellement en cours néanmoins, on trouvera des suggestions sur les potentialités qu'elles renferment en matière d'hybridation et sur quelques possibilités de recherche, ainsi qu'une proposition concernant la production d'une monographie régionale et mondiale du café.

5.7 The importance of the herbarium in plant genetic resources exploration in Africa

Africa has a great need for national herbaria to play a significant role in genetic resource exploration. In plant research and the search for new foodstuffs, the herbarium is an excellent starting point. Along with each specimen there is documentation covering the basic data required for the plant's classification and the uses to which it can be put. It is a primary source for field researchers.

The herbarium fosters accurate plant taxonomy, which reduces the confusion caused by the use of vernacular names. This clearly illustrates the relationships between species in a single genus, indicating similar characteristics.

Access to phytogeographical information is greatly facilitated and herbaria are also a source of ecological data on plant habitat, which are vital to the understanding of plant behavior under changing conditions. The herbarium is also a source of information for government conservation agencies on the distribution and the conservation status of plant species, and can indicate the areas where intervention is required.

L'importance de l'herbier dans l'exploration des ressources phytogénétiques en Afrique

L'Afrique a grand besoin d'herbiers nationaux qui lui permettront de jouer un rôle important dans l'exploration des ressources génétiques. L'herbier constitue un point de départ très utile pour la recherche sur les plantes et la quête de nouveaux produits alimentaires. Chaque spécimen est accompagné d'une documentation comprenant les données de base nécessaires à la classification des plantes et à leurs utilisations possibles. Il constitue un outil indispensable pour les chercheurs de terrain.

En encourageant la taxonomie précise des plantes, l'herbier évite la confusion provoquée par l'emploi de noms indigènes. L'indication de caractéristiques similaires illustre clairement les rapports entre espèces appartenant au même genre.

L'accès aux informations phytogéographiques est grandement facilité et les herbiers constituent aussi une source de données écologiques sur l'habitat des plantes, indispensable à la compréhension du

comportement des végétaux lorsque les conditions varient. L'herbier contient aussi des informations utiles pour les agences nationales de conservation sur la répartition et l'état de conservation des espèces végétales et peut indiquer les zones où il est nécessaire d'intervenir.

6.1 Countries' activities summary

This chapter summarizes the three main factors contributing to the loss of genetic diversity in Africa: manipulation of living habitats; selection pressure; and advance of the Sahara and other natural catastrophes

Many countries have realized the importance of plant collection and conservation, and forestry departments have played an important role in Nigeria and Kenya. Ministries of Agriculture are, however, at the center of these activities, and in Sudan and Mauritius have actively engaged in crop diversification. Coordination of plant germplasm conservation is nonetheless difficult where no plant genetic resources center exists. Most countries are making progress toward establishing such centers, but some have not yet made any plans.

The paper discusses the various conservation activities taking place, including *in vitro* culture conservation, cryopreservation, *in situ* biosphere reserves and work on plantations and in farmers' fields. The problems and progress in characterization, rejuvenation and utilization are discussed, and the importance of field documentation and training is stressed.

Résumé des activités nationales

Ce chapitre résume les trois principaux facteurs contribuant à la perte de diversité génétique en Afrique: la manipulation des habitats vivants, la pression de la sélection, ainsi que l'avancée du Sahara et autres catastrophes naturelles.

De nombreux pays ont compris l'importance de la collecte et de la conservation des végétaux; des départements des forêts ont joué un rôle important au Nigéria et au Kenya. Les ministères de l'agriculture sont toutefois au centre de ces activités; au Soudan et à l'Ile Maurice, ils ont participé activement à la diversification des plantes. Néanmoins, la coordination de la conservation du matériel phylogénétique est difficile lorsqu'il n'existe pas de centres de ressources phylogénétiques. La plupart des pays qui n'en ont pas s'efforcent de créer de tels centres; toutefois, certains n'ont pas encore établi de plans à cet égard.

Sont également présentées les diverses activités de conservation en cours, y compris la conservation de cultures *in vitro*, la cryopréservation, les réserves de biosphère *in situ* et les travaux réalisés sur les plantations et dans les champs des agriculteurs. Les problèmes et les progrès de la caractérisation, de la régénérescence et de l'utilisation sont présentés, en soulignant l'importance de la documentation et de la formation sur le terrain.

6.2 The African Ministerial Conference on the Environment (AMCEN) and a continental network for the conservation and management of genetic resources

The first session of AMCEN was held in Cairo in December 1985, where it adopted the Cairo Programme for African Cooperation, aimed at strengthening the cooperation between African countries in economic, technical and scientific activities, with the prime objective of halting and progressively reversing the degradation of the African resource base to satisfy the food and energy

needs of the peoples of the continent. The Conference decided to institutionalize itself and meet every two years. To help achieve its priority objectives, the Conference decided at its first session to establish a regional technical cooperation network (environmental monitoring, climatology, soils and fertilizers, water resources, energy, genetic resources, science and technology, and environmental education and training) and four committees (deserts and arid lands, forests and woodlands, rivers and lake basins, and seas).

The second session was held in Nairobi in June 1987 in conjunction with the 14th session of the Governing Council of UNEP, which provides the permanent secretariat of the Conference in close cooperation with the Economic Commission for Africa and the OAU.

UNEP, in collaboration with IBPGR, is contemplating the organization of an African Genetic Resources Network to promote intercountry cooperation for the conservation and management of the genetic resources of Africa and to help make material and information from such a network freely accessible for utilization in the improvement of agriculture, forestry, industry, health and the environment.

La Conférence ministérielle africaine sur l'environnement (AMCEN) et l'établissement d'un réseau continental pour la conservation et la gestion des ressources génétiques

La première session de la Conférence ministérielle africaine sur l'environnement s'est tenue en décembre 1985 au Caire. A cette occasion, elle a adopté le Programme du Caire concernant la coopération africaine visant à renforcer la coopération mise en oeuvre entre pays africains sur les plans économique, technique et scientifique. L'objectif principal était d'arrêter et d'inverser progressivement la dégradation des ressources de l'Afrique de façon à satisfaire les besoins alimentaires et énergétiques des populations du continent. La Conférence a décidé de se donner un caractère permanent et de se réunir tous les deux ans. Pour atteindre ses objectifs prioritaires, la Conférence a décidé lors de sa première session de créer un réseau régional de coopération technique (surveillance de l'environnement, climat, sols et engrais, ressources en eau, énergie, ressources génétiques, science et technologie, et éducation et formation relatives à l'environnement) et quatre comités (déserts et terres arides, forêts et régions de forêts claires, bassins fluviaux et lacustres, et mers).

La deuxième session s'est tenue en juin 1987 à Nairobi parallèlement à la quatorzième session du Conseil d'administration du PNUE qui assure le secrétariat permanent de la Conférence en étroite collaboration avec la Commission économique pour l'OUA.

En collaboration avec le CIRPG, le PNUE a l'intention d'organiser un réseau de ressources génétiques en Afrique dont l'objectif sera de promouvoir la coopération entre pays africains pour assurer la préservation et la gestion des ressources génétiques africaines et pour faciliter l'accès au matériel et aux informations nécessaires aux fins d'améliorer l'agriculture, l'agroforesterie, l'industrie, la santé et l'environnement.

6.3 Conservation of plant genetic resources in the Great Lakes countries (CEPGL: Burundi, Rwanda and Zaïre)

The gradual disappearance of plant genetic resources in the CEPGL countries of Central Africa has led IRAZ to set up a program to collect, characterize, evaluate, document, conserve and utilize the region's plant genetic resources. IRAZ initiated the program in 1983. By March 1985, in collaboration with IBPGR, it was operational. At present, it involves seven centers; this number will be increased to include two more centers to cover parts of Zaïre.

This paper reviews the achievements and activities of the program since its inception.

La conservation des ressources phytogénétiques des pays des grands lacs (CEPGL: Burundi, Rwanda et Zaïre)

La disparition progressive des ressources phytogénétiques de la CEPGL en Afrique centrale a obligé l'IRAZ de créer un programme qui a pour objectif la collecte, la caractérisation, l'évaluation, la documentation, la conservation et l'utilisation des ressources phytogénétiques de la CEPGL. Ce programme initié par l'IRAZ en 1983 fonctionne depuis mars 1985 en collaboration avec le Conseil international des ressources phytogénétiques (CIRPG). Le programme de la CEPGL comprend sept centres. Ces centres sont opérationnels et deux autres centres sont prévus pour couvrir le reste du Zaïre.

Cet article passe en revue les réalisations et les activités du programme depuis sa création.

6.4 Conservation and utilization of genetic resources in the Southern African Development Coordination Conference (SADCC) region: A collaborative approach

Angola, Botswana, Lesotho, Malawi, Mozambique, Swaziland, Tanzania, Zambia and Zimbabwe make up the Southern African Development Coordination Conference (SADCC). They have agreed to establish a Regional Crops and Forest Seed Genebank. This facility, which will be supported by a network of national genebanks, is in response to the realization that: the SADCC region has a wide assortment of domesticated and wild plants with potential for use in breeding programs; there is a very real risk of losing valuable germplasm through attack by pests, diseases or extremes of weather; and in some parts of the region seed has been removed to foreign seed banks, to which plant breeders have little access.

The project has three main objectives: to collect and document the crop and forest species of the region, especially those threatened with extinction, in order to create a documented survey of the plant heritage of each SADCC country; to conserve samples of these plants either in their natural habitat or in regional genebanks, and rejuvenate and multiply them where necessary; and to provide genetic material and information to breeders in the region concerned with developing new varieties and strains of crop and forest species.

The project envisages a regional genebank and a supporting network of national genebanks working under national plant genetic resources committees. Each regional genebank will have a multidisciplinary membership, including plant breeders, agronomists, botanists and foresters. The project integrates action at national and regional level to characterize, evaluate and conserve germplasm with the overall objective of crop and forestry species improvement. It also embodies the SADCC principle that action should be initiated at national level.

La conservation et l'utilisation des ressources génétiques dans la région de la Conférence pour la coordination du développement de l'Afrique australe (SADCC): Une démarche coopérative

L'Angola, le Botswana, le Lesotho, le Malawi, le Mozambique, le Swaziland, la Tanzanie, la Zambie et le Zimbabwe font partie de la Conférence pour la coordination du développement de l'Afrique australe (SADCC). Ces pays sont convenus de créer une banque régionale de gènes pour les espèces cultivées et forestières. Ce dispositif, qui sera étayé par un réseau de banques nationales des gènes, vient en réponse aux constatations suivantes: la région de la SADCC possède un vaste assortiment de plantes domestiquées et sauvages pouvant servir aux programmes de sélection; le risque de perdre du matériel génétique précieux à la suite d'attaques de ravageurs, de maladies ou en raison de conditions climatiques extrêmes est très réel; et dans certaines régions, des semences ont été placées dans des banques étrangères auxquelles les sélectionneurs ont difficilement accès.

Le projet a trois grands objectifs: recueillir et documenter les espèces culturales et forestières de la région, notamment celles menacées d'extinction, de façon à réaliser une enquête documentée sur le patrimoine végétal de chaque pays de la SADCC; conserver des échantillons de ces plantes soit dans leur habitat naturel, soit dans des banques de gènes régionales, et les régénérer et les multiplier, si nécessaire; et fournir du matériel génétique et des informations aux sélectionneurs de la région qui s'occupent de mettre au point de nouvelles variétés ou souches d'espèces culturales et forestières.

Le projet envisage une banque de gènes régionale étayée par un réseau de banques nationales travaillant sous l'instigation des comités nationaux pour les ressources phylogénétiques. Chaque banque régionale aura une composition multidisciplinaire, comprenant des sélectionneurs, des agronomes, des botanistes et des forestiers. Le projet intègre les actions menées aux niveaux national et régional pour caractériser, évaluer et conserver le matériel génétique dans le but général d'améliorer les espèces culturales et forestières. Il s'inspire aussi du principe de la SADCC qui estime que l'action doit démarrer au niveau national.

6.5 The role and activities of the Genebank of Kenya

This contribution describes the principal aims and activities of the Genebank of Kenya, which was initiated in 1983 and started full operation in July 1988, to offset the threat to Kenya's genetic resources. It will be a service station within the framework of KARI. The genebank receives support from and collaborates with many national and international organizations. Systematic countrywide exploration and collection missions are being organized with financial assistance from IBPGR. A database on previous crop collection activities is regarded as a necessary preliminary stage in recuperating knowledge haphazardly collected and stored in the past. Other activities are concerned with seed processing, seed drying, seed testing, seed health, seed storage and the field genebank. Genebank staff have developed descriptor lists in consultation with plant breeders, based on the recommendations of IBPGR. Long-term evaluation work will concentrate on local landraces.

A central computerized documentation system listing all information on germplasm available in the country and held by research stations and the genebank is being established at the genebank in Muguga.

Le rôle et les activités de la banque de gènes du Kenya

Cet article décrit les principaux objectifs et activités de la banque de gènes du Kenya, qui a été créée en 1983 et a commencé à fonctionner en juillet 1988 pour neutraliser la menace pesant sur les ressources génétiques du pays. Elle sera rattachée au KARI. Elle reçoit le soutien de nombreuses organisations nationales et internationales avec lesquelles elle collabore. Des missions systématiques d'exploration et de collecte à l'échelon du pays sont organisées avec l'aide financière du CIRPG. Une base de données relatives aux activités antérieures de collection d'espèces culturales est jugée indispensable pour récupérer les connaissances recueillies et emmagasinées fortuitement dans le passé. Il est prévu d'autres activités, portant notamment sur le traitement, le séchage, les essais, l'état sanitaire, le stockage des semences ainsi que sur une banque de gènes en plein champ. Le personnel de la banque de gènes a établi des listes de descripteurs s'inspirant des recommandations du CIRPG en concertation avec les sélectionneurs. Les travaux d'évaluation à long terme seront concentrés sur les races locales de pays.

Un système centralisé de documentation informatisée contenant toutes les informations sur le matériel génétique disponibles dans le pays et détenues par les stations de recherche et la banque de gènes est actuellement mis en place à la banque de gènes de Muguga.

INTRODUCTION

Welcome Address

Opening Remarks

Keynote Address

Welcome Address

M. K. TOLBA

Executive Director, United Nations Environment Programme (UNEP)

En plus du danger résultant de l'effet de serre causé par la présence excessive de gaz carbonique dans l'atmosphère, les ressources génétiques végétales diminuent rapidement, posant ainsi deux défis sans précédents à l'humanité. En Afrique en particulier, la menace est accentuée par les conditions difficiles de ce continent et ses besoins pressants pour accroître sa production agricole et constituer des réserves de nourriture et d'énergie plus stables et plus viables. Les ressources végétales sont également inestimables pour l'Afrique puisqu'elles pourraient être utilisées pour lutter contre l'érosion et la désertification, et aussi pour le repeuplement végétal des terres dévastées.

It gives me great pleasure to welcome you to the United Nations Environment Programme (UNEP) Headquarters for this most important and timely international workshop.

As you know, this workshop has been jointly organized by the International Board for Plant Genetic Resources (IBPGR) and UNEP, in association with the International Institute of Tropical Agriculture (IITA) and the Consiglio Nazionale delle Ricerche (CNR). UNEP greatly appreciates the involvement of IBPGR and IITA. I also wish to express special thanks to the Finnish International Development Agency (FINNIDA), the Norwegian Agency for International Development (NORAD), the Netherlands Directorate General for International Cooperation (DGIS) and the Swedish International Development Authority (SIDA). These four countries have a record of substantial assistance and cooperation with African governments and institutions, and this occasion is yet another example of their commitment.

A few days ago I had the privilege of addressing, in Nairobi, a group of scientists and experts who were discussing the issue of conserving global biological diversity. Today it is my pleasure to address this workshop, the second major workshop on plant genetic resources in Africa. Indeed, as you well know, scientists and specialists are playing an increasingly crucial role in defining and tackling environmental issues and questions. This workshop is another stage in that process. You are part of a growing worldwide scientific effort to protect and enhance the environment and its natural resource base in order to achieve sustainable development. From the theoretician to the researcher, from the teacher to the experimenter, from the administrator to the field worker, a great army of technicians of all nations has been mobilized in the cause of the environment.

Let me now turn to your specific field — plant genetic resources in Africa. If Charles Darwin, author of *The Origin of Species*, were writing today, he might produce a work entitled *The Disappearance of Species*, because our planet is losing its diversity of genetic resources at unprecedented rates as a result of the pressures of poverty and development on the environment. There may be debate about the specific number of losses, but there is little doubt about the general trend. Not only species, but also varieties and races within species are being lost. Traditional varieties are being abandoned in favor of the new ones. The chances of obtaining the wild relatives from which traditional varieties originated as breeding material for genetic selection and improvement are being limited by the loss or degradation of their habitats.

Another danger is the build-up of carbon dioxide and other greenhouse gases in the atmosphere. This is caused by the burning of fossil fuels, the clearing of forest land for agriculture and other economic activities. And this is likely to produce substantial global warming in the next 40 years, which will have a profound impact on ecosystems and species.

Thus one of the greatest challenges facing developing countries in general, and Africa in particular, is the conservation of the wealth of their plant genetic diversity and resources. These resources are vital to agriculture and industry — in fact, to our very survival. Most of the world's plant and animal species are located in developing countries. Many have little value currently; some have clear potential value; and countless others are undescribed or little known. As knowledge of Africa's plant genetic resources increases, and as the field of biotechnology expands, the challenge grows. This underlines the need to maintain the richest possible pool of genes.

With all this in mind, I consider that the overall objectives of this workshop should be:

- to act as a forum for information exchange;
- to promote the need to increase Africa's technical and scientific capacity and to strengthen cooperation in activities related to the conservation of plant genetic resources;
- to foster links between plant genetic resources conservation and development policies and plans.

The wealth of papers and presentations you will be discussing during this workshop will certainly allow you to deal with the basic issues facing Africa. Among these issues are:

- assessment of present systems for managing and using plant genetic resources and proposals for improvement;
- national and regional needs and priorities for the conservation of Africa's plant genetic diversity;
- development of scientific bases on which African countries can establish more effective national programs in this field;
- the integration of conservation into environmentally sound management measures for sustainable agriculture.

Although Africa is short of food, it is, ironically, not using the full potential of its plant genetic resources. To help feed, clothe, house and satisfy other basic material needs of the

rapidly growing African population, Africans will have to develop sustainable ways of exploiting the continent's plant genetic resources. They are a virtually untapped reservoir.

The range of species used for food and energy in Africa is limited. Other species need to be used to improve existing varieties and to provide new sources of food and other materials. By definition, they are already adapted to African conditions, particularly aridity. Historically, many plant species have been used for food. Today, most of the world's food comes from 20 or so species. Many lesser-known food crops, the so-called 'poor people's plants', have been neglected. Peanuts, potatoes and other crops once considered of little use are now valuable sources of food. There is much scope to look beyond today's major crops at species that may have future value, either in themselves or as sources of genes. This would expand African agriculture and build a more stable and sustainable food and energy supply. It could also revegetate land damaged by or threatened with erosion and desertification.

The conservation of plant genetic resources to ensure that diversity both for immediate benefit and for future generations is an immense and complex task. It would be presumptuous of me to enumerate to this learned group the difficulties involved in such a task. However, I would like to share with you some of these difficulties as I see them.

- the vulnerability of plant species is increasing;
- conservation efforts are limited to a number of species of immediate commercial value and of interest to those who support conservation activities;
- industrial concerns seem to discount future values when determining investment priorities;
- the resources, power and capacity to promote conservation are unequally distributed;
- potential progress from conventional breeding and the efficiency of germplasm utilization in major crops seems to have been optimized; fewer introductions are occurring now than was the case 10 years ago;
- public awareness of the significance of the issue is limited;
- local people are rarely brought into the process of planning the conservation and management of their genetic resources;
- national cross-sectoral cooperation in this field is limited;
- worldwide investment in the conservation of plant genetic resources has been very modest and is by no means assured;
- the integration of conservation and development plans is almost non-existent.

There has been international consensus on the need for the conservation of plant genetic resources for almost two decades. The United Nations Conference on the Human Environment in 1972 recommended maintenance of genetic resources, and plant germplasm is now the subject of both regional and international attention and debate. But conservation will be given the priority it needs only if all the institutions concerned coordinate their efforts.

Some progress has been made. This is reflected in, for example, the establishment of an international network of genebanks housing the World Base Collection and its coordination

by the IBPGR since 1974, the adoption by the FAO Conference in 1983 of the International Undertaking on Plant Genetic Resources, and the establishment of the Inter-Governmental Commission on Plant Genetic Resources. All these measures are important in coordinating the conservation of plant genetic resources for sustainable development.

We can also point to the decision of the African Ministerial Conference on the Environment in 1985 to establish an African network for the conservation and management of genetic resources. The 'Environmental Perspective to the Year 2000 and Beyond' and the 'Report of the World Commission on Environment and Development' both emphasize protection of biological diversity. UNEP is studying the advisability and content of a global convention on biological diversity, and the International Union for the Conservation of Nature and Natural Resources (IUCN) is now developing a convention for the conservation of biological resources. This workshop itself is also proof of progress.

All this is extremely positive, but we still need concrete actions and policy reforms by governments and development agencies. In addition, ways of sharing the costs and benefits of conserving genetic resources as a common heritage must be defined and devised.

The two major issues as I see them are:

- cost of conservation;
- rights of possession of and access to genetic resources as a common heritage.

These issues involve social, political and economic decisions by those who have the resources, those who need the resources, and those who benefit from the resources.

Of course, blanket conservation of all plant genotypes would be prohibitively expensive and technically almost impossible. However, for species with a high market value, private investment could be invited for the development of valuable varieties and the conservation of relevant species. For those with little or no commercial value at present, private investment cannot be expected, but investment could be sought from governments, nongovernmental organizations, universities, foundations and international agencies.

The potential of plant genetic resources can best be exploited if they remain freely accessible to all users and if the information and technology on how to use them is widely disseminated. Having a particular valuable genetic resource or the technical capability to develop new varieties from it must not give exclusive rights of ownership or profit. Although two-thirds of all species occur in developing countries, particularly in the tropics, in general it is the developed countries that have the technology to exploit them. While possession and custody of a potential genetic resource might be limited to one nation, the benefits from this resource can accrue to all nations. In essence, then, there has to be a fair balance of benefit between custodian and consumer. As I have said, UNEP is now considering the possibilities of a global convention for the conservation of biological diversity to address these major issues.

It is very timely that this workshop will be discussing technical aspects of plant genetic resources. What we will all expect from your deliberations are specific recommendations on how to minimize losses of these resources and ensure their sustained availability to all users. The workshop could also review and share information and views on what has been done for the conservation of Africa's plant genetic resources and, from there, define what should be done and how to do it. Like other natural resources, plant genetic resources are a foundation for the future. Part of that future is in your hands.

Opening Remarks (1)

HON. G. M. NDOTTO

Minister for Research, Science and Technology, Kenya

Chairman, Ladies and Gentlemen,

It gives me great pleasure to be with you at the official opening of the International Workshop on Plant Genetic Resources in Africa. This workshop is important because it brings together scientists and policy-makers from the whole of Africa to discuss the various ways to protect, conserve and utilize plant germplasm for the sake of sustainable economic and social development on the African continent.

Africa is endowed with a great diversity of plants. It contains one of the Vavilovian world centers of cultivated plants. Among these plants are the wild and weedy relatives of cultivated plants, as well as numerous species of under-utilized and neglected crops. Their contribution to agriculture, medicine, industry and the environment worldwide amounts to billions of dollars each year. Even if uses are not now known for some resources, they play an important role in many other ways, including stabilizing the climate, cycling nutrients and controlling soil erosion and desertification.

However, these plants are in danger of disappearing, mainly because of the factors that are associated with the environmental degradation of natural ecosystems and habitats as a result of urbanization, technological change, fires, overgrazing and — most important of all — the increase in human population. Many species are being lost every day, to the extent that by the year 2000, one million species could have been lost.

Nine years ago, the African Heads of States and Governments agreed under the Lagos Plan of Action to cooperate in the preservation, protection and improvement of the natural environment. They also recognized the importance of achieving self-sufficiency in food production and supply.

In 1985, the First African Ministerial Conference on Environment, held in Cairo, decided to establish a regional network of genetic resources in order to strengthen and promote inter-country cooperation.

On a global basis, strategies for conserving and utilizing plant germplasm in an environmentally sound way have been supported through the establishment of various international organizations, such as the International Board for Plant Genetic Resources (IBPGR) and the United Nations Environment Programme (UNEP). The establishment of crop research centers by the Consultative Group on International Agricultural Research (CGIAR) throughout the world, in cooperation with the Food and Agriculture Organization of the United Nations (FAO), has played a significant part in conservation efforts. Despite the long-

standing support of a number of agencies, a critical need still remains — particularly in Africa — to strengthen efforts to conserve the available plant genetic resources and their diversity. However, this is not always perceived as important to the national interest and may be neglected or not accorded the priority it deserves.

We are gathered here because we realize that plants are necessary for the survival of the human race as well as other animals. When agriculture began during the Neolithic period, it was because early man had noted that the plants around him were of great benefit, especially if they were found growing within easy reach. Today, the plant breeder has discovered that plants contain important genes which, *inter alia*, could turn a low-yielding variety into a high-yielding one and/or confer resistance to pests and diseases, drought and frost. Such genes are found not only among the cultivated plants, but also among the obsolete cultivars, old landraces, wild species and weedy relatives of cultivated plants.

Attempts to utilize the wild species for the improvement of crop plants is not always easy because of the genetic barriers which isolate the plant species. It is therefore necessary to carry out research to find out which plants belong to the same genepool and which ones are in different genepools and thus require the removal of the barriers that prevent natural crossing. These manipulations of genes through breeding techniques normally lead to the production of elite high-yielding varieties, which are grown as monocultures but at the expense of sharply reducing the genetic base on which these varieties are founded. Although the new plant breeds impressively increased productivity and brought great gains, their narrow genetic base caused great losses and created a number of problems. If the valuable genepools continue to be destroyed in this way, the loss could be irreparable.

It is, therefore, important to conserve a great diversity of plants so that a wide genetic base is available for plant breeders to exploit. One rationale for preserving plant genetic resources and diversity is that it is an insurance against future agricultural catastrophe. But the question remains as to how much responsibility individual nations should have for the conservation and management of these valuable resources.

Although there are various methods of conserving germplasm, the most widely used is *ex situ* conservation for orthodox seeds and *in situ* conservation for recalcitrant seed plants. Some of the orthodox seeds of cereals, legumes and vegetables are conserved as base collections in genebanks situated in the temperate regions. Some other collections are conserved as active collections, and complement the base collections. Field collections, which contain living plants, are found in many countries. Some of these are conserved as natural biospheres or protected areas.

Scientific issues concerning plant genetic resources range from the theoretical bases for collection to the need for improved methods of maintenance, both *ex situ* and *in situ*, and sound utilization for the improvement of agriculture, forestry, health and the environment.

Here in Kenya, there is a great diversity of plant germplasm which is the result of several factors, including the tropical position of the country and the variation in climate, soils and topography. Kenya has long been committed to conserving her natural resources; a number of the country's research and experimental development (R&D) institutions have been operating here since the beginning of the century, when the Department of Forestry, the Scott Agricultural Research Laboratories and the Coffee Research Services were established. Today, such institutions have increased in number and are involved in the collection and conservation of plant germplasm, especially that of crop and forest tree species. Over 50,000 accessions of crop plants have been collected and are in various institutions. Recently, a national genebank was set up to coordinate all crop plant genetic resources activities,

including the introduction of new crop plant genetic resources. There is also a major effort to rehabilitate and construct cold storage facilities at research stations so as to cater for a large number of accessions and ensure that the germplasm remains viable.

The conservation and utilization of the plant germplasm will remain high on Kenya's list of priorities. Already, the Coffee Research Station has produced an improved variety of coffee known as Ruiru II and it is hoped that more of these high-bred varieties will be produced.

With regard to documentation, this is an area where a lot of effort is needed in acquiring information on passport, characterization and evaluation data and making it available to users.

In the light of the above, I should like to highlight some of the challenging issues which I hope this workshop will address. The workshop should:

- determine potential plant species which require attention because of their possible role in solving some of the problems facing Africa, such as hunger, malnutrition and energy crises;
- determine the plant species which are threatened by genetic erosion;
- discuss and develop plans of action for surveys, documentation, evaluation, cultivation and utilization of important plant species;
- encourage the development of mechanisms for generating information and the establishment of information systems that provide effective means of data storage and retrieval;
- encourage the establishment of well-equipped national genebanks for both medium- and long-term storage;
- discuss ways of training and retraining the people working in genebanks and breeding programs, and those handling plant germplasm;
- encourage a collaborative approach through the involvement of the national, regional, and international communities so as to foster greater inter-country scientific and technical cooperation.

I feel that if the above issues are considered seriously, this workshop will have achieved its objective of enhancing the effectiveness of plant genetic resources activities in Africa for the improvement of agriculture, forestry, health and the environment.

Finally, on behalf of the Kenya Government, I wish to welcome you all to Nairobi and to thank IBPGR and UNEP for choosing Nairobi as the venue for the workshop.

I now have the pleasure of joining the Executive Director of UNEP, Dr Mostafa Tolba, in declaring this International Workshop on Plant Genetic Resources in Africa officially open.

Opening Remarks (2)

D. H. VAN SLOTEN

Acting Director, International Board for Plant Genetic Resources (IBPGR)

At this workshop you will be dealing with germplasm in Africa. From a brief look through the program, I see that we shall be presented with some extremely interesting papers. Indeed, I am looking forward to a very constructive time here. As you all know, one of the most important aspects of any conference or workshop is the opportunity to make personal contacts and to renew old friendships. Some of you may already be familiar with the organization that I represent, the International Board for Plant Genetic Resources (IBPGR). It is wholly concerned with conserving the genetic base of important food plants, cereals and legumes, as well as fruits and vegetables. I should like to explain some of its activities to you, as a way of fostering communication between us.

IBPGR was established by the Consultative Group on International Agricultural Research (CGIAR) in 1974. Its initial task was to promote a global network of genetic resources centers to ensure that the genetic diversity of important food crops and other economic species was adequately collected and satisfactorily conserved, evaluated and documented. This material was to be made available to all bona fide scientists.

The late 1980s mark a period of significant change for IBPGR. Our expanded mandate will enable us to take those actions that are needed to sustain a viable international genetic resources network. Important new priorities have been identified and they will guide the evolution of IBPGR well into the 1990s.

From the start, IBPGR has had a wide-ranging collection program to conserve landraces from areas of traditional agriculture. More recently, it has included related wild species so that the representation in collections is from the wider gene pool of individual crops. Table 1 (*overleaf*) gives the number of samples collected by IBPGR in Africa between 1974 and 1987.

After an extensive program of germplasm acquisition in its early phase, IBPGR is now consolidating that investment by completing the registration and processing of all passport and characterization data and ensuring that all material is duplicated in at least two base collections. The network of base collections will be strengthened by encouraging advances in germplasm storage technology and improving methods of exchanging information on collection holdings.

IBPGR will continue to assist plant breeders and other users to obtain germplasm through a network of active collections. A system to ensure that data on genebank accessions reflect changes in botanical nomenclature guarantees that the information is up-to-date. A 'genetic resources early warning system' is being developed to enable IBPGR to take all possible steps

TABLE 1 **Number of samples collected in Africa (1974-87)**

	Number of samples
Cereals	27,000
Legumes	7,998
Forages	5,606
Fruits	180
Industrial crops	936
Roots and tubers	2,479
Vegetables	5,854
Others	389
Total	50,442

to collect germplasm from areas under immediate threat of genetic erosion but in which no collections have been made. IBPGR field staff based in key locations around the world will play a major part in this process.

Maximum use will be made of scientific information from collecting missions and other sources to identify future collecting needs in order to complete the sampling of the full range of genetic diversity of crop species and their wild relatives. Special attention will be given to collecting germplasm that can be used for forage improvement in impoverished areas. To this end, IBPGR will seek to collaborate with other agencies that are active in forage improvement in the regions concerned.

Training of personnel to strengthen national genetic resources programs, which has always been an IBPGR priority, will be expanded to offer more training opportunities in languages other than English. In addition, a higher proportion of training courses will be based in institutions in developing countries.

IBPGR is developing a sharply focused research program with clear objectives and priorities as a means to strengthen the scientific basis of genetic resources activities. Research will focus on strategic studies utilizing the expertise of the best research scientists in the world and involving developing country scientists to the greatest extent possible. Results and follow-up research will be transferred to national programs at the earliest opportunity.

IBPGR has been involved over the past 15 years in the development of a viable global network for genetic resources activities. We have been involved in aspects of genetic resources work in over 120 countries. About 50 national programs have emerged from these countries in recent years. IBPGR emphasizes the integration of developing countries in activities through the transfer of technology on aspects of collecting, conservation, documentation, description and use of primitive forms of germplasm. Through their work on a number of priority staple crops, the other CGIAR international centers play an important role in the overall network.

At the time IBPGR was established, the loss of primitive forms of the cereals such as rice, wheat, maize, sorghum and millets was giving rise to great concern. Since then, genetic erosion has affected all crops, and thus the priorities for action on crops have expanded rapidly and IBPGR has had to initiate work on a very broad range of materials.

In its early years, IBPGR established a list of priority crops, on which it concentrated its limited resources. Then, and now, the criteria for defining a priority crop are as follows:

- the degree of risk that genetically diverse materials of the species and their wild relatives will be lost in the near future, as a result of change and development in agriculture and land use, including the introduction of new varieties; as such changes are generally local, a species or group may have high priority in one country or region and lower priority elsewhere;
- the economic and social importance of the materials to be collected, measured in terms of their present usefulness and importance (volume or value of production and trade, numbers of people depending on or using them), as well as their expected, intended or potential contributions to development (including the improvement of human diets and the income and well-being of farmers and other rural people) and the economic and social progress of mankind;
- the recognized requirements of plant breeders and research workers, in both developing and developed countries, for genetically diverse materials (including advanced breeding lines), and the expected significance in economic and social terms of the improved types and varieties of crops they will be able to produce with these materials;
- the size, scope and quality, including the documentation, of existing collections.

IBPGR PROGRAM FRAMEWORK

I should like to turn now to IBPGR's current program and discuss its operation. The program has three main elements — Field, Research and Administrative — and operates from our Headquarters and a series of Field Offices located in strategic areas of the world. The Field Program is made up of the global genetic resources network, as well as subprograms dealing with germplasm acquisition, germplasm characterization and training. The Research Program has four main sections — seed conservation, *in vitro* culture, genetic diversity and evaluation/regeneration strategy.

One point I should make here is that most of the work initiated by IBPGR in the past, especially in relation to germplasm acquisition, has outstripped the capacity of many national programs to carry out essential follow-up work. IBPGR is particularly concerned to see that this work, including documentation, is completed so that the utilization of materials by breeders is facilitated. Much material collected by IBPGR is already in use in breeding programs; among the landraces that have been used are sweet potato, cassava, tomato, cucurbits, peppers, onion relatives and beet.

The move by IBPGR in recent years to pay more attention to wild species has elicited great interest from breeders. Some of our collected samples of wild species are already in breeding programs for tomato, groundnut, rice and *Pennisetum*. In addition, numerous vegetable collections, such as those of okra, have been used for direct plant introduction programs.

IBPGR actively promotes the characterization of collected germplasm and the better use of genetic resources. It is placing greater emphasis on bringing internationally agreed scientific standards to the conservation of germplasm to ensure its safety in base collections, and more attention is being given to active collections linked functionally to base collections.

There are also a number of research challenges that IBPGR has identified, and it is making efforts to meet these, as well as to lay a basis for accommodating any research developments that will occur in the immediate future. For example, IBPGR is actively supporting research

on techniques of *in vitro* conservation and on the maintenance of genetic integrity during storage and regeneration of seed or cultures. This work will be particularly relevant to the conservation of fruit germplasm. Disease indexing to facilitate quarantine and germplasm exchange needs further consideration, and research will include investigations into non-destructive disease indexing methods. In the fast-moving area of molecular biology, IBPGR is closely monitoring developments and incorporating new techniques into its research.

Field Program

The Field Program is implemented by Headquarters staff and their colleagues in the field. After a reorganization we now have seven Field Offices, two of which are located in Africa. The Field Office in Niger, at the Sahelian Center of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), serves West Africa; the Field Office in Kenya, at the International Laboratory for Research on Animal Diseases (ILRAD), serves East and Southern Africa. Activities in North Africa are coordinated by field staff based in Rome.

The Field Program is divided into a number of specific elements, concerned with the global genetic resources network, germplasm acquisition, germplasm characterization and documentation, and training.

The global genetic resources network

IBPGR supports national programs of developing countries by providing a package of advice and assistance tailored to the requirements of each country. The priorities of IBPGR play a major role in guiding the Field Program. With a limited budget IBPGR cannot respond to all individual and localized needs, but must be guided by national or bilateral responsibilities. The primary aim of IBPGR is to develop a network with threads of influence extending to plant breeding organizations, genebanks and universities throughout the world. Interlocking institutional arrangements and operational strategies could function together to conserve germplasm and make it available for use.

In its operation of the Field Program, IBPGR has adopted two main approaches. One is the interaction with and support for national programs, and the other is the development of crop networks which will comprise base and active collections and the user community on any specific crop. The development of these crop networks will be a major objective in the years to come.

Germplasm acquisition

Since so much germplasm has been collected in the recent past, IBPGR now targets its efforts specifically at collecting material known to be under threat. To this end, a warning system, implemented by field staff, will keep genetic erosion under review. In addition, targets are set for collecting to fill gaps in diversity in existing collections. The methods of transfer of collected germplasm to genebanks have been inadequate in the past, and IBPGR has now established two distribution centers to ensure that collected seed samples can be cleaned, dried and packaged for transfer — with supporting data — to the genebanks. One genebank,

in Kew, UK, serves Africa; the other, recently opened in Singapore, deals with Asian material. Plans are under way for a third genebank which will serve Latin America.

Germplasm characterization and documentation

Much of the increased effort on characterization and documentation will be directed towards developing single-crop databases. It has been our experience that this type of database serves user needs far better than scores of institutional multi-crop databases. At the same time, in order to promote the more effective use of resources, IBPGR is actively pursuing the idea of selected cores or subsets within the large germplasm collections, based on ecogeographical origins and subsequent descriptions.

IBPGR has produced descriptor lists for many years. This year we will be publishing lists for *Citrus*, mango, papaya and eggplant. At the same time, IBPGR provides technical assistance to genetic resources centers for the organization of their data on collections.

IBPGR's support for databases covers a wide front. In addition to support for the assembly and ordering of passport and descriptive information on existing collections, there is a need to fill gaps in data for older significant collections and for cross-referencing to geographical and climatic databases. Such work will facilitate the transfer of information to scientists, breeders and other germplasm centers.

Training

IBPGR has always supported training activities. It is essential to ensure the availability of technically skilled personnel to carry out genetic resources work effectively in the global network. IBPGR's training program provides manpower for national, regional and international organizations. However, there is still a manpower shortage in most developing countries and continued emphasis on training is required.

We are currently expanding in two areas: first, training in languages other than English, with such training being located, where possible, in developing countries; and second, retraining the current core of past trainees to update skills to meet the requirements of rapidly changing technology.

Research Program

The research agenda over the next 5 years comprises a number of initiatives in three specific areas. In explaining the rationale behind research support for conservation technology — seeds and *in vitro* — it is useful to emphasize again that plant genetic diversity can be conserved in a number of complementary ways. For any one crop several methods may be applicable. Most crops can be conserved effectively as seed and, indeed, seed is the preferred method because the technology is tried and tested. Nonetheless, seed conservation technology still requires research, especially to develop and implement more cost-effective methods.

Despite progress with orthodox seeds, problems with recalcitrant seeds remain, and fundamental issues have to be addressed by research. In fact, IBPGR is about to publish an up-to-date review of research on recalcitrant seeds. An example of a new approach in this area

is the examination of embryo conservation technology. At the same time, the genetic stability of stored seeds is in urgent need of research and acceptable levels of genetic change need to be determined.

In vitro culture research

IBPGR has taken a lead in initiating *in vitro* research because it is an area full of potential for the maintenance of clones of interest to breeders and for vegetatively propagated crops such as sweet potato, cassava and aroids, as well as cocoa, coconut, banana and other fruits.

For many vegetatively propagated crops, there is the need to conserve unique clonal genotypes. Such materials are kept as growing plants in field genebanks or maintained *in vitro*. The possibility of *in vitro* conservation has attracted the genetic resources community for some time, but current methods are generally at the developmental stage, and where they are available they are used only for medium-term storage. Research on cryopreservation offers the best potential for the long-term conservation of vegetative material. IBPGR has researched the conceptual framework for the management of long- and medium-term *in vitro* genebanks. The system is currently being tested in a joint Centro Internacional de Agricultura Tropical (CIAT)/IBPGR project using cassava.

In vitro active genebanks will contain cultures under conditions of slow growth and *in vitro* base genebanks will contain cultures under cryopreservation. Both systems must be linked through multiplication cycles that involve subculturing and monitoring for genetic stability. Materials cultured *in vitro* must represent as wide a range of genotypes as possible, and most culture protocols — developed for purposes other than conservation — need to be modified by research.

There has been a practical spin-off from *in vitro* research. For some crops, cost-effective methods of germplasm collecting in the field would be greatly enhanced if *in vitro* techniques were used. IBPGR developed such a technique in 1984-85, using relatively simple technology. So far, this has been tested for cocoa, wild cotton and cassava, and is being developed in other species such as tropical grasses. Another technique has been developed for coconut embryos and is being implemented by national programs in South-East Asia.

Pathological aspects of germplasm conservation have received inadequate attention. Two elements, one involving seeds and the other *in vitro* cultures, relate to new research using biotechnological methods. In the case of seeds there are strong reasons to avoid destructive seed testing. IBPGR has increased its role in considering disease indexing and movement of germplasm. Viruses and viroids present major problems, especially for vegetative and *in vitro* materials. Recently, IBPGR developed a conceptual framework for a totally enclosed quarantine system in which a component is disease indexing. This research activity is being backed by a joint IBPGR/Food and Agriculture Organization (FAO) initiative to develop and issue, on a crop basis, guidelines for the safe transfer of germplasm.

Genetic diversity research

Many of IBPGR's projects have led to further research on collected materials to provide information on the evolutionary development of crop species relationships. IBPGR recognizes an urgent need to strengthen its role in this research because of its emphasis on

broadening the genepools in collections with representative samples of related wild species. The scientific knowledge base is still slender in many groups of priority crops considered by IBPGR and breeders as priority crops. For a large number of priority wild species, the limits of distributional areas are uncertain, and flowering and seeding times are unknown. In order to promote effective field work, further research is urgently needed.

Although the newer biochemical and molecular techniques are widely applicable in this area, and despite the fact that biodiversity has recently attracted wide international interest, in practice little funding is channeled into research on crop genepools.

IBPGR's work will remain sharply focused on immediate practical problems aimed at enabling national and international programs to better understand the ranges of variation present in collections. This work is of major importance as priorities related to utilization have moved to the greater use of wild species in breeding.

Seed conservation research

During the past decade, IBPGR's research on seed conservation has focused on basic investigation into seed physiology and practical methods of handling seed in genebanks. This research has resulted in both conceptual and technical recommendations for seed conservation. The techniques developed include a new concept of seed drying; the use of extra-low moisture contents and ambient temperatures for long-term storage; the modification of the equation quantifying seed deterioration; and the sequential testing method for monitoring seed viability. IBPGR's work has resulted in the publication of two benchmark manuals for seed conservation and handling.

Research on seed conservation will be expanded on topics such as regeneration techniques, methods for disease indexing, and plant health for seed exchange.

It now appears, from research already undertaken, that embryo storage will be the preferred conservation method for recalcitrant seeded species. However, more research still needs to be done. Furthermore, in relation to seed storage, changes at the subcellular level — which lead to genetic deterioration in stored seed, especially during low-temperature storage — are imperfectly understood and additional research is needed in this area also.

The coordinating role of IBPGR and its worldwide mandate make it essential that more attention be given by the Center to establishing and monitoring good working relationships with a wide range of other agencies. Our central activities necessitate complementarity with other genetic resources programs, but our interest in wild species should expand. In addition, our expertise in conservation technologies is responsible for numerous dialogues with environmental conservation agencies.

LONG-TERM AIMS

As a basis for its strategy for the next decade, IBPGR has adopted the following aims:

- to facilitate worldwide cooperation and advances in the conservation and utilization of plant genetic resources by providing scientific leadership, setting scientifically based standards for storage and multiplication of germplasm *ex situ* and *in vitro*, and making information freely available and readily accessible within and outside the CGIAR system;

- to *promote the acquisition of germplasm* of landraces and wild relatives of species important as crops and forages, especially where threatened by genetic erosion or not adequately represented in existing collections;
- to *strengthen and sustain the global network of plant genetic resources centers* for the long-term, cost-effective conservation of seeds and *in vitro* collections (as appropriate) of crop species and their wild relatives;
- to promote the effective utilization of materials deposited in the global network of genetic resource centers through the development of high *standards for genebank documentation and management*;
- to improve the capacity to design efficient genetic resources acquisition programs and to evaluate and utilize collections by gaining a better *understanding of the origin, evolution and variation patterns of crop gene pools*;
- to promote *strategic research* relating to the conservation of germplasm of crop species and their wild relatives;
- to provide *training opportunities* to increase conceptual, technical and management skills in plant genetic resources conservation;
- to *maintain a worldwide overview of genetic resources programs* to achieve maximum complementarity in crop genetic resources programs.

CONCLUSION

I should like to conclude my address by repeating that it has given me great pleasure to have been asked to speak at this conference. Africa contains some of the world's most important genetic resources. Collecting and conserving these resources remains critical, and IBPGR is committed to accomplishing these tasks. To back these activities, as I have said, IBPGR is moving into advanced areas of strategic research. Much of this research will be directly relevant to the particular problems of conserving genetic resources. I hope that this conference will produce significant recommendations and foster a renewed spirit of cooperation, so that together we can meet the challenges of the future.

Opening Remarks (3)

N. Q. NG

Leader, Genetic Resources Unit, International Institute of Tropical Agriculture (IITA)

It is my privilege to speak on behalf of Dr L. D. Stifel, Director General of the International Institute of Tropical Agriculture (IITA), who regrets that he cannot personally attend this highly significant International Workshop on Plant Genetic Resources in Africa. IITA has the pleasure of co-organizing this workshop with the International Board for Plant Genetic Resources (IBPGR), the United Nations Environment Programme (UNEP) and the National Research Council (CNR) of Italy.

Africa is one of the world's richest centers of diversity of many plant species that provide genetic resources of the most fundamental importance for man's food, beverage, medicine, fiber and shelter, and for animal feed. The diversity within a species or genus that we see today arises as a result of spontaneous changes or mutations and genetic recombinations, followed by natural selection over millions of years. Using plant breeding methods, this diversity can be manipulated or certain features can be isolated and combined in order to improve our crop plants and enhance their usefulness to mankind.

The African continent, like many other regions of the world, is undergoing devastating destruction of these important natural resources. Fortunately, many national, regional and international organizations, especially the Consultative Group on International Agricultural Research (CGIAR), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP) and UNEP, are working in Africa to collect and preserve these important resources.

I would like to review the historical background of the work in plant genetic resources undertaken by IITA and to relate the present workshop to the first workshop on African plant genetic resources, held at IITA in 1978.

IITA PLANT GENETIC RESOURCES ACTIVITIES

IITA was established in 1967, with its headquarters in Ibadan, Nigeria. Its primary research emphasis is on developing farming systems for the lowland humid and subhumid tropics which can sustain the productivity of food crops under continuous cultivation, as an alternative to shifting cultivation, and on crop improvement research on cassava, maize, cowpea, yam, plantain, soybean and rice. As early as 1970, scientists from IITA began to collect germplasm of the Institute's mandated crops for selection and plant breeding research

as well as for preservation. In 1975, IITA established its Genetic Resources Unit (GRU) to further the work of collection, preservation, documentation, utilization and distribution of the genetic resources of root and tuber crops, food legumes and rice in sub-Saharan Africa. Since its inception, the GRU has collaborated with national, regional and international institutes, including IBPGR, to explore, collect and conserve germplasm.

To date, the GRU has mounted over 50 plant exploration missions to 24 African countries and gathered 20,000 samples of germplasm of many crop species (including those not within IITA's mandate) and their wild relatives. The GRU has recently renovated its facilities and constructed a new and modern seed storage and processing laboratory to maintain and conserve germplasm. It now maintains over 35,000 accessions of germplasm. In addition, IITA's tissue culture laboratory has established *in vitro* techniques to preserve and distribute disease-free germplasm of root and tuber crops.

Genetic resources conservation activities at IITA do not end with collecting and storing. More emphasis is given to maintaining and evaluating materials for use in crop improvement, and to making the germplasm materials and information about them accessible to scientists. Genetic resources information gathered at IITA is computerized. All germplasm materials, including breeding lines developed from IITA's breeding programs, are available on request.

NATIONAL AND INTERNATIONAL EFFORTS DURING THE 1980s

It is exactly 10 years since the first International Workshop on African Plant Genetic Resources, financed by the Ford Foundation, was held at IITA. It was jointly organized by the Association for the Advancement of Agricultural Sciences in Africa (AAASA) and IITA. The objectives of the workshop were to: create awareness of the need to conserve the invaluable crop genetic resources of Africa; provide an opportunity for those involved to meet; collate information on the conservation of plant genetic resources in Africa; identify the location, size and condition of existing germplasm collections and review the list of crop and regional priorities published by FAO/IBP in 1973; and suggest ways in which genetic resources conservation activities should be coordinated in Africa.

Two major recommendations were made during that workshop. These were:

- to establish an African committee to promote and coordinate crop genetic resources conservation in Africa;
- to make a detailed survey on genetic resources conservation activities in Africa.

The proposed African Committee on Plant Genetic Resources was formed in 1981, but unfortunately it lacks the resources needed to carry out its objectives. With support from IBPGR, IITA conducted a survey of activities on plant genetic resources in 19 African countries during 1982, and produced a detailed report on existing plant genetic resources, storage facilities and plant genetic resources personnel in Africa. The report also analyzes the situation of crop genetic resources conservation in African national programs and provides recommendations for the collection and conservation of some individual crops. In addition, IBPGR conducted a separate survey to complement the IITA work.

During the past decade, extensive plant exploration activities have been undertaken in Africa by IBPGR, the International Crops Research Institute for the Semi-Arid Tropics

(ICRISAT), IITA, the Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières (IRAT), the Office de la Recherche Scientifique et Technique d'Outre-Mer (ORSTOM) and, more recently, the International Livestock Center for Africa (ILCA). There has also been a tremendous increase in plant genetic resources activities and development in national programs in Africa. This increase in national efforts is the result of the increased general awareness among the public, scientists and policy-makers of the importance of germplasm collection and conservation, which is strongly promoted by IBPGR, IITA and other CGIAR centers working in Africa and by FAO, UNDP, UNEP and other international bodies. I would like to highlight in particular the catalytic role which IBPGR has played in increasing germplasm collection and conservation activities in African national programs within the very short period of a decade of its activities in Africa.

CONCLUSION

After a decade of such developmental activities in Africa, the present workshop is timely. It offers an opportunity and a challenge to critically evaluate what has been done in the past and to develop future strategies for the germplasm collection, conservation, evaluation and documentation in Africa. I would like to see a recommendation made during this workshop on how to make most effective use of existing funds and human resources for the development of the collection, maintenance and, in particular, utilization of African plant genetic resources. I am sure that all the contributors will work together toward providing an integrated plan that will provide a guideline for national and international action.

The Director General of IITA takes this opportunity to thank the Government of Kenya for hosting this workshop through its National Genebank and the local organizing committee for its excellent arrangements. He wishes the workshop success in its deliberations.

Opening Remarks (4)

J. T. ESQUINAS-ALCAZAR

*Plant Genetic Resources Officer, Food and Agriculture Organization
of the United Nations (FAO)*

Since life first appeared on Earth some three billion years ago, the number of species has increased unceasingly in a process of continuous diversification. This backlog of genetic diversity has permitted effective use of the Earth's energy resources and a vast capacity for adaptation and adjustment, conferring both stability and harmony on the system.

The appearance of agriculture some 10,000 years ago in various parts of the world disrupted the ecological balance of a number of systems. Fortunately, however, plants were domesticated slowly enough to permit a new and stable equilibrium to emerge. Throughout this slow and lengthy evolution, it is estimated that humans have utilized several thousands of edible plant species. Mutual adaptation took place between man and the plants he grew and between these plants and the environment. Soil and climate conditions, as well as the cultural features of local civilizations, were major factors determining this process. All this contributed decisively to maintaining and even increasing genetic diversity during this long period; heterogeneous species and varieties well adapted to local conditions developed in each location.

EROSION OF GENETIC DIVERSITY

Ecological equilibrium has again been disrupted in modern times, but change is now so swift and the recent population explosion so massive that nature simply does not have time, biologically, to cope with it. One striking feature of this new stage is the reduction of genetic diversity. In fact, contacts and collisions between different civilizations and ethnic groups have brought about a fusion of customs and life styles. In this century alone, the development of transportation and communication systems has greatly boosted the phenomenon of cultural integration, including the imposition of the eating habits of the dominant culture. Only some 150 species are now under cultivation. According to Mangelsdorf, most of the world's population now lives off no more than 12 plant species. Diminished diversity is also mirrored in the reduction of agricultural varieties.

The concentration of population in urban areas and the rising demand for food has created a situation in which high production levels have priority over stable production levels. In the major crop species, a small group of standard and usually very high-yielding varieties have

come to replace a vast mosaic of heterogeneous primitive local landraces. This trend has made it possible to boost world food production, but at a very high price, which may be even higher because of the growing dependence on costly inputs such as fertilizers, pesticides, irrigation and the like. Moreover, many heterogeneous local varieties have been lost forever.

The problem lies in the fact that the loss of a local species or variety means the irreversible loss of the genetic diversity it contains, including, of course, the genes for local adaptation to the site where the species or variety evolved.

If the future is not going to be put in jeopardy, ways must be found to control the changes taking place and to assure their reversibility. This means that if the world is to be spared problems which we are not even in a position to predict at this time, we need to maintain, for possible future use, collections of representative samples not only of local varieties which are now in the process of being replaced but also of endangered wild species. These samples can be kept either *ex situ* or *in situ*.

Whether *ex situ* or *in situ*, the protection of the plant genetic resources of our planet is not confined to our century or to our civilization. More than 3,000 years ago the ancient Egyptians buried seeds with the Pharaohs, with different crop varieties stored separately for use in the other life. As far as *in situ* conservation is concerned, there is documented evidence that the need to conserve *in situ* forest and animal resources was taught and decreed in parts of India and China as far back as 700 BC.

During the past two centuries, travelers and scientists have collected, stored, transported and studied live and dead plants; many of our best herbaria and botanical gardens started in this way. But the systematic collection and conservation of live plants at a global level is a more recent phenomenon that started with Vavilov in the 1920s.

INTERNATIONAL ACTIONS

In the United Nations system, work on the conservation of plant genetic resources started with discussions in FAO in 1947. In 1957, FAO began publishing a newsletter on the subject; since 1974, when the International Board for Plant Genetic Resources (IBPGR) was established, this newsletter has been published jointly with IBPGR, as the *Plant Genetic Resources Newsletter*. In 1961, FAO convened an international meeting which led to the establishment, in 1965, of a Panel of Experts on Plant Exploration and Introduction; the panel was to advise FAO and to provide international guidelines for the collection, conservation and exchange of crop germplasm. A Panel of Experts on Forest Gene Resources was established in 1968. As technical problems arose, FAO convened and co-sponsored three Technical Conferences on Plant Genetic Resources, in 1967, 1973 and 1981. In 1968, FAO also set up a Plant Genetic Resources and Crop Ecology Unit, with the objective of organizing and promoting the conservation and utilization of plant genetic resources. FAO has also supported, housed and worked in close collaboration with IBPGR, an autonomous, technical and nongovernmental center in the Consultative Group on International Agricultural Research (CGIAR) system.

Other United Nations agencies or bodies directly concerned with the conservation of ecosystems and genetic resources include the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the United Nations Environment Program (UNEP). The United Nations World Health Organization (WHO) has recently joined forces with its sister organizations through its special interest in the conservation and sustained use of medicinal plants.

The important role played by the CGIAR, and particularly by IBPGR, in germplasm conservation deserves to be singled out. The crop-specific international agricultural research centers (IARCs) of the CGIAR have been crucial in collecting, conserving, evaluating, documenting and distributing germplasm for the crops with which they are concerned; they also serve as depositories of germplasm collections for international use. Within the CGIAR group, the technical and catalytic role played by IBPGR, particularly in relation to its priority crops, must be emphasized; its long-term association with FAO has also permitted it to have a great impact at the national, regional and international level.

Other nongovernmental organizations (NGOs) that deserve special mention are the International Union for the Conservation of Nature and Natural Resources (IUCN) and the World Wide Fund for Nature (WWF), which deal mainly with issues related to the conservation of ecosystems.

FAO, UNESCO, UNEP and the IUCN coordinate their work in environmental matters through the Ecosystem Conservation Group (ECG). A Working Group on *In Situ* Conservation of Plant Genetic Resources was established within the framework of the ECG in 1984. The Working Group includes a representative of IBPGR in addition to representatives of member organizations of the ECG. Invitations have also been extended to the WHO and WWF to attend the meetings of the group.

THE FAO GLOBAL SYSTEM

Most genetic resources of plants are found in the species-rich tropical and subtropical areas of the world, which to a large extent comprise developing countries with limited financial and manpower resources. However, the full potential socioeconomic value of genetic resources can be realized only if they remain freely available and, conversely, if new technologies and knowledge remain freely transferable, and national plant breeding technologies and evaluation programs are supported and developed worldwide.

Since 1979, a number of debates related to the technical, legal, social, economic and political implications of plant genetic resources have taken place. In these debates it became apparent that if no equitable global system could be established, even the safe conservation and the important principle of the free availability of plant genetic resources might be challenged. It was equally obvious that an appropriate international forum for this kind of debate was also needed.

Following these debates and at the request of its member countries, FAO has developed since 1983 a global system for action and coordination in the genetic resources field. The global system, based on FAO's long experience and within the context of its global mandate, already includes: a legal framework, the International Undertaking on Plant Genetic Resources; an international forum, the Commission on Plant Genetic Resources; and a financial mechanism, the International Fund for Plant Genetic Resources. In accordance with Article 7 of the International Undertaking two more elements — a network of base collections under FAO auspices and a global international information system — are also being developed.

- The *International Undertaking on Plant Genetic Resources* (see Resolution 8/83 over-leaf) is a flexible legal framework, based on the universally accepted principle that plant genetic resources are the heritage of all mankind. Its objective is to ensure that plant

genetic resources, especially those species of present or future economic and social importance, will be explored, preserved, evaluated and made available without restriction for plant breeding and other scientific purposes. The International Undertaking covers both *ex situ* and *in situ* conservation.

- The *Commission on Plant Genetic Resources* (see Resolution 1/85 page 30) is a unique international global forum where countries, which are donors or users of germplasm, funds and technology, can discuss matters related to plant genetic resources on an equal footing, and monitor the implementation of the principles contained in the International Undertaking. Through its debates, the Commission aims to reach consensus on areas of global interest and compromises in areas where there is disagreement. Through the Commission's meetings, activities can also be coordinated and responsibilities distributed among those concerned. A number of technical assistance agencies, donors, development banks and NGOs also formally attend these meetings.

Resolution 8/83: International Undertaking on Plant Genetic Resources

I General

Article 1: Objective

1. The objective of this Undertaking is to ensure that plant genetic resources of economic and/or social interest, particularly for agriculture, will be explored, preserved, evaluated and made available for plant breeding and scientific purposes. This Undertaking is based on the universally accepted principle that plant genetic resources are a heritage of mankind and consequently should be available without restriction.

Article 2: Definitions and scope

2.1 In this Undertaking:

- (a) 'plant genetic resources' means the reproductive or vegetative propagating material of the following categories of plants:
 - (i) cultivated varieties (cultivars) in current use and newly developed varieties;
 - (ii) obsolete cultivars;
 - (iii) primitive cultivars (landraces);
 - (iv) wild and weedy species, near relatives of cultivated varieties;
 - (v) special genetic stocks (including elite and current breeders' lines and mutants);
- (b) 'base collection of plant genetic resources' means a collection of seed stock or vegetative propagating material (ranging from tissue cultures to whole plants) held for long-term security in order to preserve the genetic variation for scientific purposes and as a basis for plant breeding;
- (c) 'active collection' means a collection which complements a base collection, and is a collection from which seed samples are drawn for distribution, exchange, and other purposes, such as multiplication and evaluation;
- (d) 'institution' means an entity established at the international or national level, with or without legal personality, for purposes related to the exploration, collection, conservation, maintenance, evaluation or exchange of plant genetic resources;

- (e) 'center' means an institution holding a base or active collection of plant genetic resources, as described in Article 7.
- 2.2 This Undertaking relates to the plant genetic resources described in para. 2.1(a), of all species of economic and/or social interest, particularly for agriculture at present or in the future, and has particular reference to food crops.

Article 3: Exploration for plant genetic resources

- 3.1 Governments adhering to this Undertaking will organize or arrange for missions of exploration, conducted in accordance with recognized scientific standards, to identify potentially valuable plant genetic resources that are in danger of becoming extinct in the country concerned, as well as other plant genetic resources in the country which may be useful for development but whose existence or essential characteristics are at present unknown, in particular:
 - (a) known landraces or cultivars in danger of becoming extinct because of their abandonment in favor of the cultivation of new cultivars;
 - (b) the wild relatives of cultivated plants in areas identified as centers of genetic diversity or natural distribution;
 - (c) species which are not actually cultivated but may be used for the benefit of mankind as a source of food or raw materials (such as fibers, chemical compounds, medicine or timber).
- 3.2 Special efforts will be made, in the context of Article 3.1, where the danger of extinction of plant species is certain, or is likely, having regard to circumstances such as the clearance of vegetation from tropical rain forests and semi-arid lands with a view to the expansion of cultivated areas.

Article 4: Preservation, evaluation and documentation of plant genetic resources

- 4.1 Appropriate legislative and other measures will be maintained and, where necessary, developed and adopted to protect and preserve the plant genetic resources of plants growing in areas of their natural habitat in the major centers of genetic diversity.
- 4.2 Measures will be taken, if necessary through international cooperation, to ensure the scientific collection and safeguarding of material in areas where important plant genetic resources are in danger of becoming extinct on account of agricultural or other development.
- 4.3 Appropriate measures will also be taken with respect to plant genetic resources held, outside their natural habitats, in genebanks or living collections of plants. Governments and institutions adhering to the Undertaking will, in particular, ensure that the said resources are conserved and maintained in such a way as to preserve their valuable characteristics for use in scientific research and plant breeding, and are also evaluated and fully documented.

Article 5: Availability of plant genetic resources

- 5. It will be the policy of adhering Governments and institutions having plant genetic resources under their control to allow access to samples of such resources, and to permit their export, where the resources have been requested for the purposes of scientific research, plant breeding or genetic resource conservation. The samples will be made available free of charge, on the basis of mutual exchange or on mutually agreed terms.

II International cooperation

Article 6: General

6. International cooperation will, in particular, be directed to:

- (a) establishing or strengthening the capabilities of developing countries, where appropriate on a national or subregional basis, with respect to plant genetic resources activities, including plant survey and identification, plant breeding and seed multiplication and distribution, with the aim of enabling all countries to make full use of plant genetic resources for the benefit of their agricultural development;
- (b) intensifying international activities in preservation, evaluation, documentation, exchange of plant genetic resources, plant breeding, germplasm maintenance, and seed multiplication. This would include activities carried out by FAO and other concerned agencies in the United Nations system; it would also include activities of other institutions, including those supported by the CGIAR. The aim would be to progressively cover all plant species that are important for agriculture and other sectors of the economy, in the present and for the future;
- (c) supporting the arrangements outlined in Article 7, including the participation in such arrangements of Governments and institutions, where appropriate and feasible;
- (d) considering measures, such as the strengthening or establishment of funding mechanisms, to finance activities relating to plant genetic resources.

Article 7: International arrangements

7.1 The present international arrangements being carried out under the auspices of FAO and other organizations in the United Nations system, by national and regional institutions and institutions which are supported by the CGIAR, in particular the IBPGR, for the exploration, collection, conservation, maintenance, evaluation, documentation, exchange and use of plant genetic resources will be further developed and, where necessary, complemented in order to develop a global system so as to ensure that:

- (a) there develops an internationally coordinated network of national, regional and international centers, including an international network of base collections in genebanks, under the auspices or the jurisdiction of FAO, that have assumed the responsibility to hold, for the benefit of the international community and on the principle of unrestricted exchange, base or active collections of the plant genetic resources of particular plant species;
- (b) the number of such centers will be progressively increased so as to achieve as complete a coverage as necessary, in terms of species and geographical distribution, account also being taken of the need for duplication, of the resources to be safeguarded and preserved;
- (c) the activities of the centers that are related to the exploration, collection, conservation, maintenance, rejuvenation, evaluation and exchange of plant genetic resources will be carried out with due account being taken of scientific standards;
- (d) sufficient support in funds and facilities will be provided, at the national and international levels, to enable the centers to carry out their tasks;

- (e) a global information system, under the coordination of FAO, relating to plant genetic resources maintained in the aforementioned collections, and linked to systems established at the national, sub-regional and regional levels, will be developed on the basis of relevant arrangements that already exist;
 - (f) early warning will be given to FAO, or any institution designated by FAO, of any hazards that threaten the efficient maintenance and operation of a center, with a view to prompt international action to safeguard the material maintained by the center;
 - (g) the IBPGR pursues and develops its present activities, within its terms of reference, in liaison with FAO;
 - (h)
 - (i) the general expansion and improvement of related professional and institutional capability within developing countries, including training within appropriate institutions in both developed and developing countries is adequately funded;
 - (ii) the overall activity within the Undertaking ultimately ensures a significant improvement in the capacity of developing countries for the production and distribution of improved crop varieties, as required to support major increases in agricultural production, especially in developing countries.
- 7.2 Within the context of the global system any Governments or institutions that agree to participate in the Undertaking may notify the Director-General of FAO that they wish the base collection or collections for which they are responsible to be recognized as part of the international network of base collections in genebanks, under the auspices or the jurisdiction of FAO. The center concerned will, whenever requested by FAO, make material in the base collection available to participants in the Undertaking, for purposes of scientific research, plant breeding or genetic resources conservation, free of charge, on the basis of mutual exchange or on mutually agreed terms.

Article 8: Financial security

- 8.1 Adhering Governments, and financing agencies, will, individually and collectively, consider adopting measures that would place activities relevant to the objective of this Undertaking on a firmer financial basis, with special consideration for the need of developing countries to strengthen their capabilities in genetic resource activities, plant breeding and seed multiplication.
- 8.2 Adhering Governments, and financing agencies, will, in particular, explore the possibility of establishing mechanisms which would guarantee the availability of funds that could be immediately mobilized to meet situations of the kind referred to in Article 7.1(f).
- 8.3 Adhering Governments and institutions, and financing agencies, will give special consideration to requests from FAO for extra-budgetary funds, equipment or services needed to meet situations of the kind referred to in Article 7.1(f).
- 8.4 The establishment and operation of the international network, insofar as it imposes additional costs on FAO, will be funded mainly from extra-budgetary resources.

Article 9: Monitoring of activities and related action by FAO

- 9.1 FAO will keep under continuous review the international situation concerning the exploration, collection, conservation documentation, exchange and use of plant genetic resources.

- 9.2 FAO will, in particular, establish an intergovernmental body to monitor the operation of the arrangements referred to in Article 7, and to take or recommend measures that are necessary or desirable in order to ensure the comprehensiveness of the global system and the efficiency of its operations in line with the Undertaking.
- 9.3 In the performance of its responsibilities outlined in Part II of this Undertaking, FAO will act in consultation with those Governments that have indicated to FAO their intention to support the arrangements referred to in Article 7.

III Other provisions

Article 10: Phytosanitary measures

10. This Undertaking is without prejudice to any measures taken by Governments — in line with the provisions of the International Plant Protection Convention, adopted in Rome on 6 December 1951 — to regulate the entry of plant genetic resources with the aim of preventing the introduction or spread of plant pests.

Article 11: Information on the implementation of this undertaking

11. At the time of adhering, Governments and institutions will advise the Director-General of FAO of the extent to which they are in a position to give effect to the principles contained in the Undertaking. At yearly intervals, they will provide the Director-General of FAO with information on the measures that they have taken or propose to take to achieve the objective of this Undertaking.

Resolution 1/85: Establishment of a Commission on Plant Genetic Resources

The council

Having noted Conference Resolution 8/83 on an International Undertaking on Plant Genetic Resources and,

Having further noted Conference Resolution 9/83 on the Establishment of a Commission of Plant Genetic Resources, and

Having considered the relevant provisions of the *Basic Tests* of the Organization and in particular Article VI.I of the Constitution and the ‘Principles and Procedures which should govern Conventions and Agreements concluded under Article VI of the Constitution, Articles XIV and XV of the Constitution’, and Commissions and Committees established under Article VI of the Constitution, set out in *Appendix R* of the *Basic Texts* of the Organization,

Decides to establish, under Article VI.I of the Constitution, a Commission to be known as ‘the Commission on Plant Genetic Resources’, the Statutes of which shall be as follows:

1. Membership

The Commission shall be open to all Member Nations and Associate Members of the Organization. It shall be composed of those Member Nations or Associate Members which notify the Director-General of their desire to be considered as Members.

2. Terms of reference

The terms of reference of the Commission shall be:

- (a) to monitor the operation of the arrangements referred to in Article 7 of the 'International Undertaking on Plant Genetic Resources', hereinafter referred to as 'The Undertaking';
- (b) to recommend measures that are necessary or desirable in order to ensure the comprehensiveness of the global system and the efficiency of its operation in line with 'The Undertaking'; and in particular,
- (c) to review all matters relating to the policy, programs and activities of FAO in the field of plant genetic resources, and to give advice to the Committee on Agriculture or, where appropriate, to the Committee on Forestry.

3. Sessions

Sessions of the Commission shall normally be held at the Headquarters of the Organization at the time or regular sessions of the Committee on Agriculture (COAG). The first session shall be convened by the Director-General and thereafter in consultation with the Chairman of the Commission.

4. Subsidiary bodies

- (a) The Commission may establish such subsidiary bodies as may be required for the effective discharge of its functions;
- (b) the establishment of any subsidiary body shall be subject to the determination by the Director-General that the necessary funds are available in the relevant chapter of the budget of the Organization or from extra-budgetary sources. Before taking any decision involving expenditure in connexion with the establishment of subsidiary bodies, the Commission shall have before it a report from the Director-General on the program, administrative and financial implications thereof.

5. Reporting

At the conclusion of each session, the Commission shall submit to the Director-General a report on its activities and recommendations taking into account the need for the Director-General to be in a position to take such reports into consideration when preparing the draft Program of Work and Budget of the Organization or other submissions to the Organization's governing bodies. The Director-General shall bring to the attention of the Conference through the Council any recommendations adopted by the Commission which have policy implications or which affect the program or finances of the Organization. As soon as they become available, copies of each report of the Commission will be circulated to Member Nations and Associate Members of the Organization and also to international organizations and agencies that are concerned with Plant Genetic Resources.

6. Secretariat and expenses

- (a) The Secretary of the Commission shall be appointed by the Director-General and shall be administratively responsible to him. The expenses of the Secretariat of the Commission shall be determined and paid by the Organization within the limits of the relevant appropriations in the approved budget of the Organization;

- (b) expenses incurred by representatives of members of the Commission, their alternates or advisers, when attending sessions of the Commission or its subsidiary bodies, as well as the expenses of observers at sessions, shall be borne by the respective Governments or organizations.

7. Observers

The participation as observers of Member Nations and Associate Members that are not members of the Commission, of states which are not Members or Associate Members of the Organization, and of international organizations shall be governed by the relevant provisions of the principles adopted by the Conference.

8. Rules of procedure

The Commission may adopt and amend its own rules of procedure, which shall be in conformity with the Constitution and the General Rules of the Organization and with the statement of principles governing commissions and committees adopted by the Conference. The rules of procedure and amendments thereto shall come into force upon approval by the Director-General.

CURRENT DEVELOPMENTS IN THE FAO GLOBAL SYSTEM

To date, 115 countries are members of the Commission and/or have adhered to the International Undertaking. Some 34 of them are African countries (*see* Table 1).

To implement the principles contained in the International Undertaking, FAO has taken a number of steps, including the following:

- It established, in 1987, an International Fund to support the conservation of plant genetic resources and promote their utilization. The Fund can also be seen as a possible mechanism for the users of germplasm to compensate the donors of germplasm for the contribution they made to world agricultural development by conserving, improving and making available the plant genetic resources over the generations. In this respect, it was considered that the simultaneous international recognition of both plant breeders' and farmers' rights would also facilitate the international movement of germplasm. Some governments, NGOs, inter-governmental organizations and private foundations have already contributed to the fund; private enterprises have also been invited to participate.
- It is establishing a network of base collections in genebanks under the auspices and/or the jurisdiction of FAO (Article 7 of the International Undertaking). This is a physical component of the global system, and aims to guarantee the continuous free exchange of germplasm across any economic or political boundaries. The basic reason for establishing this network is to ensure that the *ex situ* conservation of plant genetic resources, and unrestricted access to these resources, be assured under the authority of an inter-governmental institution such as the FAO. All countries, and a number of institutions or bodies, have been invited to participate in this network. A number of positive replies, with varying degrees of commitment, have already been received.
- The Global Information System (Article 7 of the International Undertaking) is being developed.

TABLE 1 **Members of the FAO Commission on Plant Genetic Resources
and/or countries which have adhered to the International
Undertaking on Plant Genetic Resources**

Africa	Asia/South- West Pacific	Europe	Latin America/ the Caribbean	Near East
Benin ¹	Australia ¹	Austria ^{1,2}	Argentina ^{1,2}	Afghanistan
Botswana ¹	Bangladesh ^{1,2}	Belgium ^{1,2}	Antigua and Barbuda ²	Bahrain ²
Burkina Faso ^{1,2}	Fiji ²	Bulgaria	Barbados ^{1,2}	Egypt
Cameroon ^{1,2}	India ^{1,2}	Cyprus ^{1,2}	Belize ¹	Iran
Cape Verde ^{1,2}	Indonesia	Czechoslovakia	Bolivia ^{1,2}	Iraq ²
Central African Rep. ^{1,2}	Korea, D.P.R. ^{1,2}	Denmark ^{1,2}	Brazil ¹	Kuwait ²
Chad ^{1,2}	Korea, Rep. of ^{1,2}	Finland ^{1,2}	Chile ^{1,2}	Lebanon ²
Congo ¹	Nepal ²	Germany F.R. ^{1,2}	Colombia ^{1,2}	Libya
Côte d'Ivoire ²	New Zealand ²	Greece ^{1,2}	Costa Rica ^{1,2}	Oman ²
Ethiopia ^{1,2}	Pakistan ¹	Hungary ^{1,2}	Cuba ^{1,2}	Syria
Gabon ^{1,2}	Philippines ^{1,2}	Iceland ^{1,2}	Dominica ^{1,2}	Tunisia
Gambia ¹	Solomon Islands	Ireland ^{1,2}	Dominican Rep. ^{1,2}	Yemen
Guinea ²	Sri Lanka ^{1,2}	Israel ^{1,2}	Ecuador ¹	Arab Rep.
Guinea-Bissau ¹	Thailand ¹	Italy ¹	El Salvador ^{1,2}	Yemen P.D.R. ²
Kenya ^{1,2}	Tonga ²	Liechtenstein ²	Grenada ²	
Liberia ^{1,2}		Netherlands ^{1,2}	Guatemala ¹	
Madagascar ^{1,2}		Norway ^{1,2}	Guyana ¹	
Malawi ²		Poland ^{1,2}	Haiti ^{1,2}	
Mali ^{1,2}		Portugal ¹	Honduras ^{1,2}	
Mauritania ^{1,2}		Spain ^{1,2}	Jamaica ²	
Mauritius ^{1,2}		Sweden ^{1,2}	Mexico ^{1,2}	
Morocco ¹		Switzerland ^{1,2}	Nicaragua ²	
Mozambique ²		Turkey ^{1,2}	Panama ^{1,2}	
Rwanda ¹		United Kingdom ^{1,2}	Paraguay ²	
Senegal ^{1,2}		Yugoslavia ¹	Peru ^{1,2}	
Sierra Leone			St Christopher and Nevis ¹	
Sudan ¹			St Lucia ¹	
Togo ¹			St Vincent and the Grenadines ¹	
Uganda			Uruguay ¹	
Zambia ^{1,2}			Venezuela ¹	
Zimbabwe ²				

1 Members of the Commission.

2 Countries which have adhered to the International Undertaking.

CONCLUSION

In spite of the impressive amount of work promoted and carried out during the past decade both by United Nations and non-United Nations agencies and organizations, there is still much more to be accomplished. It is our firm view that any new development in this field needs to be coordinated and should be based on previous achievements in order to avoid duplication and enhance efficiency.

During the coming years FAO, through its Commission of Plant Genetic Resources and in close cooperation with all other inter-governmental, governmental and nongovernmental organizations dealing with the plant genetic resources, will continue working to achieve the full implementation of the International Undertaking.

Keynote Address

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The African continent possesses an enormous wealth of plant genetic resources which can contribute to the perfection of new varieties, the diversification of people's diets and the production of medicinal preparations. The rational exploitation of these plants could result in the rapid development of African agriculture. Unfortunately, many of these resources are often neglected and would have disappeared but for the help of the International Board for Plant Genetic Resources (IBPGR), and the attention given to them by researchers. This is the case with a number of crops, including *Oryza glaberrima* (native rice), taro, yam and African peas. In this presentation, I shall be stressing the importance of collecting, conserving and making use of plant genetic resources, the need to train African cadres, and the need for collaboration among international institutions, national agricultural programs and African universities.

This workshop is being held at a time when the world in general and Africa in particular are experiencing unprecedented economic difficulties. Certain parts of the African continent are continuously subjected to natural disasters which put pressure on their populations to migrate in the search for food.

It is pleasing to note that most governments have begun to implement activities to improve their people's position and are continually encouraging them to grow such crops as will make it possible for them to feed, clothe and house themselves. In order to satisfy these basic needs in a continent that is experiencing a disturbing demographic increase, we ought to turn to our own natural resources with a view to making use of them in modern agriculture.

Examples which illustrate the wealth of Africa's plant genetic resources are: the flora of Ghana, studied by Irvine (1961), which reveals that there are 558 species of food plants and 754 species of medicinal plants used by people, as well as many other plants with other uses; the flora of Zaïre, which contains 51 genera, covering 160 medicinal species (INEAC, 1948, 1958, 1960, 1963); and the study made by Prinz and Heke (1986), which showed that it is possible to extract many new therapeutic substances from 260 species found in Haut-Zaïre.

The benefits that these resources can provide for us can all be produced in quantity and at the required quality, even with the sole condition that they are used in obtaining the best possible yield. Such yields are the only answer to relieving the problem of an inadequate supply of arable land to meet the needs of the population in the year 2000 on a continent which is losing a large part of its surface to the steadily advancing desert. In the area occupied by the great equatorial forest, the soil is being depleted of minor elements and is often degraded

by the unfavorable climate. Bad agricultural practices and the over-exploitation of genetic resources also inhibit the development of agriculture in Africa. We must use techniques properly adapted to the material resources, with rational management of land resources.

In the course of a conference which was organized at Yangambi, Zaïre, in 1947 by the National Institute of Agricultural Study and Research, it was stressed by many of the former settlers that our traditional methods (cultivating, fallow, non-working) were harmful because they lacked any scientific basis. They were, however, the methods which, over the long term, assured better conservation of the soil, and this is why they are being revived today. The critics of traditional techniques, which tend to produce low yields, did not take into account the fact that African rural people make use of few, if any, of the agricultural inputs, such as fertilizers, which are considered important elements in stimulating yields in modern agriculture.

It is beyond any doubt that, in order to obtain measurably increased yields for feeding an ever-increasing population, it is necessary to satisfy certain conditions, namely, the improvement of existing plants and the selection of new plants that respond to people's needs. It is a matter of providing consumers with products that have the required qualities (rich in carbohydrates or fats, high levels of vitamins and proteins with essential amino acids, and so on). In order to come within the reach of everyone, the high-yielding varieties used should also be adapted to our soils and climatic conditions (cold, heat, dryness and mediocre soil fertility). Equally, it is necessary to protect plants from the principal diseases (fungi, viruses and bacteria), from insects and from parasites which account for considerable losses in yield. Because of this, it is necessary to undertake selections based on genetic resistance.

In this paper I will show that the development of agriculture in Africa requires, as a matter of necessity, financially sustained agricultural research (Anon., 1987) based upon a multi-disciplinary approach in which the role of the 'plant improver' is paramount.

Hawkes (1978) considers that three elements ought to be taken into account in the development of African agriculture: genetic resources, genetic erosion, and the conservation of genetic diversity.

GENETIC RESOURCES

The required plant qualities can be obtained only from other varieties and they should contain the most favorable genes. Permit me to illustrate here, on a theoretical level, the genetic diversity that can be obtained through such processes as mutation, artificial insemination and combination. This genetic diversity ought to be safeguarded for use in case of need.

According to Harlan et al. (Hawkes, 1978), traditional agriculture is an important source of genetic diversity at each level of cultivation. It is felt that the extent of genetic diversity as it concerns indigenous African cultivation systems remains large. The existence of wild stock for so many plants offers enormous possibilities for the selection and creation of high-yielding varieties.

The proof of this wealth of genetic resources in Africa is shown by the numerous gathering missions organized by private, national and international bodies. Lawrence (1984) showed that more than 100,000 samples had been deposited in various genebanks by the early 1980s, 25-28% of them deriving from African tropical countries. These samples were made up principally of cereals (65.7%) and legumes (18.2%). Roots and tubers and indigenous shrubs represent 7.4% of the samples.

GENETIC EROSION

Currently, most plant varieties are relatively poor from the point of view of genetics, because they have been created from material with a restricted genetic base. The reason for this is that the sources of gene stocks are fast disappearing.

We have only vague memories of the bush forests and grasslands that we knew in our childhood and which doubtless provided refuge for precious genetic resources. The sometimes unconscious destruction of these natural habitats leads inexorably to the disappearance of numerous plant species. The centers of origin delimited by Vavilov (1951) certainly no longer contain the species and the life forms which once inhabited them. In their constant search for new space for housing and cultivation and for building materials, people have measurably reduced the chances for survival of rare and interesting species.

Such is the case, for example, of a climbing plant, *Ginetum africanum*, the foliage of which is a legume ('mfumbua') much appreciated in Zaire, which is on its way to extinction. The same can be said for some shrubs called native aubergines, such as *Solarium macrocarpor* and *S. aethiopicum*, and for a good number of roots and tubers, such as yam and taro. The most striking case is that of native rice, *Oryza glaberrima*, once a major crop in West Africa, but which today would have been completely displaced by *O. sativa* if researchers had not given it special attention.

The spectacular results achieved at the conclusion of a selection program are likewise a basis for genetic erosion in that these results spur countries on to adopt a high-yielding variety at the expense of previously cultivated species. The process of popularizing the widespread used of these new varieties also reinforces this negative attitude.

In monoculture, improved techniques lead farmers to resort to pesticides, fertilizers and irrigation, to the exclusion of any possibility of hybridization between cultures and spontaneous plants at the field level, assigning plants to conditions of weak pressure regarding natural selection, and *ipso facto* reducing the genetic pool. There is thus a need to search for a compromise. On the one hand, we ought to produce more plants in a variety of forms to feed a growing population, while on the other hand we must safeguard our traditional plant genetic resources.

CONSERVATION OF GENETIC DIVERSITY

Many rural people conserve genetic diversity in their cultivation practices through mixing varieties which often do not have a very high potential. Not being very efficient, this method of conservation does not prevent the rapid extinction of numerous species.

In order to conserve genetic diversity, there is, therefore, a place for the adoption of a strategy involving such activities as exploration and collection, conservation, evaluation, documentation and data management, training, and organization and infrastructural development.

Exploration and collection

According to Frankel (1975), we ought first to assure ourselves of the availability of resources in the realm in which we work. Later, we can determine priorities in light of the intensity of

current erosion and of the needs shown by those working on the improvement of a given material. These needs arise as a result of research using material already in a collection or being introduced into a collection.

Priorities ought to be established not only for systems of cultivation but also for regions. For example, among the 29 genera considered since 1976 as priorities by IBPGR (1987), 17 (58.6%) are of interest to Africa. We should note the presence of genera whose importance has continued to increase: *Vigna*, *Solanum*, *Manihot*, *Dioscorea*, *Colacasia* and *Amaranthus*.

Compared with the American and Asian continents, Africa does not possess many wild species. Nevertheless, collections made recently have revealed the existence of new ones, notably in the genera *Oryza* and *Vigna* (Mergeai, 1986; Mithen, 1987). Certain species, because of their importance in crop improvement, require particular attention.

Because the techniques for collecting samples are already well defined for several groups of plants, I shall not discuss them here.

Conservation

It serves no useful purpose to explore the countryside and collect material if it cannot then be conveniently conserved. It is, therefore, important to guarantee suitable conditions for conservation and to ensure the availability of the necessary staff and equipment. In Africa, many research institutions have neither appropriate buildings nor such facilities as electricity and permanent running water. These institutions are generally set up as enclaves.

Each center concerned with genetic resources ought, in principle, to maintain one or two collections of seeds:

- a basic collection of material kept under optimum conditions in such a way that it is appropriately conserved over the long term;
- an active collection of material maintained under less ideal conditions that will, however, ensure its conservation over the medium term. This collection will be used for regeneration, multiplication, evaluation and documentation. At the time of its introduction into a country, this material should pass through a quarantine station.

Because of the investment in manpower that the basic/active collection system implies, Linnington and Smith (1987) recommended the creation of an active collection out of the basic collection.

Certain grains, called 'regular', can be kept over a long period in an environment of 5% RH and -20°C without being regenerated. Regeneration would generally take place after 20 to 50 years. In practice, however, periodic tests of germination are made to decide on whether it is necessary to proceed to regeneration. Regeneration is needed every time the rate of germination drops below 85-98% of the initial rate.

Other grains, called 'recalcitrant', which are produced by the great majority of fruiting plants (coffee, cocoa, cola and oil palm), die immediately after they have been submitted to the conditions that support 'regular' grains.

In vitro methods become important where the aim is to store the maximum amount of diversity in a limited space. The cultivation of tissues, the use of which has already been extended to many plants grown in Africa (coffee, yam, manioc, sweet potato and taro),

presents some real advantages, such as a high rate of multiplication, elimination of viruses making quarantine unnecessary, and ease of transport (in the form of calluses, for example) (IITA, 1986, 1987).

Regarding types of cultivation, it is noted that the seeds of food-producing plants are relatively easy to conserve and may be rapidly renewed. Perennial plants require a great amount of work for their storage *in situ*. The great disadvantage of such conservation is the high cost of surveillance of great expanses of forests and grasslands.

We should note, in passing, an experiment currently being conducted by the Department of Biology at the University of Kinshasa, Zaïre. This consists of encouraging the urban populations to plant hedges around their plots consisting of food, medicinal and other plants. According to Kizika et al. (1988), this experiment allows for the improvement of the value of the plants conserved and such traditional plant resources as *Hibiscus* species, *Amaranthus*, *Manihot glaziovii* and *Psophocarpus scandes*.

Evaluation

The material needed to start an improvement program has many sources — local, regional, research stations and so on. Thus, we are able to acquire genetic material with as much genetic diversity as we please, but if it is not used in a selection program, its importance diminishes. This, I think, is one of the causes of the slowness of agricultural development in Africa.

Evaluation is exceedingly delicate work, particularly when one is dealing with a large continent, such as Africa, with its wide diversity of soils and climatic conditions. International tests, conceived by institutions such as IITA, provide information on the adaptability of varieties perfected in these research centers. The existence of such a body as the Association for the Advancement of Agricultural Sciences in Africa (AAASA) is a supplementary stimulus to research on behalf of African agriculture.

Documentation and data management

The role of computers in the storage, use and dissemination of information is now so well known that it seems almost superfluous to talk about it. Africa, although very rich in genetic resources, is nevertheless a continent where the dissemination of scientific information still poses many problems.

Detailed data on genetic stocks would permit selectors to establish realistic programs for the remaining cultivation systems. With the codification of data now being standardized, researchers can in future all speak the same language.

Training

We have already mentioned that the rational use of plant genetic material for the production of high-yielding varieties requires the mastering of certain disciplines. It is necessary to consider the specialization and the training of all staff involved in the implementation of a program. In fact, most African institutions concerned with genetic resources still suffer from a scarcity of middle-level technical personnel.

Numerous training programs, organized by IBPGR, the United Nations Environment Program (UNEP) and the International Institute of Tropical Agriculture (IITA) and to which all agricultural development staff are invited, enable these staff to have a taste of research, to acquire new knowledge and to become more aware of their responsibilities. We can only encourage IBPGR, UNEP and IITA to continue to strengthen these activities.

Organization and infrastructural development

In looking at the program for this workshop, I notice that others among us will enlarge on some topics that I am about to touch on. However, let me note that the success of any broad program depends on a well-structured organization, capable of coordinating all activities, avoiding duplication of work, evaluating priorities and providing the necessary direction.

The problems of coordination and financing are often aggravated by the fact that one person has to be concerned with several species at the same time. From the numerous reports published each year, it appears that IBPGR is collaborating with many national, regional and international research centers, and supplies appropriate support to developing countries. The African network, however, seems to be less active than American and Asian networks. One of the causes for this, I think, is the shortage of resources.

Although African agriculture should be based on indigenous cultural techniques, it needs to find a base also in other areas. Many of our research institutions, national and international, having already made numerous improved varieties available to farmers, should now follow up this effort by strengthening the cooperation between the different regions of Africa through the exchange of information, following the example of the cooperation on oil palm between the Institut National pour l'Etude Agronomique au Congo (INEAC), the research stations of the Institut de Recherche sur les Huiles et Oléagineux (IRHO) and the Malaysian research stations for oil palm.

The role of genetic resources in the development of agriculture has also been demonstrated by the green revolution begun by Asian researchers, of which we are beneficiaries today. Africa, which has numerous genetic resources at its disposal, ought, with all the problems it faces, to consider making its own revolution.

CONCLUSION

The African continent possesses a varied range of plant genetic resources made up principally of cereals (rice, maize, sorghum, millet and eleusine), legumes for food and fodder (groundnuts, haricots, 'niébé', African peas and 'voandzou'), starchy roots and tubers (yam, manioc, sweet potato and taro) and bananas and plantains, as well as forestry and medicinal species.

The greater part of these resources are not used; some of them are disappearing. If these resources were rationally collected, conserved and used after evaluation, they would contribute quantitatively and qualitatively to an increase in agricultural production in Africa.

All these activities require funds and thus it is necessary to have the support of organizations such as IBPGR, UNEP and FAO, which should work to reinforce the collaboration between the various international research institutes, national agricultural research programs and African universities. For the success of research programs on plant genetic resources, the

training of African cadres must be a matter of high priority and it is essential that governments allocate significant financial support to this activity.

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PART 1

Genetic Diversity

1.1

Status and Diversity of African Germplasm Collections Maintained at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

M. H. MENGESHA and S. APPA RAO

One of the major objectives of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is to act as a world repository for the genetic resources of its mandate crops: sorghum, *Sorghum bicolor* (L.) Moench; pearl millet, *Pennisetum glaucum* (L.) R. Br.; chickpea, *Cicer arietinum* L.; pigeonpea, *Cajanus cajan* (L.) Mill.; and groundnut, *Arachis hypogaea* L.. The Institute also assembles and conserves the germplasm of six minor millets: finger millet, *Eleusine coracana* (L.) Gaertn.; foxtail millet, *Setaria italica* (L.) P. Beauv.; proso millet, *Panicum sumatrense* Roth. ex Roem. & Schult.; barnyard millet, *Echinochloa* species; and kodo millet, *Paspalum scrobiculatum* L.

The usefulness of any world germplasm collection, such as the one assembled at ICRISAT, depends largely on proper sampling from various agroclimatic zones, the long-term safety and viability of the conserved material, the genetic diversity it offers in both cultivated landraces and their wild relatives, the accessibility of healthy seed samples along with their passport and evaluation data, appropriate maintenance of the germplasm accessions to minimize genetic drift, and the availability of a simple, classified and retrievable documentation system.

ORIGIN AND DISTRIBUTION OF CROPS

Sorghum is reported to have originated in the Sudan/Ethiopian border region and has since spread throughout the world (Harlan, 1975; De Wet, 1978; Mann et al., 1983). The distribution of different races and the assembly, evaluation and utilization of sorghum germplasm are described by Prasada Rao and Mengesha (in press). Pearl millet originated in

a diffuse belt of Africa, from Sudan to Senegal (Brunken et al., 1977). The diversity of pearl millet germplasm and its utilization are described by Harinarayana et al. (in press) and Kumar and Appa Rao (1988). Well-documented scientific evidence strongly suggests that pigeonpea originated in India (De, 1974; Maesen, 1980). Chickpea, an important crop in the Indian subcontinent, Ethiopia, Iran, Pakistan, Mediterranean countries and Mexico, probably originated in Turkey (Ladizinsky, 1975). The origin of groundnut is reported to be in South America (Gregory et al., 1973; Ramanatha Rao and Sadasivan, 1985).

Primitive landraces of crops that originated in harsh environments can survive in similar environments, as they evolved mainly in response to natural and, to a lesser degree, human selection (Harlan, 1975). Through the same process of survival, they have been forced to utilize their energy to withstand diseases, pests, drought and other stresses. However, the farmer needs more grain to feed a growing world population, and that is partly why he is replacing the adapted, but low-yielding, landraces with new, high-yielding cultivars. In this context, it is vital to salvage and conserve the farmers' landraces and their wild relatives for use in plant breeding. The international agricultural research centers (IARCs) located in different regions of the world are in a unique position to collect and conserve germplasm and make it readily available to scientists everywhere.

GERMPLASM COLLECTION AND ASSEMBLY

To avert food shortages and subsequent famines, we need to accelerate crop improvement programs, starting with the collection and conservation of the vanishing germplasm. Enormous diversity still exists within crops, although it is gradually dwindling. The time to collect the traditional landraces is now, before they are replaced by newly bred, high-yielding cultivars (Harlan, 1975; Hawkes, 1981). In some cases, such as with the Zerazera landraces of sorghum, it is already too late (Mengesha and Prasada Rao, 1981).

Against this background, ICRISAT started an extensive collaborative project on germplasm collection and assembly in the mid-1970s. The 34,914 germplasm accessions assembled at ICRISAT from Africa and those that will be added in the future are for the benefit of all research workers in any country that needs to use them. It must be emphasized here that those countries that continue to contribute germplasm samples for the world collection are the main beneficiaries. First, they can ensure long-term conservation and availability of their vanishing germplasm. Second, they can expect, in their own countries, a high degree of adaptation of the new and high-yielding cultivars that are developed by using their landraces.

Following its establishment, ICRISAT acquired samples of most of the germplasm of its mandate crops from national and regional programs, such as the Ethiopian Sorghum Improvement Program (ESIP), and world collections, such as the Rockefeller Foundation world collection made in the early 1960s. After identifying geographic and taxonomic gaps, expeditions were launched in priority areas in close collaboration with national programs in Africa, often with the cooperation and support of the International Board for Plant Genetic Resources (IBPGR). We also carried out collection missions for special sorghum types, such as the Zerazera landraces from Ethiopia (Prasada Rao and Mengesha, 1982) and the early-maturing, bold-grain types of pearl millet from Ghana (Appa Rao et al., 1985). All the germplasm samples collected are shared equally among the host country, IBPGR and ICRISAT. To date, ICRISAT has launched 41 expeditions in 24 countries in Africa and assembled 34,914 accessions from 47 countries (see Table 1).

TABLE 1 **Number of germplasm accessions from Africa in the ICRISAT genebank**

Country	Sorghum	Pearl millet	Chickpea	Pigeonpea	Groundnut	Minor millets
Algeria	21	0	16	0	0	0
Angola	29	0	0	0	7(1)	0
Benin	197	40	0	0	14	0
Botswana	190	45	0	0	1	0
Burkina Faso	559	587	0	0	61	0
Burundi	115(2)	0	0	0	0	11
Cameroon	2241	918	0	0	6	0
Cape Verde Is.	1	1	0	6	0	0
Central African Republic	39	58	0	0	2	0
Chad	138	62	0	0	15	0
Comoros	0	0	0	0	1	0
Congo	0	3	0	0	6	0
Côte d'Ivoire	1	0	0	0	80	0
Egypt	22	0	53	0	16	0
Equatorial Guinea	0	0	0	0	13	0
Ethiopia	4,464	1	922	14	0	28
Gambia	57	13	0	0	32	0
Ghana	148	246	0	2	53	0
Guinea	0	0	0	0	22	0
Kenya	872	69	1	316(18)	42	326
Lesotho	257	0	0	0	0	0
Liberia	0	0	0	0	12	0
Libya	0	0	0	0	1	0
Malagasy Republic	1	0	0	1	47	0
Malawi	443	245	10	245	146	248
Mali	661	1,044	0	0	161(145)	0
Mauritania	0	1	0	0	0	0
Mauritius	0	0	0	0	26	0
Morocco	8	3	249	0	21	0
Mozambique	42(6)	28	0	10	149	1
Namibia	1	0	0	0	0	0
Niger	408	1,048	0	0	21	0
Nigeria	1,436	1,145	3	43	338	0
Rwanda	150	0	0	5	1	0
Senegal	237	361	0	10	254	0
Sierra Leone	100	55	0	3	22	0
Somalia	125(294)	3	0	0	9	0
South Africa	930	115	0	4	138	4
Sudan	2,385	559	12	0	197(1)	2
Swaziland	201	0	0	0	8	0
Tanzania	437(262)	449	2	221	378(40)	20
Togo	258	104	0	0	11	0
Tunisia	0	0	33	0	0	0
Uganda	1,245	66	0	1	165	617
Zaire	53	0	0	0	108	0
Zambia	291	81	0	25(61)	240(15)	117
Zimbabwe	1,052(11)	436	0	0	504(72)	414
Total	19,815(575)	7,776	1,301	906(79)	3,328(274)	1,788

Note: Numbers in parentheses are in quarantine transit.

One serious concern we have is that germplasm collection missions are usually made when most of the crop is at prime maturity. As a result, the collector may miss early- and late-maturing lines. Therefore, our strategy has been modified to include collecting landraces at different times of the year — if necessary at several times a year from the same locations. The success of any germplasm collection mission depends largely on: the time of collection; the collectors' knowledge of the crops (including their wild relatives), the country and the region; logistic support; proper collection strategies; correct sampling; adequate field records; and the safe and rapid transfer of the collected material to genebanks.

WILD SPECIES GERMPLASM

It is well known that wild relatives are reservoirs of desirable genes for resistance to certain biotic and abiotic stresses. With the recent advances in biotechnology, it may become increasingly possible to transfer desirable genes from distant wild relatives. Accordingly, we are striving to collect and conserve wild relatives of our crops, although our initial emphasis was on cultivated types. So far, we have assembled 935 accessions of 144 wild species for all our crops. This collection is relatively small and our future plans call for accelerated collection of wild relatives from the centers of origin and diversity.

There are a few examples of wild relatives being successfully utilized as sources of desirable traits. In groundnut, where resistance to *Cercospora* leaf spot is not found in the cultivated forms (Singh et al., in press), wild relatives were successfully used as sources of resistance. In pearl millet, a single dominant gene for rust resistance was found in the wild relative *Pennisetum violaceum*; it is also found in the cultivated forms. In sorghum, resistance to shoot fly, *Atherigona soccata*, was not found in the cultivated forms, but was identified in the wild relative *Sorghum aethiopicum*. Similarly, resistance to pod borer, *Heliothis armigera*, was transferred from *Atylosia* into *Cajanus cajan* (ICRISAT, 1982).

GERMPLASM CONSERVATION

For conservation, seed is produced at ICRISAT during the post-rainy season, when good-quality seed that is free from diseases can be obtained. The standing crop is inspected by plant protection experts and only disease- and insect-free seed is harvested. The moisture content of the seed is brought down to 5-7% before storage in cold chambers at 4°C.

After harvesting, threshing and partial drying, seed is brought to a cool and dry short-term holding room where it is prepared and processed for transferring to medium- or long-term storage. All the accessions at ICRISAT are conserved either in medium- or long-term cold storage conditions that meet the international standards proposed by Roberts (1974) and IBPGR (1979). The temperature and humidity of the storage chambers and the viability of the seed viability are monitored regularly.

Our active germplasm collection is held in medium-term storage. The temperature is maintained at +4°C, with 20% RH. To minimize the frequency of rejuvenation and consequent possible genetic drift, relatively large quantities of seed (in each sample 500 g of sorghum, pearl millet and minor millets, 800 g of pigeonpea and chickpea, and 1 kg of groundnut pods) are stored. Seeds are stored in laminated aluminum cans with screw caps that have rubber gaskets to ensure that they are airtight. We draw small samples for distribution

to any scientist who needs them. We have monitored seed regularly for 5 years and found that we have around 91% viability after 5 years of conservation.

A long-term store is now ready for the base collection. To maintain the temperature at -20°C , prefabricated modules have been installed and have been under test for the past year. Seeds will soon be transferred to long-term storage. Recently, we have introduced electronic devices to maintain the desired levels of temperature and relative humidity in our cold storage chambers with a built-in alarm system against fire, high temperatures and moisture.

DIVERSITY OF GERMPLASM

All registered accessions of our mandate crops are systematically evaluated according to descriptors developed by ICRISAT and IBPGR. The variation in important morphological and agronomic characters is considerable; the range observed in different crops is given in Table 2. Considerable variation was also recorded when 343 pearl millet accessions were evaluated at five different locations in India, Burkina Faso and Niger. We have recorded the genetic diversity of 500 pigeonpea germplasm accessions that were systematically evaluated in Kenya and 900 chickpea accessions evaluated in Ethiopia. This work has helped to identify and select several desirable genotypes for crop improvement. Continuous effort is made at ICRISAT to identify new sources of diversity. In pigeonpea, for example, the germplasm

TABLE 2 Range of variation in some selected characters of African crop germplasm samples evaluated at ICRISAT

Character	Sorghum	Pearl millet	Chickpea	Pigeonpea	Groundnut
Days to 50% flowering	36-199	36-159	28-96	55-210	19-50
Plant height (cm)	55-655	63-475	16-93	39-385	-
Peduncle exsertion (cm)	0-55	-21-30	-	-	-
Head length (cm)	2.5-71	6-165	-	-	-
Head thickness (mm)	10-290	10-64	-	-	-
Number of tillers	1-15	1-26	-	-	-
Stalk sugar content (%)	12-38	4.9-19.7	-	-	-
Grain color	white to dark brown	white to dark purple	cream to black	white to black	off-white to dark purple
Seeds per pod	-	-	1-2.8	1.6-7.6	1-4
110-seed mass (g)	0.58-8.56	0.27-1.93	4.9-59.4	2.8-22.4	21.8-100.6
Plant width (cm)	-	-	18-70	-	-
Pods per plant	-	-	few-168	-	-
Harvest index (%)	-	-	21.9-64.8	-	-
Seed protein (%)	-	-	15.4-30.9	12.4-29.5	-
Oil content (%)	-	-	-	-	34.8-50.4
Leaflet length (mm)	-	-	-	-	28-79
Leaf width (mm)	-	-	-	-	14-38
Pod length (mm)	-	-	-	-	13-64
Pod width (mm)	-	-	-	-	11-22
Days to maturity	-	-	-	-	90-155

accessions have been classified into a number of well-defined diversity groups, as shown in the Pigeonpea Germplasm Catalogs (Remanandan et al., 1988a, 1988b).

The main purpose in pointing out this range in variation is to underline the potential use of germplasm for crop improvement. Although the variation that has been conserved is very useful, it is still considered small compared with that available in nature. Many remote areas have yet to be explored and collections made. Unfortunately, the continued availability of such germplasm cannot be guaranteed in view of the alarming genetic erosion that is taking place throughout the world. Good examples of such genetic erosion are the absence of the Zerazera and Hegari sorghum landraces in the Gezira province of Sudan and their replacement by newly bred cultivars (Mengesha and Prasada Rao, 1982), and the imminent extinction of the once-popular pearl millet landrace 'Gullisita' in the Punjab (Appa Rao et al., 1986).

GERMPLASM UTILIZATION

The potential use of a germplasm sample is largely unknown at the time of its collection. However, we have seen that a number of desirable characters are identified whenever a diverse group of germplasm samples is evaluated and screened. Even those lines that show susceptibility to a disease or pest may offer a rare source of breeding material for other agronomically desirable traits. For example, sorghum landraces IS 1082, IS 2122, IS 4663, IS 4664, IS 5470, IS 5484, IS 5566 and IS 18551 have been identified as having promising shoot fly resistance, which needs further confirmation. Other sorghum accessions, including IS 620, IS 621, IS 5959, IS 7237, IS 8219, IS 9308, IS 9482 and IS 11234 have promising grain-mold resistance, but they are susceptible to shoot fly and stem borer. In pigeonpea, ICP 7035 has resistance to *Fusarium* wilt and sterility mosaic, but it is susceptible to *Phytophthora* blight. ICP 7065 is resistant to blight, but highly susceptible to both wilt and sterility mosaic (Mengesha, 1984).

Some misunderstanding exists between technology-rich developed countries and gene-rich developing countries about the international collection, conservation, exchange and utilization of plant genetic resources (Mooney, 1980). The concern comes from the fear that certain private and multinational companies might patent and monopolize new, high-yielding cultivars that could be developed by using germplasm originally collected from developing countries. However, the IARCs and IBPGR, as well as the FAO Commission for Plant Genetic Resources and other international and national programs, agree on the timely collection and conservation of the world's germplasm, and on making it readily available to all who need it for crop improvement programs.

CONCLUSION

Considering the worldwide crop improvement programs and in view of the plant breeders' remarkable success in developing high-yielding cultivars, it is obvious that there are significant advantages associated with international germplasm exchange. With timely collection and imaginative methods of seed conservation and exchange, we should be able to save our valuable seeds for present and future use.

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1.2

La diversité génétique des espèces végétales sous-exploitées d'Afrique

L. AKE ASSI

Jusqu'à la fin du 19^e siècle, on admettait que les hommes avaient été, au cours de leur histoire, d'abord chasseurs, puis pâtres nomades et, enfin, agriculteurs sédentaires. Pour certains auteurs, au contraire, les peuples primitifs ont, avant l'agriculture, tiré des plantes une part essentielle de leur alimentation. L'élevage et la chasse seraient donc plutôt que des stades primitifs, des modes de vie imposés par les conditions du milieu, impropres au développement de l'agriculture; des exemples frappants en sont les peuples chasseurs des régions circumpolaires et les pasteurs nomades des déserts. Il s'agit non d'une succession de modes de vie mais d'un déterminisme historique, lorsque les éleveurs steppiques envahissent un territoire plus humide, favorable à la vie agricole; les habitants primitifs de ces régions, vivant de culture, peuvent alors subsister sous la domination de leurs envahisseurs; c'est ce qui s'est passé, par exemple, au Fouta-Djallon, en Guinée (avec l'installation des Foulah éleveurs dans des régions primitivement occupées par des Noirs agriculteurs) et en Afrique de l'Est (là où sont venus s'installer certains peuples kalamites orientaux). Quant aux régions plus humides, capables de fournir suffisamment de plantes vivrières, l'alimentation humaine paraît y avoir été, dès l'origine, principalement végétale. En effet, les peuples les plus primitifs de l'époque actuelle ont une alimentation essentiellement végétale, qui leur est fournie par la cueillette des feuilles, des tubercules et des fruits de plantes sauvages. Ce mode de vie se trouve encore chez quelques peuplades minoritaires vivant notamment dans les forêts et savanes d'Afrique sub-saharienne.

A PROPOS DES ESPECES ALIMENTAIRES DE LA FLORE SAUVAGE AFRICAINNE, POUR LA PLUPART NON EXPLOITEES

Aucun progrès durable, dans quelque domaine que ce soit, n'est à espérer des sociétés humaines, tant que celles-ci ne jouiront pas de disponibilités alimentaires suffisantes, en quantité et en qualité, pour assurer leur bon état nutritionnel. L'Afrique sub-saharienne ne

pose pas, comme certaines régions surpeuplées du monde, un problème alimentaire angoissant, dans la mesure où cette région est loin d'avoir épuisé l'exploitation de ses immenses ressources végétales. La flore naturelle de l'Afrique intertropicale compte d'innombrables espèces utiles. Outre le bois de transformation et le bois d'exportation qui contribuent largement à l'économie de certains Etats africains, il existe de nombreuses autres sources de revenu pouvant, utilement, suppléer à l'économie rurale de ces pays. Il s'agit de produits de cueillette. Ces derniers, nombreux et très variés, se classent en plantes médicinales, en plantes textiles, en plantes alimentaires, etc. Malheureusement, après l'accession à l'indépendance politique des anciennes colonies d'Afrique, il y a une trentaine d'années, hormis les plantes médicinales qui, grâce au mouvement écologiste 'Retour à la Nature', sont à l'honneur, les plantes alimentaires sauvages, autrefois si recherchées, sont ou presque à l'abandon (certaines disparues, d'autres en voie de l'être), au profit d'espèces exotiques d'introduction récente. Heureusement, grâce à quelques paysans conservateurs, qui les cultivent ou les récoltent dans la nature on trouve encore, sur les marchés, quelques-unes de ces plantes. Nous pouvons citer, par exemple: *Blighia sapida* (Sapindaceae), *Brassica integrifolia* (Brassicaceae), *Chrysophyllum albidum* (Sapotaceae), *Dioscorea burkilliana*, *D. dumetorum*, *D. praehensilis* (Dioscoreaceae), *Gnetum* spp. (Gnetaceae), *Landolphia owariensis*, *Saba florida* (Apocynaceae), *Talinum triangulare* (Portulacaceae) et *Vernonia amygdalina* (Asteraceae). Concernant la valorisation de ces plantes, la Conférence internationale sur l'alimentation et la nutrition en Afrique tropicale, tenue à Dschang, au Cameroun, en 1949, sous les auspices de l'OMS et de la FAO, recommandait déjà:

- que soit poursuivie l'analyse plus approfondie des aliments de base, des aliments secondaires d'appoint, des aliments de disette, etc;
- que la composition de ces aliments soit établie, pour chaque espèce et variété;
- que soit donné, outre le nom usuel local, le nom scientifique des espèces et variétés;
- que les méthodes analytiques utilisées soient précisées.

Afin d'attirer l'attention de la communauté scientifique internationale sur l'intérêt génétique indéniable de cette catégorie de ressources végétales en désuétude et conformément à la recommandation de la Conférence de Dschang, nous décrivons, dans les pages qui suivent, par ordre alphabétique des familles, une quarantaine d'espèces de plantes alimentaires sauvages choisies au hasard.

DESCRIPTION, ECOLOGIE ET USAGES DE QUELQUES ESPECES ALIMENTAIRES SAUVAGES EN VOIE D'EXTINCTION DE LA FLORE DE L'AFRIQUE INTERTROPICALE

Anacardiaceae

Sclerocarya birrea (A. Rich.) Hochst., Flora 27, Bes. Bell. 1 (1844); Keay, F.W.T.A. ed. 2, 1: 729 (1958). Noms vernaculaires: Kountan, Kountango (Bambara); Nobéga (Moré). (Voir figure 1)

Description

Arbre de 7 à 10 m de hauteur. Feuilles imparipennées; folioles de 5 à 10 paires, glabres, glauques. Inflorescences terminales, en épis. Fleurs petites, verdâtres. Fruits drupacés, jaunes à maturité, mesurant jusqu'à 3,5 cm de diamètre.

Répartition géographique

Espèce des régions sèches de l'Afrique intertropicale, on la trouve depuis le Sénégal jusqu'en Ouganda.

Usages

La pulpe du fruit et la graine sont comestibles. Les fruits entrent dans la composition de préparations à usage hémostatique externe.

Observation

La multiplication de la plante se fait par semis des graines.

Spondias mombin Linn., sp. Pl. 1: 371 (1753); Keay, F.W.T.A. ed. 2,1: 728 (1958).

Noms vulgaires: Mombin, Prune Mombin. Noms vernaculaires: N'Gbala (Abbey); N'Gba, N'Gba-té (Akyé); Troman (Agni, Baoulé); Tété, titi (Bété).

Description

Arbre de 10 à 15 m de hauteur. Feuilles alternes, imparipennées; folioles oblongues, de 4 à 6 paires, glabres. Inflorescences en panicules lâches. Fleurs petites, blanches, odorantes. Fruits drupacés, ovoïdes ou pyriformes, de 25 à 35 mm de longueur et de 15 à 20 mm de diamètre, jaunes et odoriférants à maturité.

Répartition géographique

Espèce afro-néotropicale, le Mombin se rencontre dans toute l'Afrique intertropicale.

Usages

Les fruits mûrs, à saveur de mangue, se consomment sous plusieurs formes. Les feuilles entrent dans la préparation de plusieurs remèdes en médecine traditionnelle africaine.

Observation

La propagation de la plante se fait par semis des graines ou par boutures.

Trichoscypha arborea (A. Chev.) A. Chev., Expl. Bot. de l'A.O.F. 1: 161 (1920); Keay, F.W.T.A. ed. 2,1: 736 (1958).

Noms vernaculaires: Dao (Abbey); Alakoui (Agni); N'Dabokou (Akyé); Alaya (Ebrié). (Voir figure 1)

Description

Arbre de 10 à 25 m de hauteur. Grandes feuilles atteignant 70 cm de longueur, comportant de 6 à 8 paires de folioles oblongues-elliptiques ou oblongues-lancéolées, glabres. Inflorescences en grandes panicules dressées. Fleurs petites, rougeâtres, subsessiles. Grandes infrutescences comprenant des drupes ellipsoïdes, mesurant jusqu'à 2,5 cm de longueur, rouge violacé.

Répartition géographique

Espèce de forêt dense humide, on la trouve depuis le Libéria jusqu'au Cameroun.

Usages

Les fruits, comestibles et très appréciés, ont le goût du ricin noir.

Observation

La propagation de la plante se fait par semis des graines.

FIGURE 1 (a) *Sclerocarya birrea* (Anacardiaceae)
(b) *Trichoscypha arborea* (Anacardiaceae)



Annonaceae

Annona senegalensis pers., syn. Pl. 2: 95 (1806); Keay, F.W. T. A. ed. 2,1: 52 (1954).

Noms vernaculaires: Amlon (Baoulé); Lomo Lomo (Djimini); Kontakpé (Lobi); Karamoko sounzou (Malinké).

Description

Arbuste de 1 à 5 m de hauteur, polymorphe, à rameaux jeunes tomentelleux à glabrescents. Feuilles coriaces, polymorphes, ovales à oblongues-obovales. Fleurs solitaires ou géminées, axillaires extra axillaires à oppositifoliées, jaune verdâtre ou jaunes. Fruits ovoïdes ou globuleux, mesurant de 4 à 6 cm de diamètre légèrement bosselés, jaunes à maturité.

Répartition géographique

Espèce commune dans toutes les savanes de l'Afrique intertropicale.

Usages

Les fruits mûrs, comestibles, ont le goût de la pomme cannelle, *Annona squamosa*.

Les diverses parties de la plante sont employées en médecine de tradition africaine.

Observation

La propagation de la plante se fait par semis des graines ou par transplantation de souches.

Apocynaceae

Carissa edulis Vahl, symb. Bot. 1: 22 (1790); Huber F.W. T. A. ed. 2,2: 54 (1963). (Voir figure 2)

Description

Arbuste sarmenteux, épineux, comportant du latex. Feuilles opposées, entières, ovales, glabres ou pubescentes, cunéiformes à la base, obtuses au sommet. Inflorescences en cymes corymbiformes axillaires ou terminales. Fleurs blanches ou rosâtres, à lobes de la corolle linéaires. Fruits bacciformes, sphériques, rouge à rouge violacé à maturité, mesurant de 12 à 15 mm de diamètre.

Répartition géographique

Espèce paléotropicale, on la trouve dans toutes les régions sèches de l'Afrique intercontinentale. On la rencontre quelquefois sur le cordon littoral dans certains pays.

Usages

Les fruits mûrs se mangent.

Au Togo, les racines de la plante entrent dans la préparation d'un remède contre l'asthme.

Observation

La propagation de la plante se fait par semis des graines ou par transplantation de souches.

Landolphia heudelotii A. Dc., DC. Prod. 8: 320 (1844); Huber, F.W.T.A. ed. 2, 2: 56 (1963).

Description

Liane atteignant 15 m de hauteur comportant des rameaux préhensiles partiellement volubiles. Feuilles opposées, oblongues-elliptiques, pubescentes ou glabrescentes,

FIGURE 2 (a) *Carissa edulis* (Apocynaceae)
(b) *Landolphia owariensis* (Apocynaceae)



arrondies ou cunéiformes à la base, arrondies ou obtuses au sommet. Inflorescences en cymes corymbiformes terminales. Fleurs blanches, assez grandes, à tube pubescent. Fruits bacciformes, sphériques, atteignant 4 cm de diamètre, jaune orangé à maturité.

Répartition géographique

Espèce soudano-zambézienne, on la trouve depuis le Sénégal jusqu'au Ghana et au Cap-Vert.

Usage

Les fruits mûrs, à goût sucré un peu acidulé, sont très appréciés.

Observation

La multiplication de la plante se fait par semis des graines.

Landolphia hirsuta (Hua) Pichon, Mém. I.F.A.N. 35: 193, t. 9, 1-4 (19537); Huber, F.W.T.A. ed. 2,2: 57 (1963).

Noms vernaculaires: N'Gbafa (Akyé); Amani (Baoulé).

Description

Grande liane poilue atteignant de 10 à 20 m de hauteur, à latex abondant, comportant des rameaux préhensiles partiellement volubiles. Feuilles opposées, obovales ou obovales-elliptiques, arrondies ou légèrement cordées à la base, acuminées, à nervures comportant des poils hirsutes en dessous. Inflorescences en petites cymes axillaires ou des fleurs fasciculées. Fleurs petites, blanc jaune, tubuleuses, à lobes linéaires. Fruits globuleux, jaunes à maturité, mesurant jusqu'à 5 cm de diamètre, contenant de nombreuses graines noyées dans une pulpe charnue.

Répartition géographique

Espèce ouest-africaine, répandue depuis le Sénégal jusqu'au Cameroun, où on la trouve aussi bien en forêt dense qu'en savane. Dans cette dernière zone, on la trouve dans les boqueteaux.

Usages

La pulpe des fruits mûrs, sucrée, légèrement acidulée, est comestible.

Le latex de la plante sert de glu pour le piégeage des oiseaux dans certaines localités en Côte d'Ivoire.

Observation

La propagation de la plante se fait par semis des graines.

Landolphia owariensis P. Beauv., Fl. owariensis 1, 54: t. 62 (1804); Huber, F.W.T.A. ed. 2,2: 55 (1963).

Nom vernaculaire: Amani (Baoulé). (Voir figure 2)

Description

Grande liane très ramifiée, glabre, à latex, pourvue de rameaux préhensiles partiellement volubiles. Feuilles opposées, glabres ou glabrescentes, elliptiques ou légèrement obovales, courtement cunées à la base, courtement acuminées. Inflorescences en panicules terminales. Fleurs blanches, tubulaires, à 5 lobes. Fruits bacciformes, atteignant 5 cm de diamètre, sphériques ou ovoïdes, jaunes à maturité, contenant de nombreuses graines dans une pulpe charnue.

Répartition géographique

Espèce de forêt dense humide répandue dans toute l'Afrique intertropicale.

Usages

La pulpe des fruits mûrs est comestible.

Le latex, coagulé avec du jus de citron, donne un caoutchouc traditionnellement utilisé dans certaines régions d'Afrique.

Observation

La multiplication de la plante se fait par semis des graines.

Saba florida (Benth.) Bullock, Kew Bull. 13: 391 (1959); Huber, F.W.T.A. ed. 2,2: 61 (1963).

Noms vernaculaires: Amani (Baoulé); Saba, Sagba (Malinké). (Voir figure 3)

Description

Grande liane glabre, atteignant 20 m de hauteur, glabre, à latex, à rameaux comportant de nombreuses lenticelles. Feuilles opposées, glabres, ovales elliptiques, elliptiques ou ovales, largement cunéiformes à arrondies à la base, obtuses ou arrondies au sommet. Inflorescences en panicules ou en cymes contactées ombelliformes. Fleurs blanches, odorantes, tubuleuses, à lobes elliptiques allongés. Gros fruits globuleux ou ovoïdes, mesurant de 5 à 7 cm de diamètre, lisses ou quelquefois bosselés, jaunes à maturité, contenant de nombreuses graines dans une pulpe jaune abondante.

Répartition géographique

Plante de savane répandue dans toute l'Afrique intertropicale, à Madagascar et aux Comores.

Usages

La pulpe charnue, entourant les graines des fruits mûrs, sucrée et acidulée, est comestible.

Observation

La propagation de la plante se fait par semis des graines.

Saba senegalensis var. *glabriflora* (Hua) Pichon, Mém. I.F.A.N. 35: 322 (1953); Huber, F.W.T.A. ed. 2,2: 61 (1963).

Noms vernaculaires: Amani (Baoulé); Saba, Sagba (Malinké).

Description

Grande liane à latex, atteignant 15 m de hauteur. Feuilles opposées, glabres, oblongues ou oblongues-elliptiques courtement et largement cunées à la base, courtement acuminées. Inflorescences en cymes corymbiformes terminales. Fleurs blanches, odorantes, tubuleuses, à lobes oblongs. Gros fruits bacciformes ovoïdes, quelquefois bosselés, atteignant de 7 à 10 cm de diamètre, jaunes à maturité, contenant de nombreuses graines noyées dans une pulpe jaune.

Répartition géographique

Espèce ouest-africaine, on la trouve dans les savanes soudaniennes, du Sénégal au Ghana.

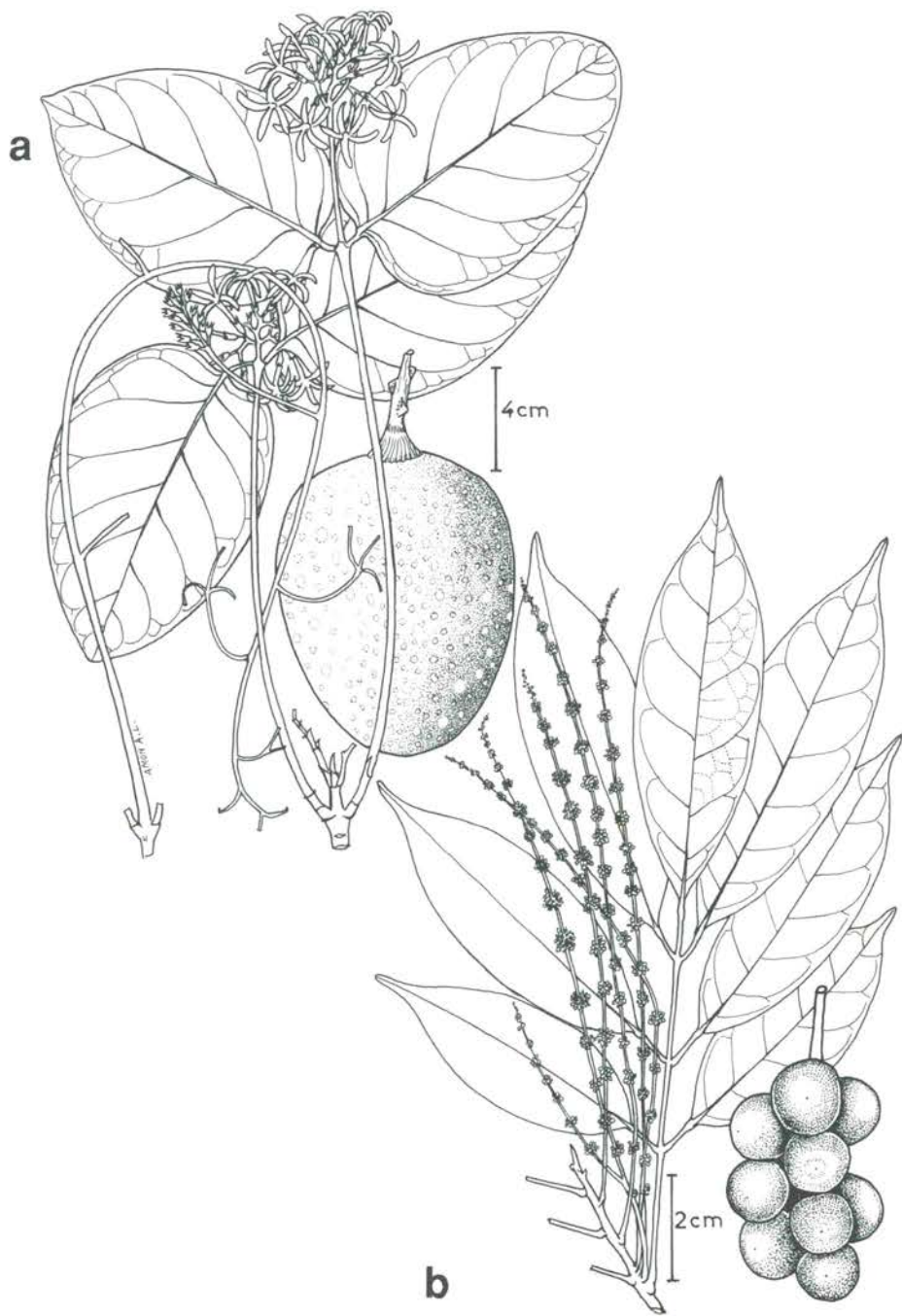
Usages

La pulpe charnue, jaune entourant les graines, sucrée, acidulée, est comestible.

Observation

La multiplication de la plante se fait par semis des graines.

FIGURE 3 (a) *Saba florida* (Apocynaceae)
 (b) *Dacryodes klaineana* (Burseraceae)



Areaceae

Phoenix reclinata Jacq., *Fragm.* 1: 27, t. 24 (1801); Russell, F.W.T.A. ed. 2,3: 169 (1968).
Nom vulgaire: Faux dattier. Nom vernaculaire: N'Glissia (Baoulé).

Description

Petit palmier épineux, croissant souvent en touffes et en groupes, à stipe droit ou courbé, atteignant de 2 à 5 m de hauteur. Feuilles retombantes, à pétiole comportant de fortes épines. Inflorescences en panicules axillaires. Fleurs petites, blanchâtres. Régimes comportant de petites dattes jaunes, charnues à maturité.

Répartition géographique

Le faux dattier est répandu dans toute l'Afrique intertropicale. On le trouve principalement dans les régions côtières et dans les savanes où il pousse aux abords des lieux marécageux.

Usages

Les fruits mûrs, à goût de dattes, sont comestibles. On obtient, par incision du bourgeon terminal, du vin de palme très apprécié.

Observation

La multiplication de la plante se fait par semis des graines ou par éclatement de souches.

Burseraceae

Canarium schweinfurthii Engl., DC., *Monogr. Burserac.* p. 145 (1883); Keay, F.W.T.A. ed. 2,1: 697 (1958).

Noms vernaculaires: Aïélé (Abbey); Singnien (Akyé).

Description

Grand arbre atteignant 35 m de hauteur, faiblement épaissi à la base, à cime ressemblant à celle des *meliaceae*, avec les feuilles rassemblées à l'extrémité des rameaux. Feuilles composées imparipennées, pubescentes, comportant de 7 à 15 paires de folioles; folioles oblongues, cordées à la base, acuminées jusqu'à 13 cm de longueur et 5 cm de largeur, coriaces, pubescentes. Inflorescences en panicules atteignant 20 cm de longueur, pubescentes. Fleurs petites, verdâtres ou jaune verdâtre. Fruits drupacés, ovoïdes, mesurant de 3 à 4 cm de longueur, violacés à maturité, contenant une graine.

Répartition géographique

Plante de forêt dense humide, répandue dans toute l'Afrique intertropicale.

Usages

Les fruits mûrs, à pulpe grasse, séchés, se mangent cuits à l'eau. La résine qu'exsude l'écorce de la tige est utilisée en médecine traditionnelle africaine.

Observation

La multiplication de la plante se fait par semis des graines.

Dacryodes klaineana (Pierre) H.J. Lam, *Bull. Jard. Bot. Buitenz. sér.* 3, 12: 336 (1932); Keay, F.W.T.A. ed. 2, 1: 696 (1958).

Noms vernaculaires: Vi (Abbey); Sè, Sin (Akyé); Korindja (Agni); Adjouaba (Apollonien); Agbaya (Ebrié). (Voir figure 3)

Description

Arbre de 15 à 20 m de hauteur, à fût régulier, à écorce se desquamant en plaquettes minces et exsudant une résine parfumée. Feuilles imparipennées, comportant jusqu'à 3 paires de folioles opposées, gaufrées, glabres. Inflorescences en panicules lâches comprenant des fleurs fasciculées. Fleurs petites, jaunâtres, parfumées, poilues. Fruits drupacés, sphériques ou ovoïdes, atteignant de 2 à 2,5 cm de diamètre, rouge orangé à maturité.

Répartition géographique

Espèce de forêt sempervirente, on la trouve depuis la Sierra Leone jusqu'au Gabon.

Usages

Les fruits mûrs, à goût de mangues greffées, sont très appréciés. Ils sont vendus sur les marchés de novembre à décembre. Les feuilles entrent dans la préparation de divers remèdes traditionnels.

Observation

La propagation de la plante se fait par semis des graines.

Caesalpinaceae

Detarium microcarpum Guill. et Perr., Fl. seneg. 271, t. 59, p (1882); Keay, F.W.T.A. ed. 2, 1: 457 (1958).

Noms vernaculaires: Tamani, Tama-Klo (Malinké); Kpèhè (Lobi).

Description

Arbuste de 8 à 10 m de hauteur. Feuilles composées-pennées, comportant de 2 à 6 paires de folioles alternes ou subopposées pubescentes; folioles oblongues-elliptiques, coriaces, arrondies à émarginées au sommet, arrondies à courtement et largement cunées à la base, nervures secondaires nombreuses et fines. Inflorescences en panicules axillaires contractées. Fleurs nombreuses, petites, blanches. Fruits drupacés, suborbiculaires, aplatis, fibreux, mesurant jusqu'à 4 cm de diamètre et 2,5 cm d'épaisseur.

Répartition géographique

Espèce soudano-zambézienne, on la trouve dans toute l'Afrique de l'Ouest, du Sénégal au Cameroun et en République centrafricaine et au Soudan.

Usages

Le péricarpe des fruits mûrs, fibreux, farineux, un peu sucré et acidulé, est comestible. Les diverses autres parties de la plante sont employées en médecine de tradition africaine.

Observation

La multiplication de la plante se fait par semis des graines.

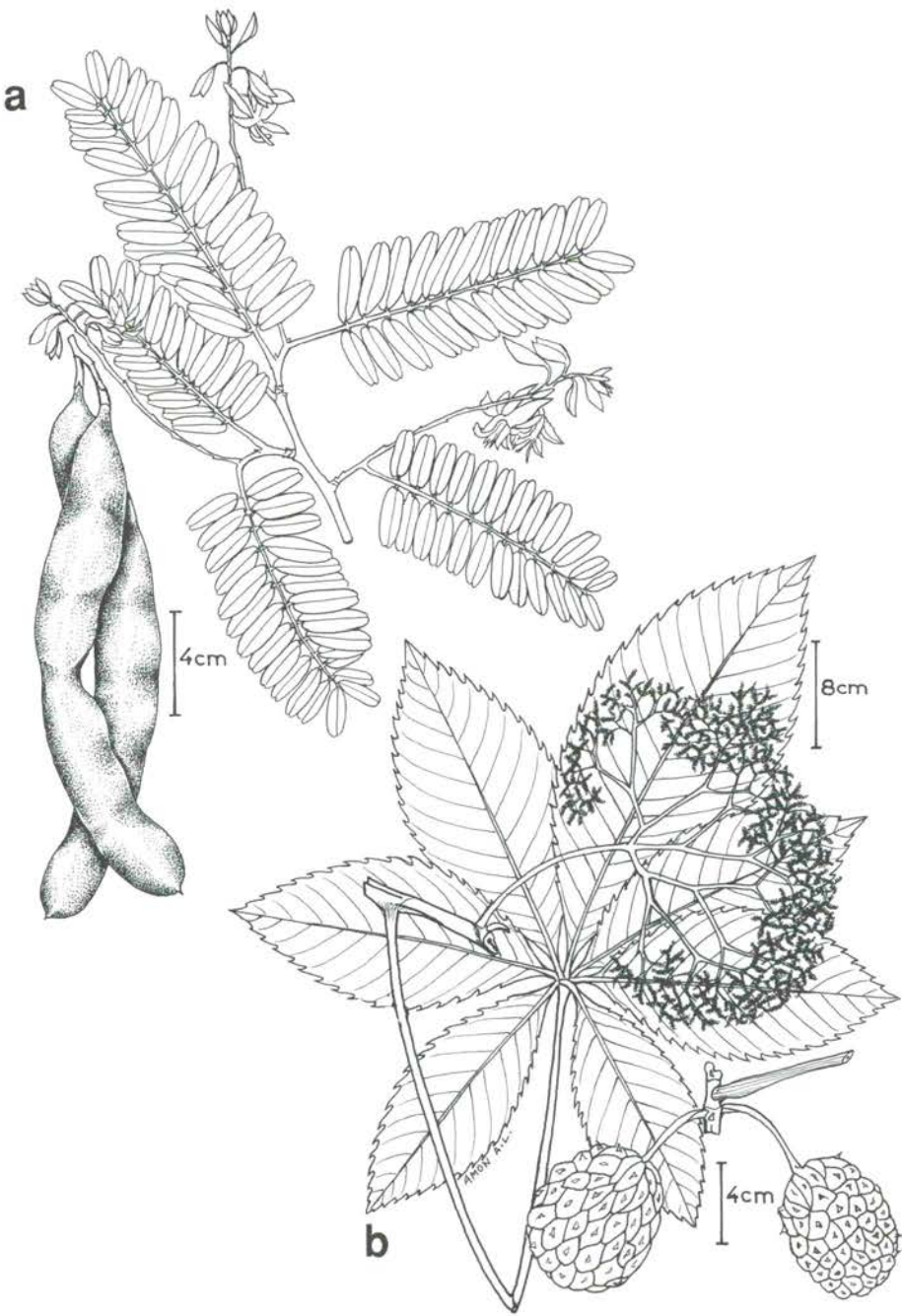
Tamarindus indica Linn., sp. pl. 34 (1753); Oliver, F.T.A. 2: 308 (1871); Keay, F.W.T.A. ed. 2, 1: 477 (1958).

Nom vulgaire: Tamarinier (Français). Nom vernaculaire: Tomi (Malinké). (Voir figure 4)

Description

Arbuste de 12 à 15 m de hauteur. Feuilles paripennées, comportant de 7 à 12 paires de folioles opposées; folioles oblongues ou ovales-oblongues, disymétriques à la base, arrondies ou émarginées au sommet, glabres, glauques. Inflorescences en

FIGURE 4 (a) *Tamarindus indica* (Caesalpinaceae)
(b) *Myrianthus arborens* (Cecropiaceae)



racèmes terminales. Fleurs jaunâtres, maculées de pourpre. Gousses épaisses, ligneuses, souvent courbées, atteignant 10 cm de longueur et 2 cm d'épaisseur; pulpe charnue, mêlée de fibres. Graines de 5 à 6.

Répartition géographique

Plante pantropicale, le tamarinier est répandu dans toute l'Afrique intertropicale. On la trouve plus en abondance dans les régions soudaniennes et sahéliennes.

Usages

La pulpe des fruits mûrs sert à préparer des boissons rafraîchissantes. Les diverses autres parties de la plante sont employées en médecine de tradition africaine.

Observation

La multiplication de la plante se fait par semis des graines.

Cecropiaceae

Myrianthus arboreus P. Beauv., Fl. oware 1: 17, t. 11 (1804); Hutchinson, F.T.A. 6,2: 231 (1917); Keay, F.W.T.A. ed. 2,1: 614 (1958).

Noms vernaculaires: Wougnan (Abbey); Djin (Akyé). (Voir figure 4)

Description

Arbre dioïque, atteignant 15 m de hauteur, beaucoup branchu. Feuilles composées-digitées, ayant de 5 à 7 folioles; folioles régulièrement et profondément dentées, oblongues ou oblongues-elliptiques, sessiles ou subsessiles, mesurant jusqu'à 50 cm de longueur et 20 cm de largeur, coriaces, comportant de nombreuses nervures latérales; pétiole atteignant de 30 à 40 cm de longueur. Inflorescences géminées, axillaires à l'extrémité des rameaux, les mâles en panicules, les femelles des capitules sphériques. Syncarpes sphériques atteignant 15 cm de diamètre, comprenant les fruits soudés les uns aux autres renfermant chacun une graine.

Répartition géographique

Espèce guinéo-congolaise, on la trouve depuis la Sierra Leone jusqu'au Cameroun et du Gabon jusqu'en Angola. C'est une plante des formations végétales remaniées.

Usages

Les fruits mûrs, à goût sucré un peu acidulé, sont comestibles. Les jeunes plantes sont employées pour confectionner de la sauce. Les feuilles sont utilisées, en médecine traditionnelle africaine, pour la préparation de divers médicaments.

Observation

La multiplication de la plante se fait par semis des graines.

Clusiaceae

Garcinia kola Heckel, Journ. Pharm. et Chim. 8: 88 (1883); Keay, F.W.T.A. ed. 2,1: 294 (1954).

Nom vulgaire: Petit kola. Noms vernaculaires: Aouolié (Abbey); Tchouakpé (Akyé). (Voir figure 5)

Description

Arbre de 10 à 18 m de hauteur, à rameaux cylindriques ou un peu anguleux. Feuilles

largement elliptiques, cunées ou arrondies à la base, courtement acuminées, de 6 à 15 cm de longueur et de 3 à 6 cm de largeur; nervures latérales de 10 à 15 paires, fines. Inflorescences en petites ombelles terminales. Fleurs blanc verdâtre. Fruits ovoïdes ou globuleux, mesurant de 5 à 9 cm de diamètre, jaunes ou oranges à maturité, contenant de 3 à 4 graines ellipsoïdes, atteignant de 3 à 3,5 cm de longueur et jusqu'à 1,5 cm de diamètre, assez dures après séchage.

Répartition géographique

Espèce de forêt dense humide, le petit kola est répandu depuis la Sierra Leone jusqu'au Zaïre.

Usages

Les graines, de saveur amère, sont consommées pour leur effet stimulant. Les brindilles, le bois de la tige ainsi que les racines, employés comme frotte-dents, ont aussi un effet revigorant.

Observation

La multiplication de la plante se fait par semis des graines. Mais les graines étant très recherchées pour le commerce dont elles sont l'objet, les plantules et les jeunes plants sont rares dans les forêts.

Cucurbitaceae

Telfairia occidentalis Hook. f., F.T.A. 2: 524 (1871); Keay, F.W.T.A. ed. 2, 1: 211 (1954).

Noms vernaculaires: Agbli Mi, Boton Mi (Akyé). (Voir figure 5)

Description

Grande liane atteignant 25 m de longueur, dioïque. Feuilles pétales, comportant de 3 à 5 folioles; folioles obliquement elliptiques ou ovales, courtement pétiolulées, courtement acuminées, mesurant 15 cm de longueur et 10 cm de largeur, dentées vers leur partie supérieure, légèrement scabres; 3 nervures principales partant de la base du limbe. Vrilles fourchues, en spirale. Inflorescences mâles en racèmes, mesurant 15 cm de longueur, fleuries seulement dans leur moitié supérieure; bractées foliacées, subrhomboïdes, pétiolées. Fleurs blanc crème, pourvues de taches rouge pourpre. Gros fruits ellipsoïdes, ovoïdes ou oblongs, pourvus de nombreuses côtes longitudinales, contenant de nombreuses grosses graines. Graines de 20 à 25 mm de longueur et de 8 à 15 mm de largeur, ovales à elliptiques, à coque épaisse.

Répartition géographique

Liane de forêt dense humide, on la trouve depuis la Sierra Leone jusqu'à Fernando Po.

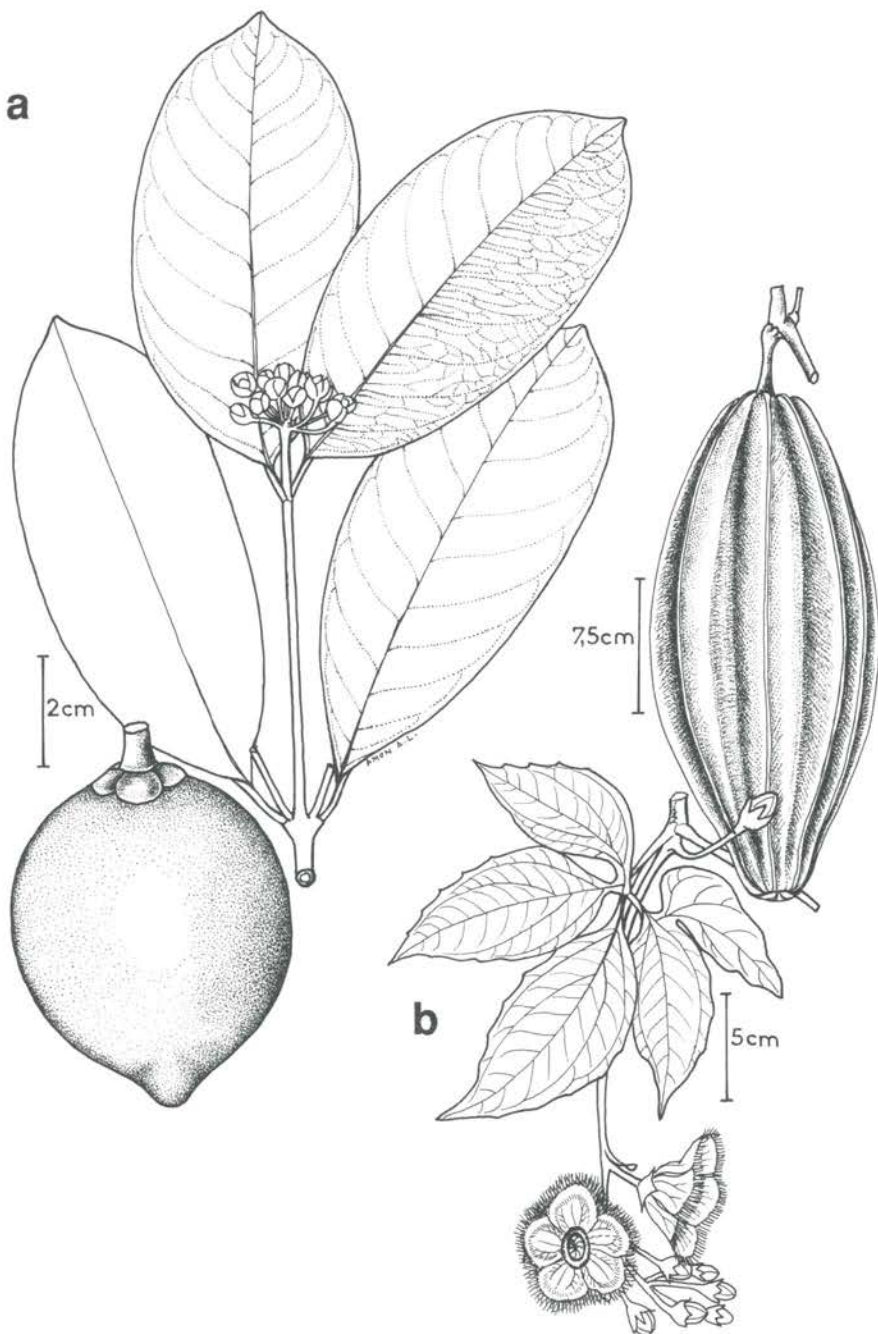
Usages

Les graines, séchées, grillées et pilées, on obtient une pâte qui sert à confectionner de la sauce. On extrait aussi des graines une huile alimentaire. Les jeunes feuilles se consomment cuites, en épinards.

Observation

La multiplication de la plante se fait par semis des graines ou par transplantation de souches.

FIGURE 5 (a) *Garcinia kola* (Clusiaceae)
 (b) *Telfairia occidentalis* (Cucurbitaceae)



Ebenaceae

Diospyros mespiliformis Hochst. ex A. DC., Prod. 8: 672 (1844); White, F.W.T.A. ed. 2,2: 12 (1963).

Noms vernaculaires: Blablè N'Golè (Baoulé); Sounzou (Malinké). (Voir figure 6)

Description

Arbuste de 7 à 15 m de hauteur, à écorces noirâtres. Feuilles alternes, elliptiques à oblongues-elliptiques, cunées à la base, courtement et graduellement acuminées, mesurant jusqu'à 15 cm de longueur et jusqu'à 5,5 cm de largeur, à face inférieure légèrement pubescente à glabrescente. Inflorescences en petites cymes pédonculées comportant de 3 à 9 fleurs. Fleurs blanchâtres. Fruits bacciformes subglobuleux, atteignant 3 cm de longueur et 2, 5 de diamètre, jaunes à maturité.

Répartition géographique

Espèce de savane, la plante se rencontre dans toute l'Afrique intertropicale et en Arabie.

Usages

Les fruits mûrs, à goût de litchi, sont très appréciés. Les diverses parties de la plante sont employées en médecine traditionnelle africaine.

Observation

La multiplication de la plante se fait par semis des graines ou végétativement, par transplantation de drageons.

Diospyros tricolor (Schum. et Thonn.) Hiern, Trans. Camb. Phil. Soc. 12: 183, t. 5 (1) (1873).

Description

Arbrisseau de 1 à 2 m de hauteur, beaucoup branchu dès la base. Feuilles alternes, atteignant de 2 à 6 cm de longueur et de 1 à 3 cm de largeur, elliptiques, courtement cunées à la base, courtement acuminées ou arrondies au sommet, poilues en dessous, brunissant au séchage au-dessus. Fleurs petites, jaunâtres, en fascicules axillaires. Fruits bacciformes, ovoïdes ou oblongs-ovoïdes, mesurant de 2 à 3 cm de longueur et de 1,2 à 2,5 cm de diamètre, jaunes à maturité.

Répartition géographique

Plante de bord de mer, on la trouve depuis la Côte d'Ivoire jusqu'au Gabon.

Usages

La pulpe entourant les graines des fruits mûrs, à goût de litchi, est comestible.

Observation

La propagation de la plante se fait par semis des graines ou par transplantation de souches ou de drageons. Mais étant donné son écologie très particulière, cette plante s'adapte très difficilement en dehors du cordon littoral.

Euphorbiaceae

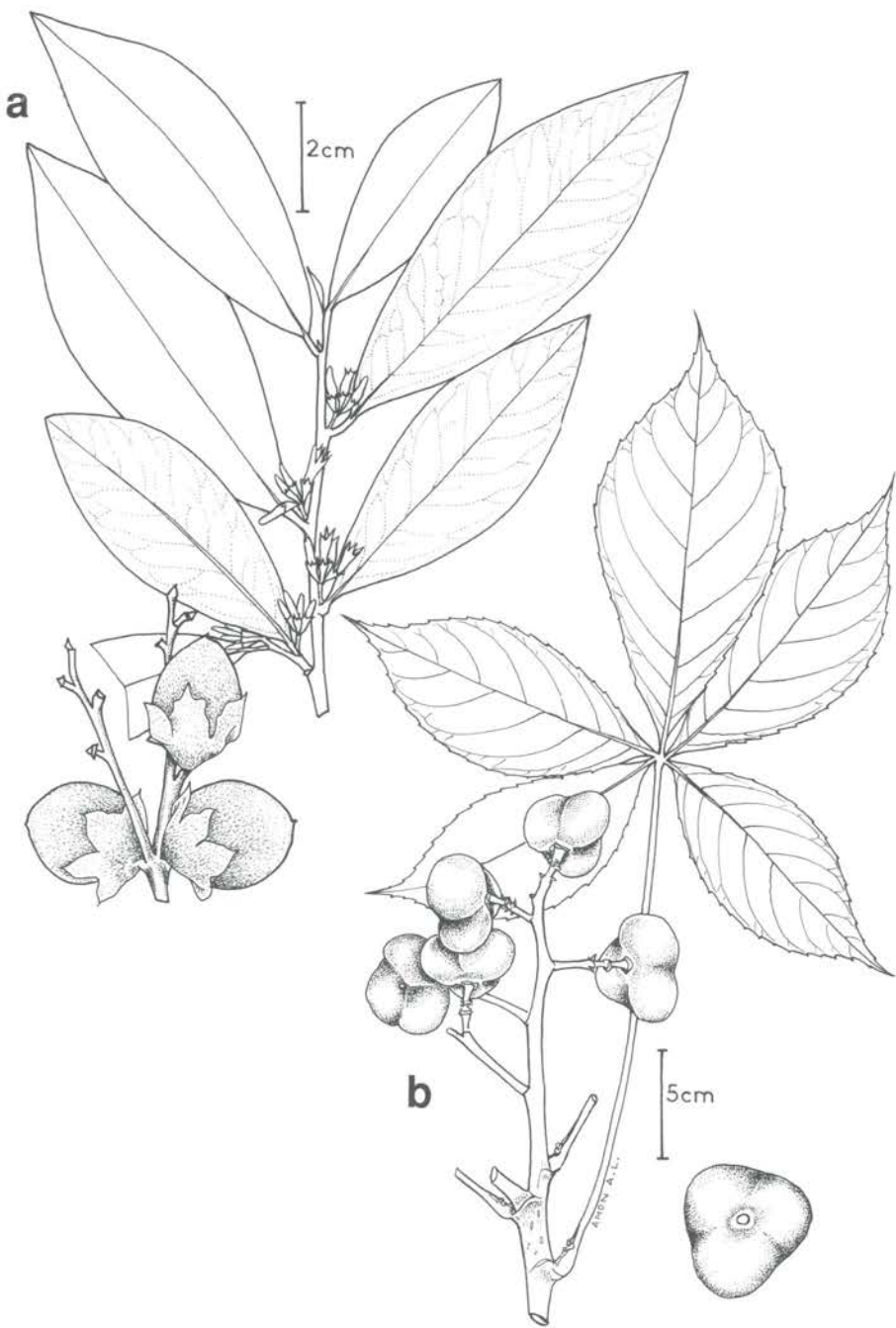
Ricinodendron heudelotii (Baill.) Pierre ex Pax, Pflanzenr. Euph. 3: 46, figs. 13, c-D et 16 (1911); Keay, F.W.T.A. ed. 2,1: 393 (1958).

Nom vernaculaire: Akpi (Abbey, Agni, Akyé, Baoulé). (Voir figure 6)

Description

Grand arbre de 35 à 40 m de hauteur, à fût tordu, peu élevé, à cime beaucoup branchu. Feuilles composées-digitées, comportant de 3 à 5 folioles; folioles

FIGURE 6 (a) *Diospyros mespiliformis* (Ebenaceae)
(b) *Ricinodendron heudelotii* (Euphorbiaceae)



sessiles, obovales à obovales-elliptiques, rétrécies à la base, les latérales souvent plus petites, atteignant de 6 à 20 cm de longueur et de 2,5 à 12 cm de largeur, dentées, couvertes de poils étoilés à l'état jeune; nervures latérales de 10 à 16 paires; pétiole jusqu'à 20 cm de longueur; stipules grandes, foliacées, orbiculaires, persistantes, mesurant jusqu'à 2,5 cm de longueur, profondément dentées. Inflorescences mâles en panicules de 30 cm de longueur, minces; inflorescences femelles robustes, plus courtes. Fleurs jaunâtres. Fruits bacciformes, trilobés, couverts de poils étoilés, atteignant 3 cm de diamètre et 2 cm de hauteur, jaunes à maturité, contenant de 2 à 3 graines noires à coque dure et à amande huileuse.

Répartition géographique

Espèce de forêt dense humide, répandue dans toute l'Afrique intertropicale.

Usages

L'amande de la graine, grillée et pilée, donne une pâte qui est utilisée pour la confection d'une sauce semblable à celle d'arachide. Les diverses autres parties de la plante sont utilisées en médecine traditionnelle africaine.

Observation

La propagation de la plante se fait par semis des graines ou par boutures.

Hippocrateaceae

Salacia owabiensis Hoyle, Kew Bull. 1934: 186; N. Hallé, Monographie des hippocrateacées d'Afrique occidentale, Thèses de Doctorat Université, Paris, 213 (1958).

Description

Arbuste sarmenteux ou liane, atteignant 8 m de hauteur, glabre. Feuilles opposées à subopposées, entières, glabres, ovales ou oblongues, papyracées, courtement cunéiformes à la base, courtement acuminées atteignant de 13 à 20 cm de longueur et de 3 à 8 cm de largeur; nervures latérales de 5 à 7 paires; pétiole de 6 à 11 cm de longueur, contenant du caoutchouc. Fleurs jaune verdâtre, nombreuses, en fascicules axillaires; pédicelles grêles et longs. Fruits bacciformes sphériques ou sub-sphériques, muriqués, réticulés, atteignant 5 cm de diamètre, contenant de nombreuses graines; pédoncule robuste.

Répartition géographique

Espèce de forêt dense humide, répandue depuis la Guinée jusqu'au Nigéria.

Usages

La pulpe qui entoure les graines des fruits mûrs, à goût de litchi, est comestible.

Observation

La propagation de la plante se fait par semis des graines.

Irvingiaceae

Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) Baill., Trait. Méd. Phan. 2: 881 (1883); Keay, F.W.T.A. ed. 2,1: 693 (1958).

Noms vernaculaires: Boborou (Abbey); Bè (Akyé); Kaklou (Baoulé); Sakossou (Bété); Kakourou (Gouro); Kplé (Guéré). (Voir figure 7)

Description

Grand arbre dépassant 35 m de hauteur, à fût droit, comportant des contreforts développés à la base. Feuilles alternes, elliptiques, glabres, courtement cunées à la base, largement acuminées, mesurant de 6 à 12 cm de longueur et de 4 à 6 cm de largeur, brillantes sur les 2 faces; nervures latérales de 6 à 8 paires fines; pétiole court; stipules atteignant 2 cm de longueur. Inflorescences en racèmes axillaires comprenant des fascicules de fleurs jaune verdâtre pédicellées. Drupes ovoïdes, un peu aplaties latéralement, jaune verdâtre, atteignant 8 cm de longueur et 6,5 cm de largeur, à pulpe fibreuse attachée fortement à l'endocarpe qui contient une graine aplatie oléagineuse.

Répartition géographique

Espèce de forêt dense humide, la plante est répandue dans toute l'Afrique intertropicale.

Usages

Les cotylédons de la graine, frais ou séchés, constituent un condiment servant à la confection d'une sauce, gluante et aromatique, particulière à la région ouest ou sud-ouest de la Côte d'Ivoire. Le mésocarpe du fruit, à goût de mangue, mais un peu amer, est quelquefois comestible.

Observation

La multiplication de la plante se fait par semis des graines.

Irvingia grandifolia (Engl.) Engl., Bot. Jahrb. 46: 288, fig. 4 (1911); Keay, F.W.T.A. ed. 2,1: 693 (1958).

Description

Grand arbre atteignant 40 m de hauteur, à fût droit, comprenant des contreforts à la base. Feuilles elliptiques-oblongues, cordées ou subcordées à la base, courtement et largement acuminées, mesurant de 10 à 27 cm de longueur et de 4,5 à 13,5 cm de largeur, coriaces, glauques en dessous; nervures latérales de 14 à 16 paires; pétiole court; stipules jusqu'à 3 cm de longueur, caduques. Inflorescences en panicules terminales, atteignant de 7 à 15 cm de longueur comportant des petites fleurs sessiles. Drupes ovoïdes, un peu aplaties, mesurant jusqu'à 7 cm de longueur et 5 cm de largeur, à pulpe fibreuse, contenant une graine aplatie.

Répartition géographique

Espèce de forêt dense humide, la plante se rencontre depuis la Côte d'Ivoire jusqu'au Zaïre et en Angola.

Usages

Les cotylédons de la graine, frais ou séchés, constituent un condiment servant à confectionner une sauce, gluante et aromatique, particulière à la région ouest ou sud-ouest de la Côte d'Ivoire.

Observation

La propagation de la plante se fait par semis des graines. Les paysans confondent les deux espèces et les désignent indifféremment par les mêmes noms vernaculaires.

Lauraceae

Beilschmiedia mannii (Meisn.) Benth. et Hook. f., Gen. Pl. 3,1: 158 (1880); Keay, F.W.T.A. ed. 2,1: 57 (1954).

FIGURE 7 (a) *Irvingia gabonensis* (Irvingiaceae)
(b) *Beilschmiedia mannii* (Lauraceae)



Noms vernaculaires: Atiokouo (Abbey); Sioko, Nobotou, Biétou, Bitéi (centre-ouest et sud-ouest de la Côte d'Ivoire). (Voir figure 7)

Description

Arbuste de 8 à 10 m de hauteur, beaucoup branchu, à écorce odorante, de tranche rougeâtre. Feuilles tombantes, alternes, sans stipules, ovales-oblongues, atteignant jusqu'à 15 cm de longueur et de 3 à 7 cm de largeur, glabres, coriaces; nervures latérales de 8 à 10 paires. Inflorescences en panicules grêles. Fleurs petites, à pétales, verdâtres ou brunâtres. Fruits ellipsoïdes ou oblongs-ellipsoïdes, jusqu'à 3 cm de longueur et 1,5 cm de largeur, à sommet atténué; pédoncules grêles.

Répartition géographique

Plante de sous-bois, répandue dans toute la région forestière dense de l'Afrique intertropicale.

Usages

Les cotylédons de la graine, frais ou séchés, constituent un condiment servant à la confection d'une sauce, gluante et aromatique, particulière à la région ouest de la Côte d'Ivoire.

Observation

La propagation de la plante se fait par semis des graines.

Loganiaceae

Strychnos spinosa Lam., *Illust.* 2:38 (1794); Onochie et Leeuwenberg, *F.W.T.A. ed.* 2,2: 41 (1963).

Noms vernaculaires: Koukoubombouo (Lobi); Koulé N'lé (Malinké).

Description

Arbuste de 3 à 5 m de hauteur, à tronc court et ramifié près de la base, à cime arrondie, à branches garnies d'épines plus ou moins longues, légèrement arquées. Feuilles opposées, suborbiculaires ou largement ovales, avec 2 nervures latérales arquées partant de la base du limbe. Inflorescences en petites cymes axillaires. Fleurs blanchâtres ou jaunâtres, avec la gorge de la corolle villose. Gros fruits ligneux, sphériques ou subsphériques, mesurant de 5 à 10 de diamètre, lisses, verts puis jaunes à maturité, renfermant de nombreuses graines.

Répartition géographique

Plante de savane répandue dans toute l'Afrique intertropicale. On la trouve aussi à Madagascar, aux Iles Comores et à l'Ile Maurice.

Usages

La pulpe qui entoure les graines, sucrée et acidulée, est comestible. Les diverses autres parties de la plante sont employées en médecine de tradition africaine.

Observation

La propagation de la plante se fait par semis des graines ou par transplantation de drageons.

Marantaceae

Thaumatococcus daniellii (Benn.) Benth. et Hook. f. *Gen. Pl.* 3: 652 (1883); Mangenot, *Ik. Pl. Afr.*, fasc. 4, n° 95 (1957); Hepper, *F.W.T.A. ed.* 2,3: 81 (1968).

Nom vulgaire: Feuille d'Akièkè. Noms vernaculaires: Ayo (Abbey); N'Dè Baté (Akyé); Angondro N'Gna (Agni, Baoulé). (Voir figure 8)

Description

Plante herbacée à tige entièrement souterraine, représentée par rhizome horizontal cylindrique. Feuille aérienne orthotrope, très longuement pétiolée, à base embrassante-caniculée, entourant le bourgeon; pétiole de la feuille aérienne cylindrique, rigide, extérieurement vert, lisse et glabre, intérieurement lacuneux, atteignant de 2 à 3 m de hauteur, renflé légèrement vers son sommet; limbe ovale-elliptique, glabre, mesurant de 30 à 50 cm de longueur et de 20 à 30 cm de largeur, arrondies à légèrement cordées à la base, courtement acuminées; nervure principale proéminente en dessous; nervures secondaires nombreuses. Inflorescences en épis de 10 à 20 cm de longueur, naissant, sous terre, à l'aisselle de la feuille orthotrope. Fleurs bleuâtres. Fruits triédriques, à arêtes courbes, de 3 à 5 cm de hauteur et de 3 à 5 cm de largeur, glabrescents, rougeâtres à maturité, contenant dans chacune des 3 loges 1 graine noire un peu aplatie, et entourée d'un mucilage transparent.

Répartition géographique

Plante de forêt dense humide, on la trouve dans toute l'Afrique intertropicale.

Usages

Le mucilage qui entoure la graine dans les fruits mûrs est édulcorant. Les pétioles sont utilisés pour confectionner des nattes. Les grands limbes foliaires sont utilisés pour la couverture des toits des cases, et pour l'emballage des aliments.

Observation

La multiplication de la plante se fait par transplantation des rhizomes.

Meliaceae

Carapa procera DC., Prod. 1: 626 (1824); Keay, F.W.T.A. ed. 2,1: 702 (1958).

Noms vernaculaires: Dona (Abbey); Kangassakiè (Akyé); Kondou (Baoulé); Kobi, Kébi (Malinké).

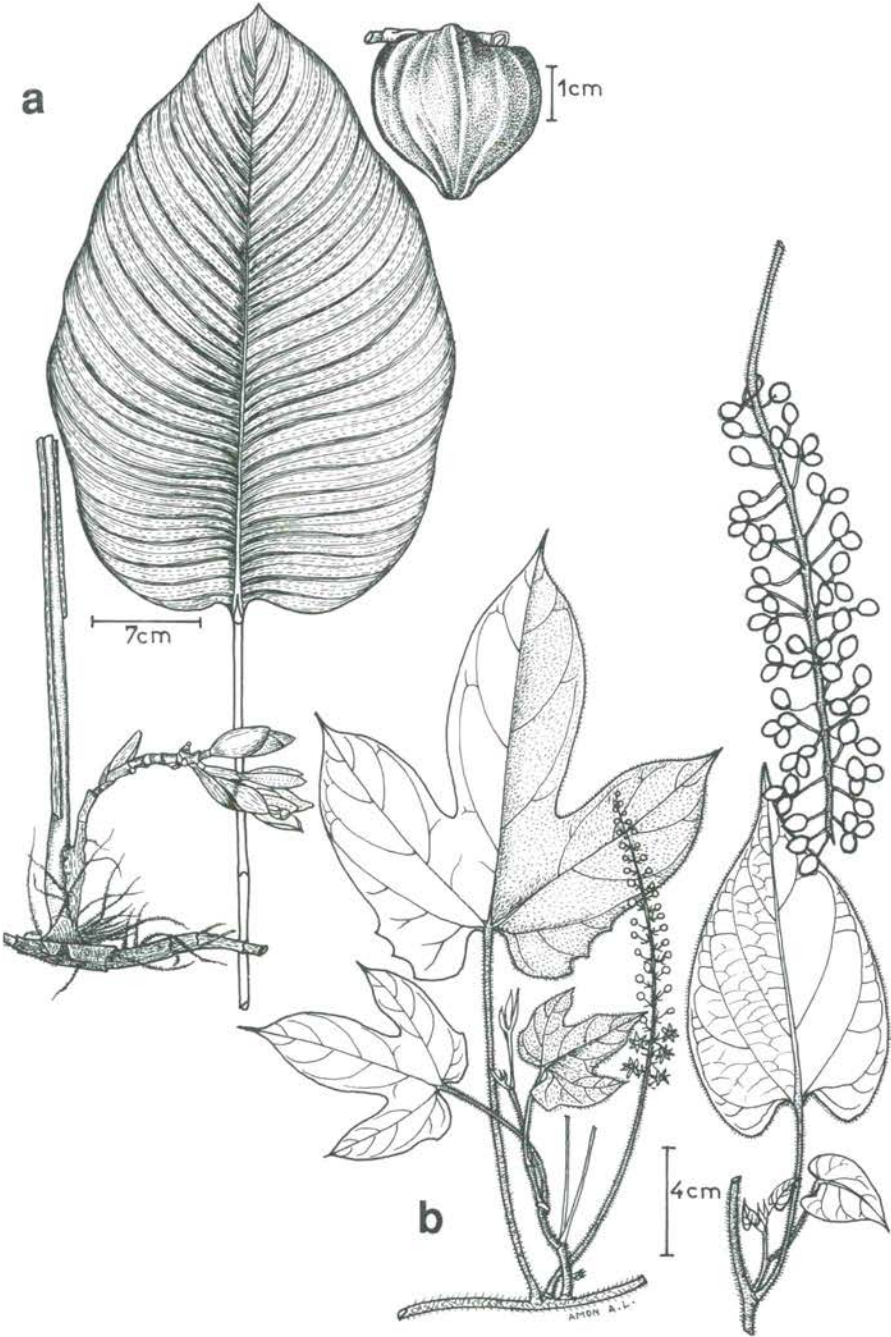
Description

Arbre de 10 à 25 m de hauteur, à fût irrégulier, beaucoup branchu. Feuilles grandes, variables en grandeur et en forme, à rachis atteignant jusqu'à 1,5 m, comprenant jusqu'à 20 paires de folioles, mais habituellement 40 cm de longueur avec de 5 à 8 paires de folioles opposées ou alternes; folioles variables en grandeur et en forme, généralement plus ou moins oblongues-allongées, mesurant de 10 à 50 cm de longueur et jusqu'à 15 cm de largeur. Inflorescences en grandes panicules lâches, glabres ou pubérulentes, comportant de petites fleurs blanc rosé, parfumées, pédicellées. Capsules ovoïdes ou oblongues-ellipsoïdes, grossièrement pentagonales, avec 5 côtes proéminentes, brunâtres, atteignant 15 cm de longueur et 10 cm de diamètre, s'ouvrant en 5 valves coriaces, contenant jusqu'à 20 graines anguleuses. Graines brunâtres, mesurant jusqu'à 3,5 cm de diamètre, avec un épiderme finement rugueux.

Répartition géographique

Espèce afro-néotropicale, elle est répandue dans toute l'Afrique intertropicale, où on la trouve surtout le long des cours d'eau, les stations humides en général.

FIGURE 8 (a) *Thaumatococcus daniellii* (Marantaceae)
(b) *Dioscoreophyllum cumminsii* (Menispermaceae)



Usages

Les graines fournissent une huile amère employée en savonnerie traditionnelle africaine. Cette huile est utilisée dans la préparation de plusieurs recettes médicamenteuses africaines.

Observation

La multiplication de la plante se fait par semis des graines.

Menispermaceae

Dioscoreophyllum cumminsii (Stapf) Diels, Engl. Pflanzenr. Menisp. 181, t. 64 a-f (1910); Keay, F.W.T.A. ed. 2,1: 73 (1954). (Voir figure 8)

Description

Liane grêle couverte de poils ferrugineux, atteignant de 3 à 5 m de hauteur. Feuilles entières ou irrégulièrement palmatilobées, comportant de 3 à 5 lobes, mesurant 12 cm de longueur et 10 cm de largeur; pétiole de 6 à 15 cm de longueur. Inflorescences en racèmes de 6 à 8 cm de longueur, comprenant de nombreuses fleurs jaune verdâtre. Fruits drupacés, ovoïdes, atteignant 1 cm de longueur, pointus, rouge orangé à maturité, réunis par 3 sur un axe poilu.

Répartition géographique

Plante de recrûs secondaires répandue dans toute la région forestière dense humide de l'Afrique intertropicale.

Usages

La pulpe des fruits mûrs est édulcorante.

Observation

La multiplication de la plante se fait par semis des graines ou végétativement, par fragments des tubercules.

Mimosaceae

Parkia biglobosa (Jacq.) Benth., Hook., Journ. Bot. 4:328 (1842); Oliver, F.T.A. 2:324 (1871); Keay, F.W.T.A. ed. 2,1:487 (1958).

Nom vulgaire: Néré. Noms vernaculaires: Kpalè (Baoulé); Néré (Malinké).

Description

Arbre de 8 à 12 m de hauteur, à fût court et cylindrique, robuste. Feuilles bipennées, comprenant de 8 à 16 paires de pennes, comportant chacune de 15 à 35 paires de petites foliolules. Inflorescences en glomérules de 4 à 6 cm de diamètre, pendant à l'extrémité de longs pédoncules. Fleurs étroites, rouges, atteignant 3 cm de longueur. Gousses étroites, légèrement aplaties, mesurant jusqu'à 30 cm de longueur, pendantes. Graines ovoïdes, entourées d'une pulpe farineuse jaunâtre.

Répartition géographique

Espèce soudano-zambézienne, le néré se rencontre dans toute l'Afrique de l'Ouest, depuis le Sénégal jusqu'au Togo. On trouve la plante aux Antilles où elle a été introduite depuis longtemps.

Usages

Les fruits entrent dans plusieurs recettes alimentaires. Les diverses autres parties de la plante sont largement employées en médecine traditionnelle africaine.

Observation

La multiplication de la plante se fait par semis des graines ou par drageonnage.

Moraceae

Treculia africana Decne. var. *africana* - Hutchinson, F.T.A. 6,2: 226 (1917); Keay, F.W.T.A. ed. 2,1: 613 (1958).

Noms vernaculaires: Bébé n'dou (Akyé); Bléblé n'dou (Agni, Baoulé). (Voir figure 9)

Description

Arbre de 15 à 25 m de hauteur, à fût ordinairement cannelé, régulier. Feuilles oblongues, ovales-oblongues ou ovales-elliptiques, arrondies ou subcordées et disymétriques à la base, courtement acuminées, glabres, coriaces; stipules caduques et laissant, alors, sur les rameaux, des cicatrices annulaires. Inflorescences globuleuses, axillaires ou caulinaires, atteignant 6 cm de diamètre. Infrutescences globuleuses, volumineuses, mesurant 35 cm de diamètre, jaune verdâtre à maturité, comprenant plusieurs centaines de fruits soudés les uns aux autres, renfermant chacun une grosse graine.

Répartition géographique

Espèce de forêt dense humide, on la trouve dans toute l'Afrique intertropicale. Elle pousse le plus souvent le long des cours d'eau et aux abords des lieux marécageux.

Usages

La pulpe du syncarpe séchée sert à faire de la sauce comme succédané de la viande. Les graines, grillées, sont comestibles. Les diverses parties de la plante sont employées en médecine traditionnelle africaine.

Observation

La propagation de la plante se fait par semis des graines.

Napoleonaceae

Napoleonaea vogelii Hook. et Planch., Hook. Ic. Pl. t. 799-800 (1848); Keay, F.W.T.A. ed. 2,1: 244 (1954).

Nom vernaculaire: Tèkpi (Akyé). (Voir figure 9)

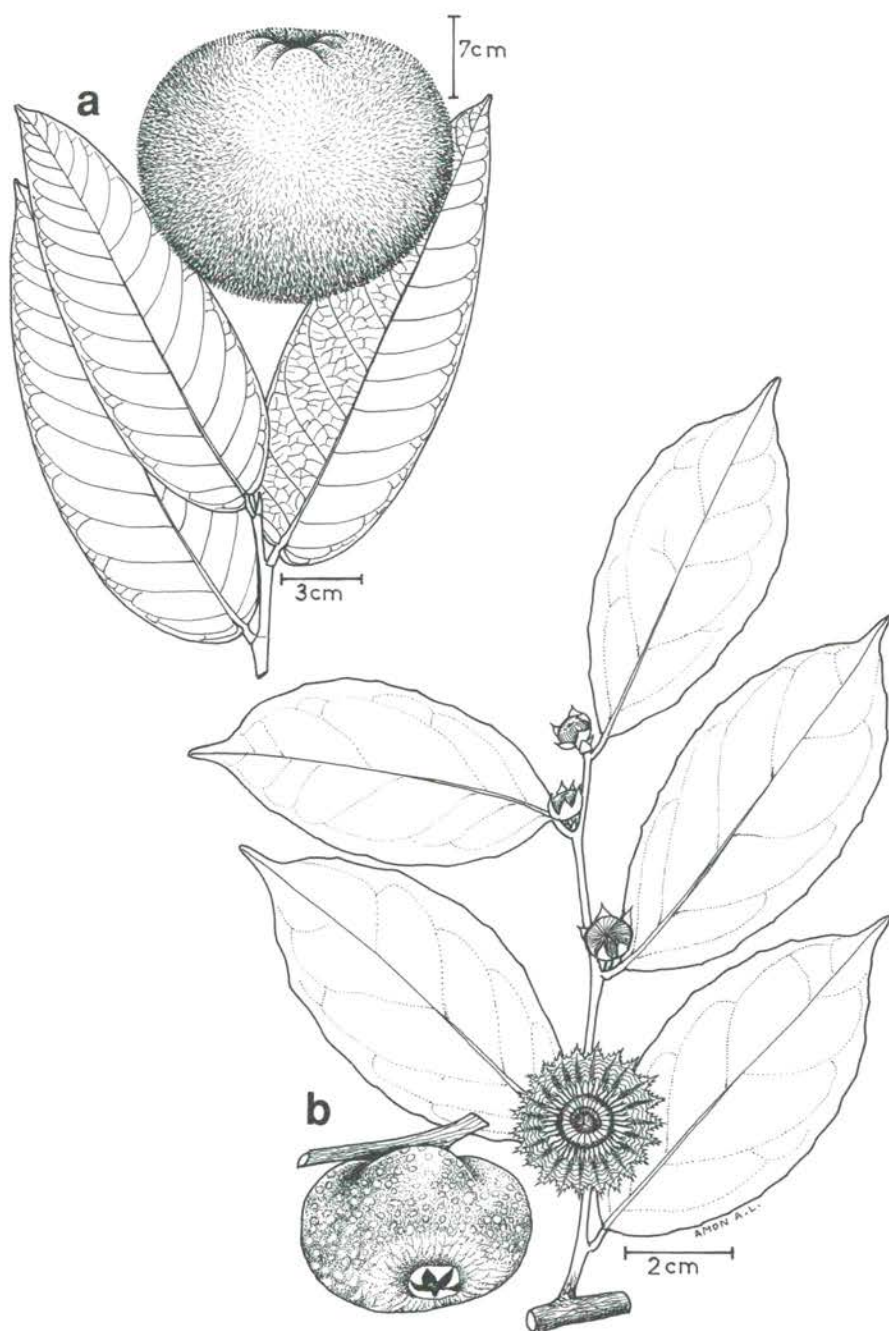
Description

Arbuste de 3 à 6 m de hauteur, à branches verticillées, horizontales. Feuilles alternes, largement elliptiques, courtement cunées à la base, acuminées, atteignant de 5 à 10 cm de longueur et de 3 à 5 cm de largeur; nervures latérales ascendantes le long de la marge; glandes foliaires nettes, présentes près du bord du limbe, à la base. Fleurs solitaires axillaires ou parfois fasciculées et alors caulinaires, blanchâtres ou jaunâtres, comportant des raies pourpres, environ 4 cm de diamètre. Fruits subsphériques, aplatis, légèrement lobés, quelquefois couverts de lenticelles blanchâtres, mesurant 6 cm de diamètre et environ 4,5 cm de hauteur.

Répartition géographique

Espèce de sous-bois de forêt dense humide, cette plante se rencontre depuis la Sierra Leone jusqu'au Nigéria.

FIGURE 9 (a) *Treculia africana* (Moraceae)
(b) *Napoleonaea vogelii* (Napoleonaceae)



Usages

La pulpe entourant les graines, à goût de litchi, est appréciée. Les feuilles sont utilisées en médecine de tradition africaine.

Observation

La multiplication de la plante se fait par semis des graines.

Ochnaceae

Lophira lanceolata van Tiegh. ex Keay, Kew Bull. 1953: 488 (1954); Keay, F.W.T.A. ed. 2,1: 231 (1954).

Noms vernaculaires: N'Gouin Yassoua (Baoulé); Mana Méné (Malinké).

Description

Arbre atteignant 12 m de hauteur, à écorce brun rougeâtre, se desquamant par petites plaquettes. Feuilles caractéristiques, situées vers l'extrémité des rameaux, oblongues ou oblanceolées, atteignant de 25 à 40 cm de longueur et de 4 à 6 cm de largeur, avec de nombreuses et fines nervures; pétiole mince, mesurant de 2 à 6 cm de longueur. Inflorescences en panicules terminales. Fleurs grandes, blanches, à nombreuses étamines. Fruits ovoïdes apiculés, ligneux, avec 2 ailes représentant les sépales accrescents persistants, les 3 autres ne s'étant pas développés.

Répartition géographique

Plante de savane répandue depuis le Sénégal jusqu'au Cameroun, en République centrafricaine, au Soudan et en Ouganda.

Usages

On extrait des graines une huile alimentaire ou de savonnerie connue sous le nom d'huile de Méné.

Observation

La multiplication de la plante se fait par semis des graines ou par drageonnage.

Olacaceae

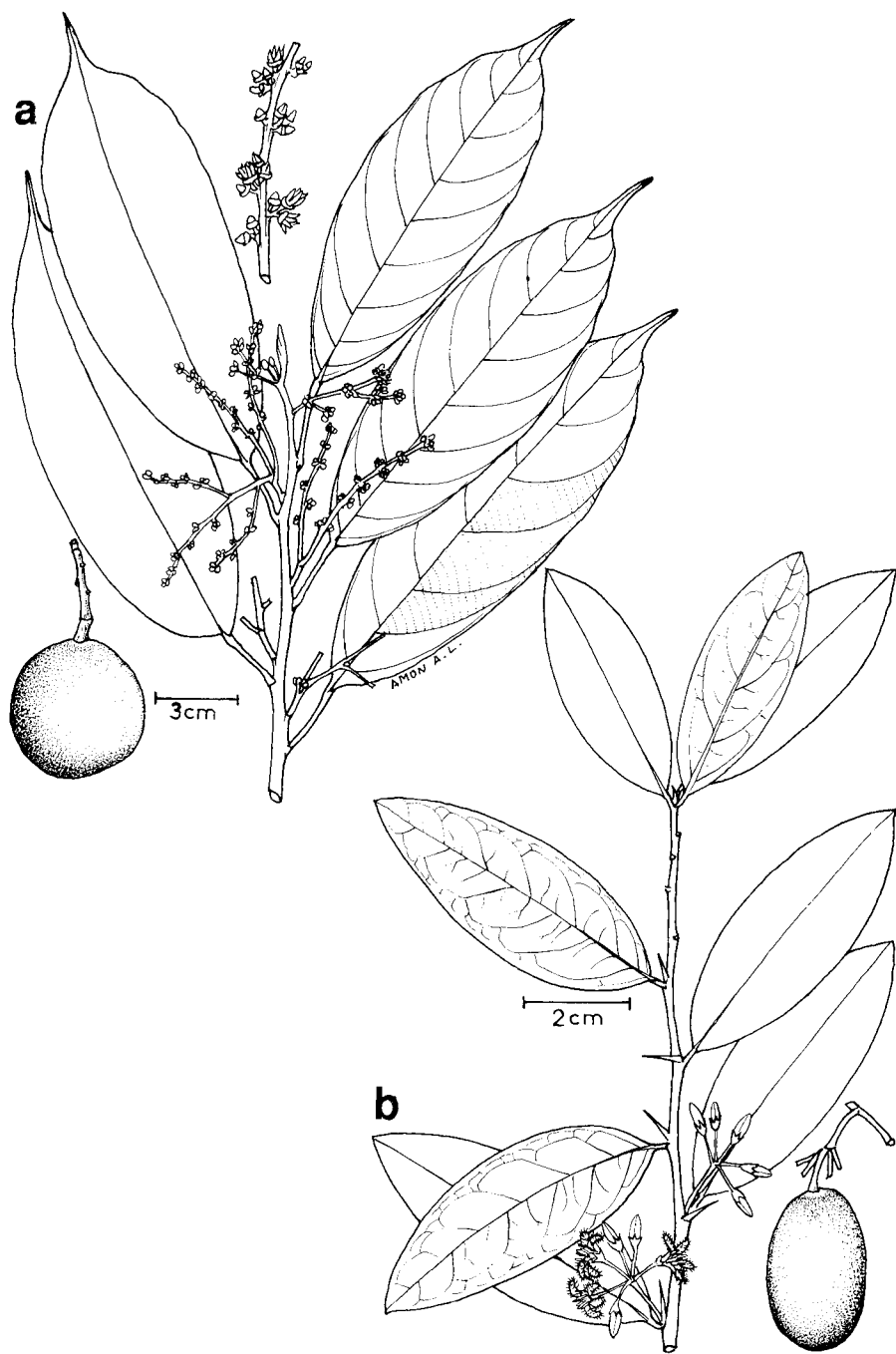
Coula edulis Baill., Adansonia, 3: 64, t. 3; Keay, F.W.T.A. ed. 2,1: 645 (1958).

Noms vulgaires: Noix d'Afrique, noix du Gabon (Français). Noms vernaculaires: Attia (Abbey); Atsan (Akyé); Akiouhia (Ebrié); Koula (Gabon). (Voir figure 10)

Description

Arbre atteignant 15 m de hauteur, à cime feuillue donnant beaucoup d'ombre. Feuilles elliptiques ou oblongues-elliptiques, cunéiformes à la base, longuement acuminées, coriaces, mesurant de 15 à 20 cm de longueur et de 5 à 7 cm de largeur, glabres ou glabrescentes; nervures latérales de 10 à 15 paires, proéminentes en dessous; pétiole canaliculé, coudé, pubescent ferrugineux, atteignant de 2 à 3 cm de longueur. Inflorescences en racèmes axillaires, mesurant 10 cm de longueur, courtement branchues, pubescents ferrugineux, comportant de petites fleurs pédicellées. Drupes sphériques, lisses, atteignant de 3,5 à 4 cm de diamètre, verdâtres, à endocarpe très dur, à surface grumeleuse, contenant une graine.

FIGURE 10 (a) *Coula edulis* (Olacaceae)
(b) *Ximenia americana* (Olacaceae)



Répartition géographique

Plante de forêt humide, répandue depuis la Sierra Leone jusqu'au Zaïre.

Usages

L'amande de la graine, à goût de noix, est très appréciée.

Observation

La multiplication de la plante se fait par semis des graines. Mais les fruits étant très recherchés pour la consommation, la régénération de la plante devient difficile. Plusieurs essais de transplantation de souches n'ont pas été couronnés de succès.

Heisteria parvifolia Sm.; Oliver, F.T.A. 1: 346 (1868); Keay, F.W.T.A. ed. 2,1: 645 (1958).
Nom vernaculaire: Amin-min-mon (Abbey).

Description

Arbrisseau atteignant de 2 à 3 m de hauteur, beaucoup branchu, à jeunes rameaux anguleux ou étroitement ailés. Feuilles oblongues ou oblongues-elliptiques étroitement arrondies à la base, courtement acuminées, mesurant de 8 à 12 cm de longueur et de 3 à 6 cm de largeur, glabres; nervures latérales de 5 à 6 paires. Inflorescences condensées en petits glomerules axillaires, comprenant de 2 à 8 petits fleurs. Fruits drupacés mesurant de 8 à 10 mm de longueur et de 7 à 8 mm de diamètre, blanchâtre, sur lequel persiste le calice devenu accrescent. Noyau subsphérique brun sombre contenant une seule graine.

Répartition géographique

Plante de sous-bois, on la trouve dans toute la région forestière dense de l'Afrique intertropicale.

Usages

Les graines, grillées, sont comestibles. Les diverses autres parties de la plante sont employées en médecine traditionnelle africaine.

Observation

La multiplication de la plante se fait par semis des graines ou par transplantation de souches.

Ximenia americana Linn., Oliver, F.T.A. 1: 346 (1868); Keay, F.W.T.A. ed. 2,1: 646 (1958).
Noms vulgaires: Citron de mer, prune de mer (Français). Noms vernaculaires: Mingoh (Djimini); Léaman (Lobi); N'Gbani (Malinké). (Voir figure 10)

Description

Arbuste de 2 à 4 m de hauteur, très branchu dès la base, épineux, glabre, à rameaux grêles. Feuilles alternes, ovales à étroitement elliptiques, mesurant de 3 à 5 cm de longueur et de 2 à 3 cm de largeur, cunées à la base, courtement et largement acuminées, arrondies ou émarginées au sommet, glabres. Inflorescences en petits racèmes ombelliformes axillaires. Fleurs blanchâtres, comportant 4 pétales couverts, intérieurement, de longs poils blancs. Fruits drupacés, ellipsoïdes, atteignant 3 cm de longueur, glabres, pendants, jaunes à maturité.

Répartition géographique

Plante pantropicale, elle est répandue dans toute l'Afrique intertropicale où on la trouve généralement dans les savanes. Dans certaines régions côtières de l'Afrique de l'Ouest, la plante est présente dans le bush littoral.

Usages

Les fruits mûrs, à goût de mirabelles, sont très appréciés. Les différentes autres parties de la plante sont utilisées en médecine traditionnelle africaine.

Observation

La multiplication de la plante se fait par semis des graines ou par transplantation de drageons.

Piperaceae

Piper guineense Schum. et Thonn., Beskr. Guin. Pl 19; Baker et Wright, F.T.A. 6,1: 145 (1913); Keay, F.W.T.A. ed. 2,1: 84 (1954).

Nom vulgaire: Poivrier (Français). Nom vernaculaire: Pako (Akyé).

Description

Liane semi-épiphyte, atteignant de 12 à 15 m de hauteur, pourvue de nombreuses racines-crampons. Feuilles ovales, ovales-elliptiques ou elliptiques, courtement cunées à arrondies ou disymétriques à la base; graduellement acuminées. Inflorescences spiciformes, oppositifoliées ou terminales. Fleurs petites, à pétales, jaunâtres ou jaune verdâtre, comportant 3 stigmates. Infrutescences racémiformes, avec des petits fruits brun rouge noircissant au séchage.

Répartition géographique

Plante répandue dans toute la région forestière humide de l'Afrique intertropicale.

Usages

Les jeunes feuilles, les tiges et les fruits sont employés comme condiment ou épice. Les tiges et les fruits sont utilisés dans la préparation de divers remèdes traditionnels africains.

Observation

La multiplication de la plante se fait, végétativement, par bouturage.

Sapindaceae

Blighia sapida Konig, Konig et Sims, Ann. Bot. 2: 571, tt. 16 et 17 (1806); Keay, F.W.T.A. ed. 2,1: 722 (1958).

Nom vulgaire: Akee Apple (Anglais). Noms vernaculaires: Baza (Abbey); Bè, Baza (Akyé); Kaha (Agni, Baoulé); Fizan (Malinké). (Voir figure 11)

Description

Arbre de 20 à 25 m de hauteur, à feuillage sombre, à rameaux jeunes tomenteux roussâtres. Feuilles composées-paripennées, comportant de 2 à 4 paires de folioles ovales, ovales-elliptiques ou elliptiques, arrondies à la base, obtusément acuminées ou arrondies au sommet, atteignant de 5 à 15 cm de longueur et de 3 à 7,5 cm de largeur. Inflorescences en racèmes axillaires, mesurant de 10 à 20 cm de longueur. Fleurs blanches. Fruits capsulaires pyriformes, subtrigones, contenant 3 graines noires à arille jaunâtre épais.

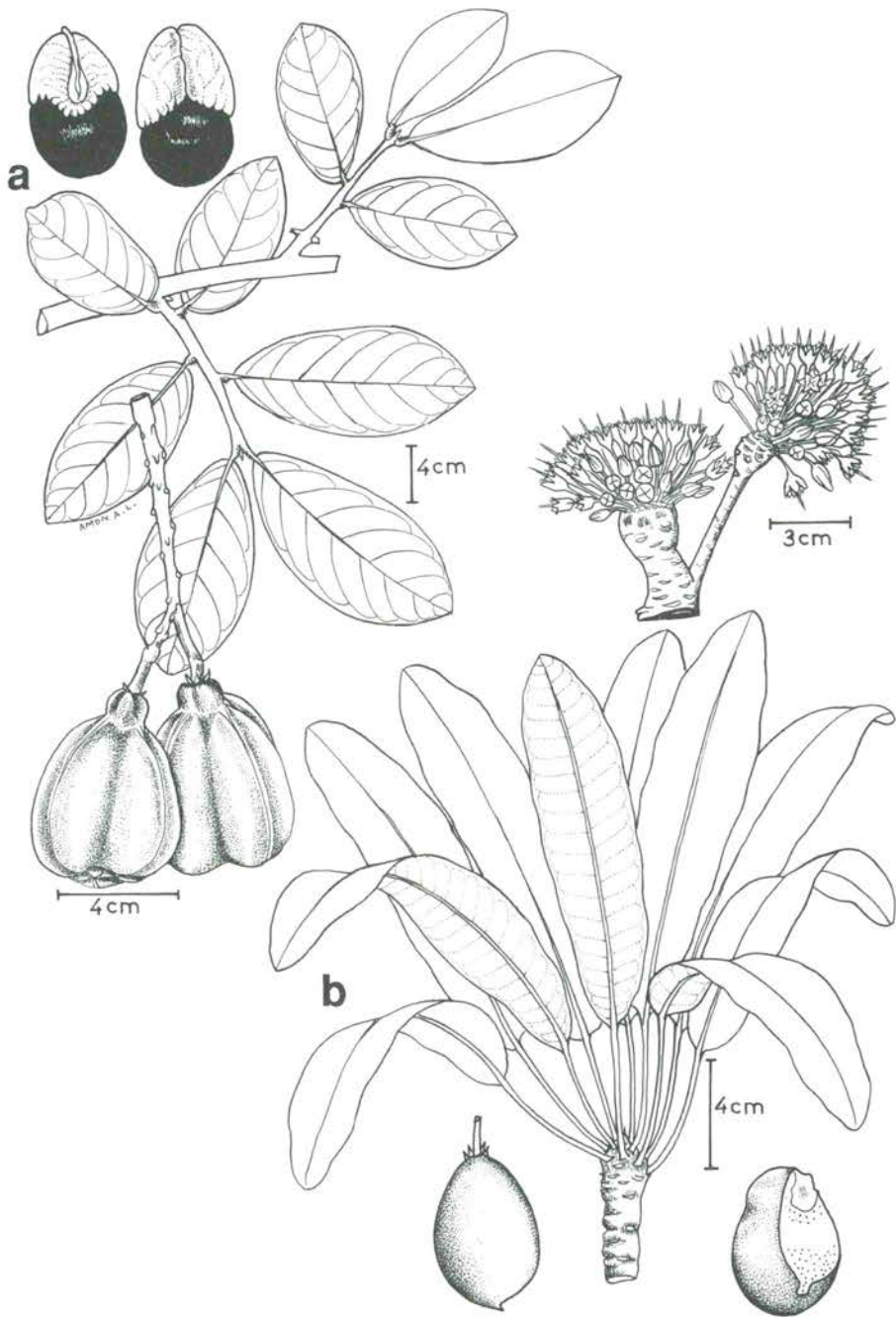
Répartition géographique

Plante répandue dans toute l'Afrique intertropicale. Etant donné sa facilité d'adaptation, elle est devenue pantropicale. La plante est souvent cultivée.

Usages

L'arille de la graine est consommé sous diverses formes. Les différentes autres parties de la plante sont employées dans la pharmacopée traditionnelle africaine.

FIGURE 11 (a) *Blighia sapida* (Sapindaceae)
(b) *Butyrospermum paradoxum* subsp. *parkii* (Sapotaceae)



Observation

La multiplication de la plante se fait par semis des graines.

Deinbollia pinnata Schum. et Thonn., Beskr. Guin. Pl. 242 (1827); Keay, F.W.T.A. ed. 2,1: 715 (1958).

Description

Arbuste de 2 à 5 m de hauteur, pubescent ou glabrescent. Feuilles composées-imparipennées, pubescentes ou glabrescentes, comprenant de 5 à 9 paires de folioles; folioles elliptiques à oblongues courtement cunées ou arrondies à la base, courtement acuminées, mesurant de 5 à 18 cm de longueur et de 2,5 cm de largeur, nervures latérales de 6 à 12 paires. Inflorescences en racèmes ou en panicules atteignant 60 cm de longueur, comportant une pubescence ferrugineuse. Fruits subglobuleux de 1,5 cm de diamètre, jaune orangé à maturité.

Répartition géographique

Plante de région forestière dense, on la trouve depuis la Guinée jusqu'au Nigéria.

Usages

La pulpe entourant la graine des fruits mûrs, à goût de litchi, est comestible.

Observation

La propagation de la plante se fait par semis des graines.

Sapotaceae

Butyrospermum paradoxum subsp. *parkii* (G. Don) Hepper, Taxon 11: 227 (1962); Hepper, F.W.T.A. ed. 2,2: 21 (1963).

Nom vulgaire: Karité. Noms vernaculaires: N'Gouin (Baoulé); Chié, Ché (Malinké). (Voir figure 11)

Description

Petit arbre de 6 à 10 m de hauteur. Feuilles disposées en bouquets à l'extrémité des rameaux, oblongues ou oblongues-obovales, mesurant de 10 à 25 cm de longueur et de 5 à 8 cm de largeur, courtement et largement cunées à la base, obtuses ou arrondies au sommet glabres ou glabrescentes; nervure primaire saillante en dessous; nervures secondaires nombreuses, parallèles entre elles. Inflorescences en ombelles compactes à l'extrémité des rameaux, comportant de 20 à 30 fleurs. Fleurs blanc crème, parfumées, pédicellées. Fruits drupacés, ovoïdes, atteignant de 4 à 6 cm de longueur et de 3 à 4 cm de diamètre, contenant une ou rarement 2 graines.

Répartition géographique

Plante de savane soudano-sahélienne, le karité est répandu depuis la Guinée-Bissau jusqu'au Cameroun et en République centrafricaine.

Usages

Les amandes de la graine fournissent le beurre de karité bien connu. La pulpe du fruit, charnue, sucrée, est comestible. Les autres diverses parties de la plante sont utilisées dans la préparation de divers remèdes traditionnels.

Observation

La propagation de la plante se fait par semis des graines ou par transplantation de drageons.

Kantou guereensis Aubrév. et Pellegr. Bull. Soc. Bot. fr. 104: 276 (1957); Heine, F.W.T.A. ed. 2,2: 23 (1963).

Noms vernaculaires: Kantou, Toukla (Guéré).

Description

Grand arbre atteignant 50 m de hauteur, à fût régulier pourvu de contreforts à la base. Feuilles grandes, groupées au sommet des rameaux, oblongues-oblancéolées, cunéiformes à la base, obtuses ou arrondies au sommet, glabres, coriaces; nervure primaire saillant en dessous; nervures secondaires de 10 à 12 paires, proéminentes en dessous; pétiole assez long. Fleurs blanchâtres, pédicellées, fasciculées à l'extrémité des rameaux feuillés. Gros fruits globuleux, rouges, mesurant jusqu'à 8 cm de diamètre, contenant une seule graine noyée dans une pulpe épaisse charnue. Graine brune, atteignant 5 cm de longueur, 2,5 cm de largeur et 2 cm d'épaisseur.

Répartition géographique

Espèce de forêt dense humide, endémique de Côte d'Ivoire.

Usages

On extrait des amandes de la graine une matière grasse comestible.

Observation

La propagation de la plante se fait par semis des graines. Plante rare.

Synsepalum aubrevillei (Pellegr.) Aubrév. et Pellegr., Notulae Syst. 16: 263 (1961); Heine, F.W.T.A. ed. 2,2: 496 (1963).

Nom vernaculaire: Nigrité (Bakoué). (Voir figure 12)

Description

Arbuste de 2 à 10 m de hauteur, beaucoup branchu. Feuilles panduriformes, étroitement cordées à la base, graduellement acuminées, mesurant de 10 à 30 cm de longueur et de 4 à 9 cm de largeur, glabres dessus, couvertes de poils argentés en dessous, coriaces, gaufrées; nervure médiane proéminente dessous; nervures latérales de 8 à 10 paires, proéminentes en dessous. Fleurs blanchâtres, petites, fasciculées, axillaires ou caulinaires. Fruits bacciformes, axillaires ou caulinaires, ellipsoïdes mesurant de 4 à 5 cm de longueur et de 2,5 à 3 cm de diamètre, portant de 3 à 4 ailes longitudinales, rouge orangé à maturité, contenant une grosse graine.

Répartition géographique

Espèce de sous-bois de forêt dense humide sempervirente, elle est endémique de Côte d'Ivoire.

Usages

La pulpe entourant la graine des fruits mûrs est édulcorante.

Observation

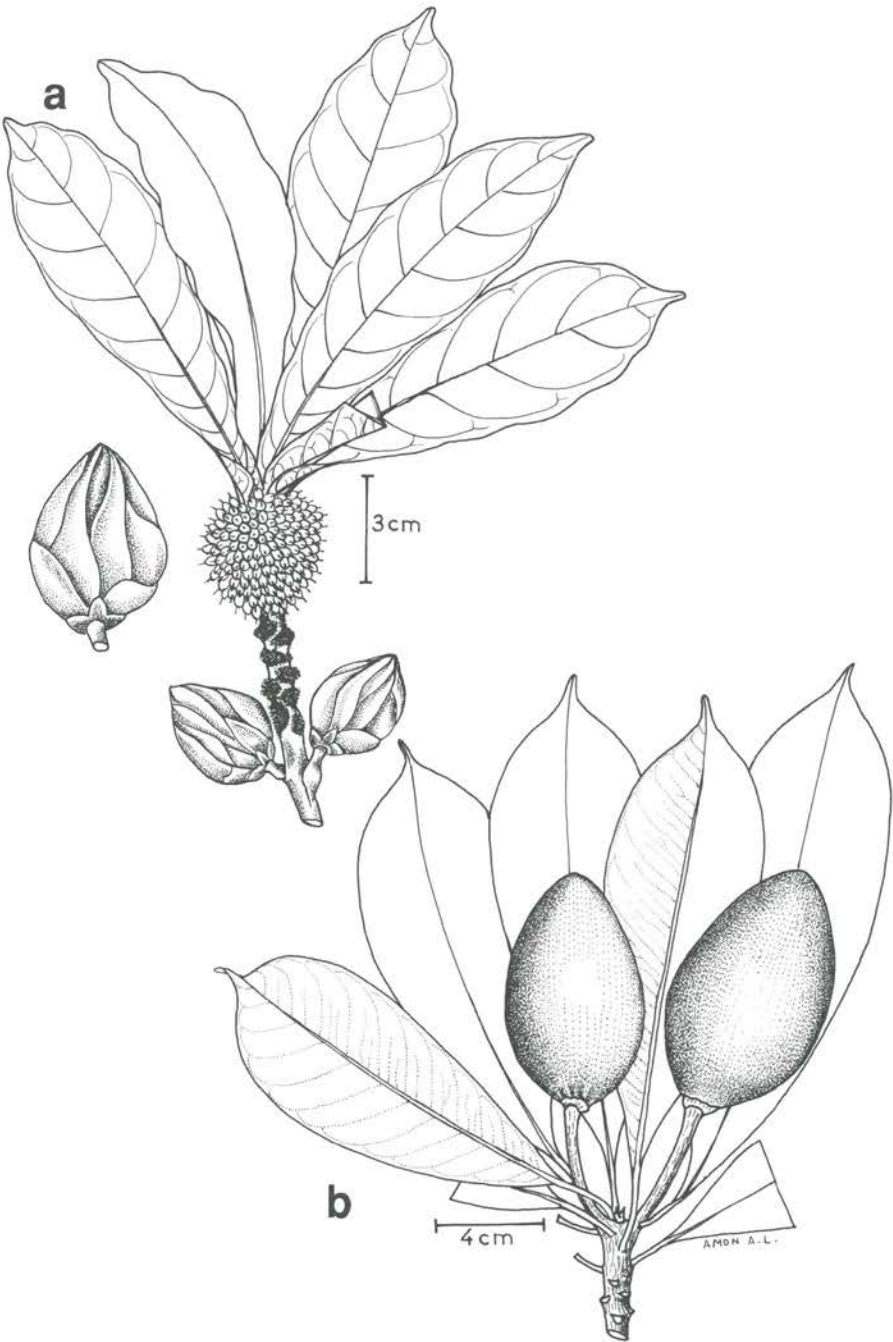
La multiplication de la plante se fait par semis des graines ou végétativement, par transplantation de souches ou de drageons.

Synsepalum dulcificum (Schum. et Thonn.) Daniell., Bell Pharm. Journ. Trans. 11: 445 (1852); Heine, F.W.T.A. ed. 2,2: 22 (1963).

Description

Arbuste de 2 à 4 m de hauteur, à rameaux grêles, glabrescents ou glabres. Feuilles elliptiques à obovées-oblongues, étroitement arrondies à la base, obtuses à courtement acuminées, glabres, mesurant de 5 à 10 cm de longueur et de 2 à 4 cm de largeur; nervures latérales de 8 à 10 paires; pétiole très court. Fleurs petites,

FIGURE 12 (a) *Synsepalum aubrevillei* (Sapotaceae)
 (b) *Tieghemella heckelii* (Sapotaceae)



blanches, en fascicules axillaires. Fruits ellipsoïdes ou ovoïdes, glabres, atteignant 2 cm de longueur, monospermes, rouges à maturité.

Répartition géographique

Plante de forêt, poussant dans le sous-bois, au bord des rivières. On la trouve depuis le Ghana jusqu'au Gabon, en République centrafricaine. Elle est souvent cultivée.

Usages

La pulpe qui entoure la graine est édulcorante.

Observation

La multiplication de la plante se fait par semis des graines.

Tieghemella heckelii Pierre ex A. Chev., vég. ut. Afr. trop. fr. 2: 172 (1907); Heine, F.W.T.A. ed. 2,2: 21 (1963).

Nom vulgaire: Makoré. Noms vernaculaires: M'Babou (Akyé); Garessou, Gueuli (Bété); Makoré, Makourou (Appollonien). (Voir figure 12)

Description

Grand arbre, atteignant 50 m de hauteur, et quelquefois jusqu'à 3 m de diamètre, à fût droit et régulier, cylindrique, élargi à la base, sans contrefort, à écorce épaisse, fissurée longitudinalement, avec latex. Feuilles glabres, groupées à l'extrémité des rameaux, obovales, cunéiformes à la base, obtusément acuminées ou arrondies au sommet, mesurant de 10 à 15 cm de longueur et de 4 à 6 cm de largeur, brillantes dessus, comportant de nombreuses et fines nervures latérales parallèles. Pétiole grêle, atteignant de 2 à 4 cm de longueur. Fleurs blanc verdâtre, en fascicules axillaires. Fruits bacciformes, ovoïdes, mesurant jusqu'à 12 cm de longueur et de 4 à 5 cm de diamètre, charnus, jaune verdâtre ou jaunes à maturité, contenant une grosse graine à amande oléagineuse.

Répartition géographique

Espèce guinéo-congolaise, répandue depuis la Sierra Leone jusqu'au Nigéria.

Usages

On extrait, de l'amande séchée de la graine, une matière grasse alimentaire appréciée connue sous le nom de beurre de makoré. L'écorce de tige est employée en médecine traditionnelle africaine.

Observation

La multiplication de la plante se fait par semis des graines.

CONCLUSION

Autrefois, dans les campagnes africaines, se nourrir ou se soigner n'était pas un problème insoluble. Il suffisait d'entrer dans la forêt toute proche pour en ressortir avec, par exemple, des tubercules d'igname, des fruits ou des feuilles, constituant la ration de la denrée alimentaire journalière de la famille ainsi que les drogues nécessaires à l'amélioration de l'état de santé de cette famille.

Certaines plantes ont pu, ainsi, être domestiquées par les paysans. C'est le cas, par exemple, de *Chrysophyllum albidum* (Sapotaceae), *Dioscorea burkilliana*, *D. dumetorum*, *Di. praehensilis* (Dioscoreaceae), *Tamarindus indica* (Caesalpiniaceae), pour les plantes alimentaires, et de *Buchholzia coracea* (Capparidaceae), *Clerodendrum formicarum*

(Verbenaceae), *Mikania cordata* var. *cordata* (Asteraceae), *Calliandra portoricensis* (Mimosaceae), pour les plantes médicinales.

Mais, après l'avènement des indépendances, il y a eu, dans nos pays, un délaissement quasi total des produits de cueillette, dû à l'abondance des plantes alimentaires introduites, plus accessibles.

La raréfaction des plantes alimentaires sauvages a, aussi, pour cause la mise en valeur industrielle des Etats; cet aménagement a eu pour effet l'exploitation inconsidérée d'étendues considérables de la végétation naturelle, entraînant, comme conséquence, la disparition de nombreuses espèces végétales utiles, parmi lesquelles les plantes considérées ici.

La sauvegarde de ces espèces permettra des études futures quant à leur amélioration, en vue de leur réhabilitation.

Pour ce faire, il serait souhaitable que les gouvernements des Etats concernés et la communauté scientifique internationale envisagent des solutions, à la fois, adéquates et urgentes.

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1.3

Potentially Valuable Crop Plants in a Vavilovian Center of Diversity: Ethiopia

A. DEMISSIE

The study and proper documentation of the diversity, uses and distribution of little known but potentially valuable plant species are exceedingly important and are a prerequisite for their exploitation.

The diversity of food plants and the food habits of local communities have influenced the process of plant domestication. Species of plants with a wide geographical range are at different levels of domestication at different places, depending on the needs of local inhabitants. The early native inhabitants of a particular region, more specifically of a center of diversity, have contributed immensely to the domestication of plants which are now sources of food and other items to people the world over.

The richness of Ethiopia's biological resources is well documented. Many scientists have noted that the country exhibits enormous genetic potential in many cultivated crop plants, such as wheat, barley, sorghum, linseed, sesame and castor, and in other less well-known but potentially valuable plant species. Zohary (1970) identified 11 cultivated crop species as having their centers of diversity in Ethiopia. Vavilov (1951) indicated that some 38 species are connected with Ethiopia by having primary or secondary centers in this region.

The objective of this paper is to list the less well-known but potentially valuable crop plants in the Ethiopian context and in the wider context of Africa. In addition, an attempt is made to provide details of geographical distribution, altitudinal ranges, edaphic factors, regional uses in Ethiopia and taxonomic classification, based on personal studies and on information from the available works.

SIZE OF ETHIOPIAN FLORA

According to Cufodontis (1953-72), about 6,370 species have been recorded in Ethiopia, of which 1,182 are indigenous. Gebre-Egziabher (1986) estimated that the number of higher plants was about 6,700, of which 12% are believed to be endemic to the country.

Here I deal with 12 species of crop plants belonging to 11 plant families (see Table 1). Of these species, four are known to be endemic to Ethiopia: enset, *Ensete ventricosum*; anchote, *Coccinia abyssinica*; oromo dinich, *Coleus edulis*; and yeheb, *Cordeauxia edulis*.

TABLE 1 Some potentially valuable crop plants collected and conserved by PGRC/E

Scientific name	Common name	Family name
<i>Abelmoschus esculantus</i>	Okra	Malvaceae
<i>Amorphophallus abyssinica</i>	Bagana	Araceae
<i>Coccinia abyssinica</i>	Anchote	Cucurbitaceae
<i>Coleus edulis</i>	Oromo dinich	Labiatae
<i>Corchorus olitorius</i>	Jute	Tiliaceae
<i>Cordeauxia edulis</i>	Yeheb	Leguminosae
<i>Dioscorea abyssinica</i>	Boena	Dioscoraceae
<i>Ensete ventricosum</i>	Enset	Musaceae
<i>Lathyrus sativum</i>	Grass pea	Leguminosae
<i>Moringa stenopetala</i>	Cabbage tree	Moringaceae
<i>Phytolacca dodecandra</i>	Endod	Phytolaccaceae
<i>Vernonia galamensis</i>	Vernonia	Asteraceae

ROOT AND TUBER CROPS

Root and tuber crops are major constituents of the diet of the population, particularly in the south-western part of the country. They are cultivated in small holdings, often near homesteads. In general, the country produces and uses diverse root crops. Getahun (1973) listed the most important root and tuber crops grown in Ethiopia for human consumption in order of importance (see Table 2). Potentially valuable root crop species in this list are discussed here.

Enset, *Ensete ventricosum* (Welw.) Cheesman

Botanical relationship and description

The genus *Ensete* consists of herbaceous plants and belongs to the family Musaceae, which also includes abaca, *Musa textillis*, and banana, *M. paradisiaca*. It was formerly classified as a member of the genus *Musa* by H. F. Gmelin in 1791 (Bezuneh et al., 1967). Cheesman (1947) made an extensive genetic and taxonomic investigation and placed African, Australian and a few Asian *Musa* species in a new genus *Ensete*, separate from *Musa*, as initially proposed by Haraninow in 1962. Thereafter, various scientists, including Simmonds (1960) and Baker and Simmonds (1953), extensively studied and documented its taxonomic characters.

Enset is a single-stemmed plant, usually growing up to 9 m and forming a pseudostem like that of *Musa*. The plant consists of a rhizome from which arise aerial shoots 3-9 m tall. It is a monocarpic plant and seeds are produced after 4-7 years, depending on the agroecological

TABLE 2 The most important root and tuber crops grown in Ethiopia for human consumption, in order of importance

Scientific name	Common or vernacular name	Family name
<i>Ensete ventricosum</i>	Enset	Musaceae
<i>Solanum tuberosum</i>	Potato	Solanaceae
<i>Colocacia esculanta</i>	Taro, dasheen	Araceae
<i>Dioscorea</i> spp.	Yams	Dioscoraceae
<i>Ipomoea batatas</i>	Sweet potato	Convolvulaceae
<i>Coccinia abyssinica</i>	Anchote	Cucurbitaceae
<i>Coleus edulis</i>	Oromo dinich	Labiatae
<i>Amorphophallus abyssinica</i>	Bagana	Araceae
<i>Manihot esculanta</i>	Cassava	Euphorbiaceae

Source: Getahun, 1973.

environment. The pseudostems and the corm, which are sources of food, are ready for harvesting before the onset of flowering or at the flowering stage.

The cultivation of enset is restricted to Ethiopia. Elsewhere it is not known as a cultivated plant. Vavilov (1951) indicated Ethiopia to be its primary center of diversity. Furthermore, Kuls (1958) suggested that the natural center of distribution of enset is higher areas of Kefa, in southern Ethiopia, where it occurs in the forests (Westphal, 1975).

Uses

- It is the most important staple food in south-western Ethiopia. It is used by over 7 million people. Table 3 (*overleaf*) provides information on its food composition.
- The pseudostem of enset is a source of fiber. The quality of the fiber is comparable to that of abaca (Bezuneh et al., 1967).
- Its leaves can be used as a source of feed for animals, as well as for wrapping and baking.

Anchote, *Coccinia abyssinica* (W and A) Cogn.

Botanical relationship and description

Coccinia abyssinica is a member of the family Cucurbitaceae to which such genera as *Cucurbita* and *Cucumis* belong. It is a tuberous perennial, with shoots having simple tendrils. The plant dies after the fruits have matured. The underground tubers produce new shoots at the onset of the wet season.

According to Cufodontis (1953-72), 11 *Coccinia* species have been recorded in Ethiopia. Tadesse (1979) listed four: *C. abyssinica*, *C. adoensis*, *C. grandis* and *C. schliebenii*. Only *C. abyssinica* is cultivated for human consumption.

The cultivation of anchote in Ethiopia is sporadic but widespread in the western and south-western regions. In these regions it grows at altitudes ranging from 1,300 to 2,800 m, where

TABLE 3 Composition of some potential food plants in Ethiopia

Species	Protein (g)	Fat (g)	Carbohydrate (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	References
<i>Ensete ventricosum</i>	0.6	0.3	9.0	82	36	3.7	Agren and Gibson (1968)
<i>Coleus edulis</i>	1.5	0.2	16.0	29	90	9.3	Agren and Gibson (1968)
<i>Coccinia abyssinica</i>	1.7	—	—	119	—	—	Getahun (1973)
<i>Amorphophallus abyssinica</i>	2.7	—	—	157	109	—	Getahun (1973)
<i>Abelmoschus esculantus</i>	2.3	0.5	8.6	79	74	3.8	Agren and Gibson (1968)
<i>Lathyrus sativus</i>	22.6	1.4	63.6	336	273	108.2	Agren and Gibson (1968)
<i>Cordeauxia edulis</i>	13.0	11.0	13.0	—	—	—	Anonymous (1979)

the rainfall varies from 762 mm to 1,016 mm (Getahun, 1973). It also occurs in the wild state in drier regions.

Uses

- It is a valuable food source (*see* Table 3) and, according to local farmers, it helps in fast mending of broken bones.
- Tubers of the wild form of *C. abyssinica* are inedible, but the fruits can be eaten. However, fruits of cultivated anchote are not normally eaten.

Oromo dinich, *Coleus edulis* Vatke

Botanical relationship and description

The genus *Coleus* is a member of the family Labiatae, subfamily Ocimoideae. Fifteen species have been recorded in Ethiopia, including *C. edulis* which is cultivated on a small scale in highly localized areas of south-western Ethiopia.

It is a small, hairy, rather succulent herb about 50-60 cm high, with ovate and shallowly serrate leaves. The inflorescence is a raceme of small flowers which are usually purplish-blue. The leaves vary from dark green to purplish-green.

The plant is cultivated in small holdings at altitudes ranging from 1,880 to 2,200 m and is, therefore, regarded as a highland root crop.

Tubers and stem cuttings are used for propagation. Planting is usually undertaken in April and May during the short rainy period. The tubers come in many shapes, sizes and colors.

Uses

- The tubers are usually boiled and consumed as a vegetable. In some areas, rhizomatous roots are often roasted on live charcoal and eaten with the skin on.
- The leaves are often eaten as a green vegetable in some regions.

Boena, *Dioscorea abyssinica* Hochst. Ex. Kunth

Botanical relationship and description

Dioscorea abyssinica belongs to the family Dioscoraceae. Related species include *D. schimperana*, *D. quartiniana* and *D. bulbifera*, the first two occurring in northern Ethiopia and used as famine crops; *D. bulbifera* has edible areal tubers and occurs in the moisture-rich south.

The plant is a herbaceous twiner growing up to 3 m tall, with starchy underground stem tubers. The tubers are flattish and exhibit an array of shapes, mostly old types. Boena can be propagated vegetatively.

The species is indigenous to Ethiopia (Coursey, 1967). It grows at altitudes ranging from 1,700 to 1,900 m and prefers loose, deep loamy soils. In Ethiopian conditions it is planted in March and April and harvested 7-10 months later. Each plant produces six to seven tubers, each weighing 2-3 kg.

Use

- It serves as a valuable food source. The tubers are cooked or fried like potatoes.

Bagana, *Amorphophallus abyssinica*

Botanical relationship and description

The genus is a member of the family Araceae (the aroid family), which consists mainly of herbaceous plants. Two species are recorded for Ethiopia — *A. abyssinica* and *A. gambozianus*.

Bagana has an inflorescence consisting of a large spathe (bract) subtending a spadix of numerous unisexual flowers.

It grows wild in southern Ethiopia at altitudes ranging from 900 to 1,200 m, with relatively low annual rainfall (about 900 mm).

Use

- The tubers are edible, and are eaten particularly at times of food shortage. The species is said to be drought tolerant compared with other aroids.

VEGETABLES

The diversity in less well-known but potentially valuable leaf vegetables in Ethiopia is apparently limited to three plant families — Moringaceae, Tiliaceae and Malvaceae. The most important leaf vegetable in traditional farming communities is *Brassica cerinata*. The seeds are used for oil production, while the leaf is a valuable vegetable mainly in the cereal-producing highlands of Ethiopia. Lesser known regionally important vegetables include *Moringa stenopetala*, *Abelmoschus esculantus* and *Corchorus olitorius*. The last-mentioned plant is also an important fiber crop.

Cabbage tree, haleko or shiferaw, *Moringa stenopetala*

Botanical relationship and description

Moringa belongs to the unigeneric family Moringaceae and consists of 10 species. Five of these species have been recorded in Ethiopia, including the bean oil or horseradish tree, *M. oleifera*, and cabbage tree, *M. stenopetala* (Tadesse, 1979).

Cabbage tree, known locally as haleko, is a soft-wooded deciduous tree with a smooth gray bark. It has alternate leaves. The fruit is an elongated pod-like capsule with many winged seeds.

The plant is found wild in the Konso area of south-western Ethiopia in the Rift Valley at altitudes of 100 to 1,800 m with annual rainfall below 900 mm. It is a perennial source of leaf vegetable in the drier region.

Uses

- It is used as a leaf vegetable. The young leaves are eaten after boiling. The leaves are a market vegetable, second in importance to brassica in the Konso area.
- It is reported to be of medicinal value and to be used in purifying muddy water (Jahn, 1981)

Okra, *Abelmoschus esculantus*

Botanical relationship and description

Okra belongs to the Malvaceae family, which includes such genera as *Gossypium* and *Hibiscus*. There are over 24 species recorded in Ethiopia under its former generic name. The taxonomy of *Abelmoschus* needs a thorough revision. However, recent observation indicates the presence of at least two species — *A. manihot* and *A. moschatus* — in areas where okra was recently collected by the Plant Genetic Resources Centre/Ethiopia (PGRC/E).

According to Purseglove (1968), Harlan (1969) and Martin and Ruberte (1972), this species might have been domesticated in Ethiopia. Vavilov (1951) considered Ethiopia a center of diversity for the species. However, in a more recent publication by Charrier (1984), East Africa was not cited as a center of diversity, despite the presence of tangible diversity of the crop in the region.

Okra is a relatively popular vegetable in some parts of Ethiopia, mainly in the south-west area bordering on the Sudan. It grows at altitudes ranging from 550 to 650 m with an annual rainfall of 1,270 mm. The maximum mean annual temperatures range from 31.7°C in September to 38°C in March. The minimum mean temperatures ranges from 18.3°C in December to 22°C in April. It is basically a warm climate vegetable.

In Ethiopia this species is little known outside its relatively small area of cultivation in Gambella. The fruit is cut into pieces to make soup with which a local bread is eaten.

INDUSTRIAL CROP PLANTS

In the past two decades a few far-sighted scientists have been considering the value of potential industrial crop plants in Ethiopia. Their interest has led to a series of regional workshops and a growing international interest in some of these plants.

Here I deal with the diversity of potential industrial crop plants in *Phytolacca* and *Vernonia*. Despite the potential of the two crop plants described here, they have been neglected for centuries and basic information on them has only recently become available.

Vernonia galamensis

Botanical relationship and description

Vernonia galamensis belongs to the family Asteraceae (Compositae), which includes important oil-bearing genera such as *Helianthus* and *Carthamus*. In Ethiopia, 30 different species have been identified within the genus, including *V. lasiopus*. Gilbert (1986) described six subspecies within *V. galamensis*, one with four varieties. In his study, Kenya is given as the center of genetic diversity for the species.

V. galamensis is a semi-arid plant. An annual rainfall of about 500 mm is probably ideal, but a good seed crop can be produced in areas with as little as 250 mm if the rainfall is timely (Perdue, 1986). In areas with much higher rainfall, the flowering season is prolonged and the seed does not mature uniformly. In Ethiopia, matured seeds were collected from altitudes ranging from 1900 to 2,000 m where the annual mean rainfall ranges from 600 to 700 mm.

Economic importance

The seed contains 42% oil, of which 73% is vernolic acid and much superior to that from the best improved lines of *V. anthelmintica*. The oil is suitable for plastic formulations and has potential as raw material for the coating industry (Perdue, 1986).

The plant has good seed retention capacity compared with its close relatives.

Endod, *Phytolacca dodecandra*

Botanical relationship and description

Endod is the Ethiopian name for the soapberry plant. The plant belongs to the family Phytolaccaceae. Two other related species — *P. dioica* and *P. americana* — have also been identified.

Endod is a scrambling plant which grows up to 6 m tall, sometimes climbing up to 12 m with hanging branches. The leaves are glossy. It is a dioecious plant and can be propagated readily from berries and cuttings (stem and root). Flowers are dimorphic and scented. Berries are star-shaped in outline, orange or red when mature.

The plant grows naturally at between 1,600 and 3,000 m in Ethiopia. However, it has been reported growing in hot lowlands at 750 m and bearing fruit (Wolde-Yohannes, 1983).

Although in a recent collecting expedition endod was found at altitudes between 1,900 and 2,950 m, most of the samples were collected above 2,400 m. It is basically a highland species and grows mainly in well-drained soils in sparsely forested areas and around dwellings.

Economic importance

The berries, when dried and crushed and mixed with water, provide a foaming detergent solution which can be used as a soap for washing clothes. The root and leaves, despite their toxicity, have been reported to have medicinal values for various ailments, including termination of unwanted pregnancies.

Sun-dried and crushed endod berries suspended in water have molluscicidal properties and can kill a variety of snails, including those that transmit schistosomes and *Fasciola*. Recent findings indicated that endod berries also have potent spermicidal properties that can be used in birth control (Lemma, 1983).

LEGUMES

Next to the grasses, the legumes are the most important plant group used by man as a source of human and animal food. It is the family Leguminosae that exhibits most potential for producing the increased supplies of vegetable protein that the world requires. In developing countries in particular, where other sources of protein are too expensive, the cultivation of legumes is the best and the quickest alternative for increasing the production of food proteins.

The Leguminosae consists of about 18,000 species and 650 genera; of these, less than 20 species are used extensively today. Nutritionally, the legumes are two to three times richer in protein than the common cereal grains (Anon., 1979).

Both the species diversity and the intraspecific diversity in legumes are relatively large in Ethiopia. Crops such as faba bean, field pea, chickpea and lentil are associated with Ethiopia as a center of diversity. There are over 599 species of legumes recorded for the country; only a handful of these (such as peas, lentils, chickpea, common bean, cowpea, alfalfa and clovers) are utilized. The remaining species are little known and under-utilized. Here only two species that are little known but potentially valuable are described.

Yeheb, *Cordeauxia edulis*

Botanical relationship and description

Cordeauxia edulis is a member of the family Leguminosae (Fabaceae) and subfamily Caesalpinoideae. The species is monotypic and is closely related to *Caesalpinia*; it is doubtful that it warrants genetic status (Thulin, 1983).

Yeheb is a many branched shrub, occasionally becoming a small tree, about 2-3 m high. Unlike its close relative, it is unarmed. The young shoots produce red or purple glands. The fruit is a dehiscent pod containing one or two seeds, each about 4 cm long.

This semi-desert bush is native to Ethiopia's arid Ogaden region and neighboring Somalia. It is a hardy shrub that during drought periods is sometimes the only food source in the region.

In the past, yeheb was reported to constitute up to half the woody vegetation in many areas in the region (Anon., 1979). Today it is much reduced and is now further threatened by drought and regional conflicts.

Yeheb grows well in areas ranging in altitude from 300 to 1000 m where the annual precipitation is 250-400 mm. It also grows in areas receiving even lower annual rainfall.

Uses

- Yeheb is used mainly for human consumption, the seeds being an important component of the diet of the local people. The seeds are roasted or eaten raw. They have a high protein (13%), fat (11%) and starch (13%) content (Anon., 1979).
- The plant is browsed by animals and serves as a good source of forage.
- The leaves contain a brilliant red dye that stains the hand.

CONCLUSION

The genetic resources of potential crop plants should be collected and conserved for the three major reasons: to avert their replacement by genetically narrow-based commercial cultivars; to fully evaluate them for important characters such as food value and ability to withstand stresses; and to protect the genetic resources from genetic wipeout by natural calamities such as drought and desertification.

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1.4

Forage Species Diversity in Africa: An Overview of the Genetic Resources

H. N. LE HOUEROU

The phanerogamic flora of continental and insular Africa comprises a minimum of 63,000 species, about 20,000 of which are consumed to a greater or lesser extent by livestock and large wild herbivores. These 20,000 more or less edible species may further be divided into some 4,200 grass species (out of about 6,000), 1,800 legume species (out of about 6,000) and 1,500 other species.

The number of African species (including those from Mediterranean Africa) used in current routine farming practice throughout the world (including agroforestry) is little more than 100 grass species, 100 legume species and some 20 other species. However, the contribution of African species to the tropical pasture and fodder genepool of the world is high, particularly where grasses are concerned (70-75% of the pasture and fodder crop tropical grasses and 25-30% of the legumes).

African pasture and fodder crop species are among the potentially most productive in the world since yields of 20 t DM/ha/yr are being routinely obtained with grasses or grass-legume mixtures in various tropical zones. Some 10 species of African grasses can reach a production level of 40 t DM/ha/yr in small plot experiments, under close-to-optimal conditions and heavy fertilizer inputs. Three to four species have been reported repeatedly to yield 60-85 t DM/ha/yr under experimental conditions in the humid tropics of Central and South America and South-East Asia. These grasses can thus outyield sugarcane and woodlots in terms of dry-matter production, with incoming energy conversion rates of 3-6% — that is, 7-15% of photosynthetically active radiation (PAR) — compared with 1-3% for the best temperate climate crops, with an energy conversion rate of 4,250 cal/g DM produced.

Not only is Africa rich in terms of species diversity, but also intraspecific variability is high in many species, such as *Panicum maximum*, *Cenchrus ciliaris* and *Cynodon dactylon*. Polyploidy is common and apomixis is not rare, particularly (but not only) in the Panicoideae.

Many cultivars have been selected or bred (often overseas) as routine pasture species, including *Panicum maximum*, *P. coloratum*, *Chloris gayana*, *Pennisetum purpureum*,

Cenchrus ciliaris, *Setaria sphacelata* var. *sericea* (= *S. anceps*), *Cynodon dactylon*, *Sorghum sudanense* × *Sorghum bicolor*, *Pennisetum glaucum* (= *P. americanum* = *P. typhoides*) × *P. purpureum* and many others, excluding staple food millets and sorghums.

However, what has been done so far is only the visible part of the iceberg, so to speak. Much more remains to be done, particularly when arid and semi-arid zone herbaceous and browse species are concerned. But there are a couple of outstanding exceptions where grasses are concerned: *Cenchrus ciliaris* has received considerable attention in Australia, India and the USA, and much work has been done on *Cynodon dactylon* in the USA. Consequently, many cultivars of these two species have been developed.

There are many excellent and productive 'wild' species both in the Mediterranean zone and in the tropics. The relevant genera are:

- Mediterranean: *Digitaria*, *Dactylis*, *Cynodon*, *Festuca*, *Lolium*, *Oryzopsis*, *Phalaris*, *Sporobolus*, *Hedysarum*, *Lotus*, *Medicago*, *Melilotus*, *Onobrychis*, *Trigonella*, *Trifolium*, *Vicia*, *Atriplex*, *Colutea*, *Coronilla* and many other browse species.
- The tropics: *Andropogon*, *Brachiaria*, *Digitaria*, *Cynodon*, *Chrysopogon*, *Eragrostis*, *Lasiurus*, *Panicum*, *Pennisetum*, *Sporobolus*, *Crotalaria*, *Desmanthus*, *Desmodium*, *Indigofera*, *Lablab*, *Melilotus*, *Rhynchosia*, *Tephrosia*, *Trifolium*, *Vigna*; and, among the browse species, *Acacia*, *Baphia*, *Bauhinia*, *Boscia*, *Brachystegia*, *Cadaba*, *Canthium*, *Combretum*, *Cordeauxia*, *Crataeva*, *Faidherbia*, *Feretia*, *Grewia*, *Griffonia*, *Julbernardia*, *Justicia*, *Maerua*, *Milletia*, *Ormocarpum*, *Pterocarpus*, *Salvadora*, *Ziziphus* and many others.

Wild herbaceous and browse species from arid and semi-arid zones should be given priority in official research programs for a number of reasons, including the following:

- there is a large and recognized potential;
- some excellent, drought-tolerant and productive species, a rather rare combination, are endangered by cultivation, overstocking, fuel collection, desertification and general land and vegetation degradation;
- these species are essential for arid land reclamation and for the rehabilitation of areas suffering from degradation and desertification; however, seeds and propagation material are usually not available in commercial quantities, and this lack of availability has hindered many recent development efforts;
- public sector research resources, being what they are, should concentrate on these species as commercial research and overseas organizations are able and willing to handle the more directly profitable species adapted to the humid and sub-humid zones.

Programs such as those recently developed by the International Board for Plant Genetic Resources (IBPGR), the International Livestock Center for Africa (ILCA), the International Institute of Tropical Agriculture (IITA), the International Council for Research in Agroforestry (ICRAF), the International Center for Agricultural Research in the Dry Areas (ICARDA), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and other international and national organizations and universities should be encouraged by

financing agencies and cooperating organizations, including NGOs. A good example is provided by the programs adopted by Australian scientific and agricultural organizations and farmers (for stylos, subclovers, lupins, medics, siratro and *Leucaena*, among others).

But research programs would be much more efficient if the African states would more fully meet their responsibility in taking — and enforcing — the urgently needed measures to protect threatened species and environments. This would constitute a significant contribution to the welfare of mankind.

RICHNESS OF THE AFRICAN FLORA

Using Brenan (1978), Goldblatt (1978), Leroy (1978), Quézel (1978), Le Houérou (1974a, 1974b, 1988a, 1988b) and a compilation from White (1983), Table 1 shows the number of endemic species and the total number of species in the African flora a decade ago. The number of non-endemic species in inter-tropical Africa is 18,000, while the number of non-endemic species north of the Tropic of Cancer is 4,500. According to Leonard's estimate (1971, 1975) of an average of 350 descriptions per annum, the number of newly described species between 1978 and 1988 is approximately 3,500. Thus the total African flora would be 63,200, comprising 22,500 non-endemics, 37,200 endemics and 3,500 newly described species.

TABLE 1 Richness of the African flora

Areas	Total no. of species	No. of endemics	Endemics (%)
Inter-tropical Africa (Brenan, 1978; Good, 1974)	30,000	12,000	40
Southern Africa (Killick, 1971; Goldblatt, 1978)	18,550	15,000	81
Madagascar (Leroy, 1978; Keraudren-Aymonin, 1976; Koechelin et al., 1974)	8,200	6,700	82
North Africa (Le Houérou, 1974 a, b, 1986, 1988; Quézel, 1978)	6,000	1,500	24
Offshore islands (compiled from White, 1983)	3,000	2,000	67
Total		37,200	

The mean areal richness for continental and insular Africa is thus 63,200/3,000 10⁴ km² or 21.1 species per 10⁴ km² (see Table 2 *overleaf*). This figure is in an intermediate position compared with other continents or continental-sized countries (see Table 3 *page 104*).

Tables 1–3 show that, contrary to a popular belief, Africa is neither particularly poor nor particularly rich in terms of floristic diversity. Some areas are very poor: the Sahara and the

TABLE 2 **Richness of flora in some geographical zones and countries of Africa (1988)**

Zone or country	Estimated no. of species	Area (10⁴ km²)	Areal richness (no. spp./10⁴ km²)
Continental and insular Africa	62,200	3,000.0	20.7
FWTA (A)	7,500	503.4	14.9
FTEA (B)	11,000	176.0	62.5
Southern Africa (C)	18,550	261.3	71.0
Flora Zambesiaca (D)	6,500	324.5	20.2
Madagascar (E)	12,000	58.7	204.4
North African steppes (F)	2,000	60.0	33.3
Mediterranean North Africa (G)	4,500	42.0	107.1
Sahara (H)	2,000	800.0	2.5
Sahel (J)	1,500	300.0	5.0
Zaire, Rwanda and Burundi	12,000	239.9	50.0
Horn of Africa (K)	8,000	182.2	43.9
Algeria	3,800	238.1	16.0
Angola	4,600	124.7	36.9
Burundi	2,500	2.8	892.9
Canary Islands	1,800	0.7	2,572.4
Cape Verde	659	0.4	
Cameroon	6,500	47.5	168.4
Central African Republic	3,600	62.3	57.8
Chad	1,600	128.0	12.5
Comores	1,000	0.2	5,000.0
Congo (Brazzaville)	4 000	34.2	117.0
Côte d'Ivoire	4,900	32.2	152.2
Djibouti	550	2.2	250.0
Egypt	2,100	100.0	21.0
Ethiopia	7,000	112.2	62.4
Gabon	6,000	26.8	223.9
Ghana	3,600	23.9	150.6
Guinea	4,500	24.9	180.7
Guinea-Bissau	1,000	2.3	357.1
Kenya	7,000	58.3	120.3
Lesotho	1,600	3.0	533.3
Libya	1,800	176.0	10.2
Madagascar	12,000	58.7	204.4
Mali	2,000	150.0	12.0
Mauritania	1,100	103.1	10.7
Malawi	5,500?	9.4	585.1?
Morocco	4,200	62.0	67.7
Mozambique	6,000	78.5	76.4
Namibia	3,300	82.3	57.9
Natal	4,830		
Niger	1,200	124.7	9.6
Nigeria	4,520	92.4	50.0
Rwanda	2,200	2.6	846.2

Zone or country	Estimated no. of species	Area (10 ⁴ km ²)	Areal richness (no. spp./10 ⁴ km ²)
Senegal	2,100	20.0	105.0
Seychelles	240	0.03	8,000.0
Sierra Leone	1,700	7.2	234.0
Somalia	3,700	70.0	44.3
Socotra	650		
Sudan	3,300	250.0	13.2
South Africa, Republic of	13,400	122.0	109.8
Swaziland	2,120		
Tanzania	6,000?	93.9	63.9?
Togo	2,200	5.6	392.9
Tunisia	2,200	16.0	137.5
Uganda	4,400?	23.7	185.7?
Western Sahara	330	26.6	12.4
Zaire	11,000	234.5	46.9
Zambia	6,050	73.0	140.1
Zimbabwe	5,450	38.9	157.0

A FWTa = Flora of West Tropical Africa (west of Lake Chad).

B FTEA = Flora of Tropical East Africa (Kenya, Tanzania, Uganda).

C Southern Africa = Botswana, Namibia, Republic of South Africa.

D Flora Zambesiaca = Malawi, Mozambique, Zambia, Zimbabwe.

E Madagascar: 8,200 species in 1976, many new species described over the past 12 years; our present estimate >10,000 species, with 82% endemic.

F North African steppes = from Morocco through Egypt, 50-400 mm mean annual rainfall (Le Houérou, 1988a).

G Mediterranean Zone of North Africa = areas above 400 mm mean annual rainfall (Morocco, Algeria, Tunisia, Libya).

H Sahara = below 100 mm mean annual rainfall.

J Sahel = areas with 100-600 mm mean annual rainfall south of the Sahara, from the Atlantic Ocean to the Red Sea (6,000 x 500 km).

K The Horn of Africa = Ethiopia, Djibouti, Somalia.

Sahel with 2.5 spp./10⁴ km² and 5.0 spp./10⁴ km², respectively. Other areas are among the richest in the world: the Canary Islands (2,572 spp./10⁴ km²) and the Cape of Good Hope peninsula (5,000/10⁴ km²).

The overall African figure of 21 spp./10⁴ km² makes it second only to South America in the continental context. Other, smaller zones within continents are richer (for example, Central America, the Caribbean, South-East Asia and the Indo-Pacific Archipelagos), but not much richer than Cameroon, Madagascar, Zaire or the Republic of South Africa; and the Canary Islands are more than twice as rich as Hawaii, although not much smaller.

It should be borne in mind that a comparison of areal richness is a meaningful exercise only when the size of the areas under investigation is comparable or, at least, of the same order of magnitude (Cailleux, 1953).

TABLE 3 Comparative richness in other floristic zones of the world (arranged according to surface area)

Zone or country	Estimated no. of species	Area (10 ⁴ km ²)	Floristic richness (no. spp./10 ⁴ km ²)
USSR	18,000	2,227.4	8.0
USA and Canada	20,000	1,993.9	10.0
South America	80,000	1,692.1	47.3
China	25,000	956.0	26.1
Tropical America	95,000	1,285.3	73.9
Tropical Asia	35,000	680.0	51.5
USA	18,000	936.3	19.2
Brazil	40,000	851.2	47.0
Australia	15,000	771.6	19.5
Indian subcontinent (A)	20,000	508.8	39.3
Mexico	20,000	197.3	101.5
Indian peninsula	5,000	186.0	26.9
Mediterranean basin (B)	15,000	160.0	94.0
Iran	7,000	164.8	42.5
Indonesia	25,000	149.1	167.7
Tibet	700	117.8	5.9
Europe	11,500	100.0	115.0
Turkey	8,000	78.1	102.4
Chile	4,200	75.7	55.5
Texas	5,000	69.2	72.2
Germany	2,600	57.9	44.9
France	4,500	55.0	81.8
Spain	5,500	50.1	109.8
California	5,200	41.1	126.5
Malaysia	9,000	33.2	271.0
British Isles	1,440	30.8	46.9
Italy	5,700	30.1	189.4
Philippines	8,100	30.0	270.0
Arizona	3,300	29.5	111.9
Greece	5,000	13.2	378.8
Guatemala	7,800	10.9	715.6
Panama	7,500	7.6	986.8
Cuba	8,000	4.5	1,777.8
Switzerland	2,600	4.1	634.2
Hawaii	1,800	1.7	1,117.6

A Indian subcontinent = India, Pakistan, Bangladesh, Kashmir, Nepal, Bhutan, Sikkim, Burma.

B Areas of the Mediterranean basin with a Mediterranean climate and a Mediterranean type of vegetation.

AFRICAN FORAGE SPECIES

For the sake of clarity, forage species could be subdivided into grasses, legumes and browse (woody) species.

★ Grasses

Among the estimated 450 families, 12,500 genera and 300,000 species of flowering plants in the world, Gramineae is the fifth largest family, with 600 genera and an estimated 12,000 species. Larger families are Compositae (25,000 species), Orchidaceae (18,000 species), Leguminosae (15,000 species) and Rubiaceae (13,500 species).

Knowing the proportion of grasses in the flora of various African countries or areas, one can reach an estimate of the number of species in the overall flora. Table 4 provides this information for a number of countries and zones, for both grasses and legumes. According to this rough estimate, there are approximately 6,200 species of grasses and 6,200 species of legumes in the overall African flora.

TABLE 4 **Number and proportion of grasses and legumes in various areas and countries of Africa**

Area/country	Grasses		Legumes		Overall flora
	No.	%	No.	%	No.
FWTA	600	8.0	622	8.3	7,500
FTEA	1,000	9.0	1,500	14.0	11,000
North Africa	400	8.0	450	9.0	5,000
Sudan	370	11.5	355	11.1	3,200
Ethiopia	650	10.0	600	9.0	6,500
Chad	250	17.0	200	13.0	1,500
Southern Africa	750	4.0	1,500	8.0	18,550
Madagascar	500	5.0	600	6.0	10,000
Kenya	600	11.0	850	12.5	7,000
Uganda	370	8.0	500?	11.1	4,400
Niger	200	17.0	150	13.0	1,200
Senegal	280	13.0	240	11.0	2,100
Arithmetic average		10.0		10.3	

It is noticable, however, that countries or regions having large expanses of arid land tend to harbor a higher proportion of grasses, such as in the Sahelian region (Chad 17%, Niger 17%, Senegal 13%, Sudan 11.5%), while the opposite is true of rain forest regions (Madagascar 5%, Uganda 8%). Southern Africa goes against this trend for, despite its huge areas of arid grasslands, it has only 4% of grasses in its flora. However, Southern Africa is a peculiar floristic case in many other respects too (Oliver, 1871; Dalziel, 1937; Acocks, 1953; Cufodontis, 1953-72; Monod, 1957; Brenan, 1958, 1967; Hutchinson et al., 1958, 1972; Meredith et al., 1959; Harker and Napper, 1960; Hedberg, 1965; Clayton, 1970, 1972;

Clayton et al., 1971, 1982; Gillett et al., 1971; Hepper, 1971; Werger, 1973; Fröman and Persson, 1974; Fröman, 1975; Bodgan, 1976, 1977; Field, 1976; Le Houérou, 1976, 1988b; Wickens, 1976; UNESCO, 1979; Humphreys, 1982; Anon., 1984; Boudet, 1984).

Making an educated guess, based on 35 years of field experience in various parts of Africa, I would expect about 70% of African grasses to be fairly palatable to herbivores, at least in their juvenile stage. That represents some 4,400 species, about 3,500 of them located in the inter-tropical zone. Common species playing a significant role in grazing would probably not exceed 1,000 species in the inter-tropical zone.

Species of high fodder quality throughout most of their annual cycle are still fewer, perhaps 150 in the tropics and 50 in the extra-tropical zone (North Africa and South Africa). Among the former one may cite some 40 species and subspecies:

<i>Andropogon gayanus</i>	<i>D. foveolatus</i> (= <i>Eremopogon foveolatus</i>)
var. <i>gayanus</i>	<i>Digitaria decumbens</i>
var. <i>squamulatus</i>	<i>D. milanjiana</i>
var. <i>bisquamulatus</i>	<i>D. pentzii</i>
var. <i>tridentatus</i>	<i>D. umfolozi</i>
<i>Antheophora pubescens</i>	<i>Echinochloa stagnina</i>
<i>Brachiaria brizantha</i>	<i>Eragrostis superba</i>
<i>B. decumbens</i>	<i>Lasiurus scindicus</i> (= <i>L. hirsutus</i>)
<i>B. mutica</i>	<i>Melinis minutiflora</i>
<i>B. nigropedata</i>	<i>Panicum antidotale</i>
<i>B. ruziziensis</i>	<i>P. coloratum</i>
<i>Cenchrus ciliaris</i>	<i>P. maximum</i>
<i>C. setigerus</i>	<i>Paspalum scrobiculatum</i> (= <i>P. commersonii</i>)
<i>Chloris gayana</i>	<i>Pennisetum clandestinum</i>
<i>Chrysopogon plumulosus</i>	<i>P. purpureum</i>
<i>Cynodon aethiopicus</i>	<i>Schmidtia pappophoroides</i>
<i>C. dactylon</i>	<i>Setaria sphacelata</i> var. <i>serucea</i> (= <i>S. anceps</i>)
<i>C. nlemfuensis</i>	<i>Sporobolus ioclados</i>
<i>C. plectostachyus</i>	<i>Urochloa mosambicensis</i>
<i>Dichanthium annulatum</i>	<i>U. trichopus</i>

There is a large number of Andropogoneae, particularly in the genera *Andropogon* and *Hyparrhenia*, that may be considered as good grazing grasses until earing; at that stage they become very coarse and have little or no grazing value. Among the very common and often dominant species are:

<i>Andropogon chinensis pseudapricus</i>	<i>Hyparrhenia filipendula</i>
(= <i>A. ascinodis</i>)	<i>H. hirta</i>
<i>A. tectorum</i>	<i>H. rufa</i>
<i>Botriochloa</i> spp.	<i>H. smithiana</i>
<i>Heteropogon contortus</i>	<i>Hyperthelia dissoluta</i>
<i>Hyparrhenia diplandra</i>	

One of the rare Andropogonoideae used in cultivation is *A. gayanus* which, under proper management, may be fairly productive, as well as being very tolerant to fire and drought. In my opinion, this has been a grossly under-utilized species in pasture development in the subhumid tropics. The main reasons for the low use of Andropogonoideae as a pasture crop is their usually low germination rate, the difficulty of handling and processing their hairy/bristly seeds and their low palatability and feed value when maturing.

Among the outstanding forage species mentioned above, several show a high intraspecific and/or intravarietal variability. These include:

Cenchrus ciliaris
Chloris gayana
Cynodon dactylon
Panicum coloratum

P. maximum
Pennisetum purpureum
Setaria sphacelata var. *serucea* (= *S. anceps*)

These (and some others) are morphologically and genetically very heterogeneous, with many morphotypes and ecotypes; for *Panicum maximum*, for example, refer to Combes (1972) and Pernes (1975). Polyploidy is common and apomixis is frequent in Panicoideae (Brown, 1958). With such variable groups, species names have little meaning, as each 'species' consists of a wide array of genomes. Besides *Panicum maximum* and *P. coloratum*, this is also the case for the *Setaria anceps* 'complex', *Cenchrus ciliaris* and *Cynodon dactylon*. Hybridization of sexual *Cenchrus ciliaris* and *C. setigerus* at Texas A and M University resulted in 'a wide spectrum of sexual and apomictic types, some of which might easily be classified as new species if discovered in natural habitat' (Bashaw et al., 1970, quoted by Whyte, 1974).

Other species appear rather stable and fairly homogeneous morphologically; for some of them, this is possibly because they have not yet been 'domesticated' and therefore not yet studied in detail. Among these species are:

Antheophora pubescens
Botriochloa pertusa
B. insculpta
Brachiaria decumbens
B. mutica
B. ruziziensis
Chrysopogon plumulosus
Cynodon aethiopicus
C. plectostachyus

Digitaria decumbens
Eragrostis superba
Lasiurus scindicus (= *L. hirsutus*)
Panicum antidotale
Paspalum scrobiculatum (= *P. commersonii*)
Sehima nervosum
Sporobolus ioclados
Themeda triandra

Among the most variable cultivated species, *Cenchrus ciliaris* (buffel grass) possesses at least 20 cultivars (10 in Australia alone) and countless biotypes and ecotypes. *Chloris gayana* (Rhodes grass) and *Panicum maximum* (Guinea grass) have at least 12 cultivars each, and a large number of clones. *Panicum maximum* var. *trichoglume* (green panic) has over eight cultivars. *Pennisetum purpureum* (elephant grass), although usually propagated vegeta-

tively, has over five clones in Africa and 20 in Venezuela (Bogdan, 1977). *Setaria anceps*, a common but seldom dominant grass in the subhumid African tropics, is a continuum-complex of many biotypes more or less artificially split into three species, sometimes separated and sometimes lumped (*S. anceps*, *S. sphacelata* and *S. splendida*). *Cynodon dactylon* (Bermuda grass, Star grass) holds many American cultivars and countless ecotypes, as the species *sensu lato* is common between the equator and latitude 50°N.

A fair number of perennial species seem promising for pasture development in the arid and semi-arid tropics. These include:

<i>Antheophora pubescens</i>	<i>Eragrostis superba</i>
<i>Cenchrus ciliaris</i>	<i>Eremopogon foveolatus</i>
<i>Chrysopogon plumulosus</i>	<i>Lasirius scindicus</i> (= <i>L. hirsutus</i>)
<i>Cynodon dactylon</i>	<i>Panicum antidotale</i>
<i>Dichanthium annulatum</i>	<i>P. coloratum</i>
<i>Digitaria nodosa</i> (= <i>D. commutata</i> subsp. <i>nodosa</i>)	<i>P. maximum</i> var. <i>trichoglume</i>
	<i>Sporobolus ioclados</i>

A number of African pasture and fodder crop grasses are among the highest yielders in the plant kingdom, with potential yields of 40-85 t DM/ha/yr in small plot trials (Cooper, 1970). These show a linear response to fertilizers up to several hundred kg/ha (1,800 kg N/ha/yr and 300-500 kg of P and K). Such massive productivity outyields sugarcane crops and any kind of woodlot or natural forest or savanna. It does correspond with incoming global energy conversion of 3-6% on an annual basis (7-15% PAR), compared with 1-3% in the most productive temperate climate crops. All these tropical grasses belong to the group of C4 carboxylation pathway species.

The most productive species are:

<i>Panicum maximum</i>	<i>Pennisetum purpureum</i> x <i>P. americanum</i>
<i>Pennisetum purpureum</i>	(bana grass, babala grass, pusa giant)
	<i>Digitaria decumbens</i> (pangola grass)

These species have been reported to yield 40 t DM/ha/yr under close-to-optimum farming conditions and heavy fertilization, and up to 60-85 t DM/ha/yr in small-scale trials, particularly in Central America, the Caribbean and South America.

A group of 10-15 other African tropical grasses have shown a theoretical yield potential of 20-40 t DM/ha/yr. This group includes:

<i>Brachiaria brizantha</i>	<i>Melinis minutiflora</i>
<i>B. decumbens</i>	<i>Panicum coloratum</i>
<i>B. ruziziensis</i>	<i>Paspalum commersoni</i>
<i>Chloris gayana</i>	<i>Pennisetum clandestinum</i>
<i>Cynodon plectostachyus</i>	<i>Sorghum sudanense</i> x <i>S. bicolor</i>
<i>Digitaria umfolozi</i>	<i>Urochloa mosambicensis</i>
<i>Echinochloa stagnina</i>	

Under the Mediterranean climate of North Africa, a number of native species and populations have a potential yield of 10-20 t DM/ha/yr or more under irrigation. These include:

Festuca arundinacea
Lolium multiflorum
L. rigidum
Oryzopsis holciformis

O. miliacea
Phalaris aquatica (= *P. bulbosa*)
P. coerulescens
P. truncata

Among the most productive and drought-tolerant forage species in the arid and semi-arid zones where mild winter conditions (mean minimum temperature of the coldest month $>3^{\circ}\text{C}$) prevail are a few populations of subtropical grasses that have become very rare and localized as a result of centuries-old overgrazing:

Cenchrus ciliaris
Digitaria commutata subsp. *nodosa*

Lasiurus hirsutus
Sporobolus ioclados

I tested these species in small-scale cultivation experiments and they exhibited excellent agronomic potential in terms of pasture establishment, palatability, nutritive value, yield and tolerance of severe drought conditions, growing as they do in areas with a mean annual rainfall of 150-300 mm or less.

Many grass-like species, such as sedges, are not consumed by herbivores; there are, however, a few exceptions, notably: *Cyperus conglomeratus*, common on sandy soils on both the northern and southern edges of the Sahara.

A fairly large number of grasses which are sometimes physiognomically dominant (many of them increasingly so) are unpalatable to livestock at any time of their annual development cycle. Among these, the following are worth mentioning:

Aeluropus lagopoides
A. littoralis
Agropyron spp.
Andropogon spp.
Aristida spp.
Arundo donax
Chloris spp.
Ctenium spp.
Cymbopogon spp.
Diheteropogon hagerupii
Eleusine jaegeri
Elionurus spp.
Eragrostis spp.
Festuca spp.
Harpchne spp.

Hyparrhenia spp.
Imperata cylindrica
Leptothrium spp. (*Latipes*)
Loudetia spp.
Microchloa indica
Panicum repens
Pennisetum schimperii
P. villosum
Phragmites spp.
Rhynchelytrum spp.
Saccharum spp.
Schizachyrium spp.
Tricholaena spp.
Tripogon spp.

LEGUMES

As shown in Table 4, legumes represent some 11% of the African flora (that is, some 6,600 species). These species are unevenly distributed among three subfamilies: Caesalpinioideae, Mimosoideae and Papilionoideae (Fabaceae).

The Caesalpinioideae, the more primitive subfamily, are predominantly woody, the Mimosoideae are almost entirely ligneous and most (55-60% in the African tropics) of the Papilionoideae are herbaceous species, of which 40-45% are shrubs, trees and woody vines. Some of the perennial herbs, however, have woody basal and underground parts.

I would estimate that not more than 30% of the African legumes are actually consumed by livestock and game, and some are toxic. The palatable legumes can be subdivided into herbage and browse. The latter will be dealt with later in this paper, together with species belonging to other families.

Judging from the various floras available, Caesalpinioideae represents about 13% of the legumes, Mimosoideae about 11% and Papilionoideae some 76%. But these proportions may vary substantially from one area to another; for example, Papilionoideae represents 78% of the legumes in the Flora of West Tropical Africa (FWTA), 66% in the Flora of Tropical East Africa (FTEA) and 81% in the Sudan. The figures for Caesalpinioideae are 23% in the FWTA, 12% in the FTEA and 7% in the Sudan.

I estimate that the number of species consumed by large herbivores is about 2,000. The proportions of these seem about evenly distributed in the three subfamilies. The herbaceous forage legumes would then number about 550 species. It is noteworthy that many species in large genera of Papilionoideae and Caesalpinioideae are predominantly unpalatable or toxic; relevant genera include *Aeschynomene*, *Crotalaria*, *Indigofera* and *Tephrosia* in Papilionoideae and *Cassia* in Caesalpinioideae. It should be borne in mind that these are very large genera; for example, there are about 280 species of *Indigofera* in inter-tropical Africa (Gillett, 1958).

These genera make up nearly 55% of the 1,005 species of Papilionoideae in the FTEA:

<i>Aeschynomene</i>	50 spp.
<i>Crotalaria</i>	195 spp.
<i>Eriosema</i>	45 spp.
<i>Indigofera</i>	144 spp.
<i>Tephrosia</i>	60 spp.
<i>Trifolium</i>	22 spp.
<i>Vigna</i>	28 spp.

In the FWTA, the proportions according to subfamily are:

Caesalpinioideae	150 spp. of which 141 (94%) are woody
Mimosoideae	72 spp. of which 69 (96%) are woody
Papilionoideae	430 spp. of which 100 (23%) are woody

In this flora, the following genera of Papilionoideae are particularly rich in species and account for 68% of the subfamily:

<i>Aeschynomene</i>	20 spp.
<i>Crotalaria</i>	52 spp.
<i>Desmodium</i>	17 spp.
<i>Dolichos</i>	16 spp.
<i>Eriosema</i>	20 spp.
<i>Indigofera</i>	83 spp.
<i>Rhynchosia</i>	18 spp.
<i>Tephrosia</i>	21 spp.
<i>Vigna</i>	26 spp.

Overall, we therefore have among the FWTA Papilionoideae: 100 woody (23%) and 330 herbaceous (77%) species. The herbaceous species are thus only 52% of the legumes within the boundaries of the FWTA, but substantially more in the FTEA.

In the Sudan, the largest country in Africa, with great variation in climate (0-4000 mm mean annual rainfall), vegetation (absolute desert to rain forest), latitude (2°-20° N.), and altitude (0-3000 m), we have the following (Andres, 1950-56): Caesalpinioideae 31, Mimosoideae 55 and Papilionoideae 270. This gives a total of 356, of which 120 (34%) are palatable to large herbivores. In Papilionoideae, three genera represent 48% of the subfamily and 36% of the legumes: *Crotalaria* 44 species, *Indigofera* 60 species and *Tephrosia* 25 species.

In the inter-tropical zone the most important genera of herbaceous legumes with regard to grazing are: *Alysicarpus*, *Calopogonium*, *Centrosema*, *Desmodium*, *Dolichos*, *Lablab*, *Macrotyloma*, *Mucuna*, *Phaseolus*, *Rhynchosia*, *Vigna* and *Zornia*. Among the predominantly unpalatable genera (such as *Aeschynomene*, *Crotalaria*, *Indigofera*, *Sesbania* and *Tephrosia*) a few species are consumed; some have been tested as fodder crops, a few with moderate success (Skerman, 1977), but none of them has come into sustained routine pasture establishment on any significant scale to date.

Some species have been successfully used as green manure for land and crop improvement. A West African herbaceous legume, *Sesbania rostrata*, a tall species with stem nodulation and nitrogen fixation, has been used to improve rice-field fertility. Experiments showed that applying this green manure led to an improvement equal to the application of 230 kg/ha/yr of chemical nitrogen input (Dreyfus and Dommergues, 1980, 1981; Lahbib et al., 1985).

It is worth noting that African tropical pasture legumes represent only 25-30% of the world cultivated species (50% originating in Central and South America, including *Stylosanthes*, *Calopogonium*, *Desmodium*, *Centrosema*, *Macrotylium* and *Pueraria*, and about 20% in South-East Asia), whereas African grasses make up 70% of the world tropical pasture species (Bogdan, 1977; Skerman, 1977; Whiteman et al., 1974; Whyte et al., 1959; Whyte, 1974).

The most important tropical pasture species among herbaceous legumes are the following, some of which are not exclusively African:

<i>Cajanus cajan</i>	<i>Pueraria lobata</i> (= <i>P. thunbergiana</i>)
<i>Canavalia ensiformis</i>	<i>Rhynchosia minima</i>
<i>Clitoria ternatea</i>	<i>R. memnonia</i>
<i>Lablab purpureus</i>	<i>Stylosanthes fruticosa</i>
<i>Lotononis bainesii</i>	<i>Trifolium semipilosum</i>
<i>Macrotyloma axillare</i> (= <i>Dolichos biflorus</i>)	<i>Vigna unguiculata</i>
<i>Neonotonia wightii</i> (= <i>Glycine wightii</i>)	

Some promising species have been successfully tried in local experiments or small-scale farming. These include *Melilotus suaveolens* from the East African highlands, a very high-yielding fodder crop cultivated at Assela in the Bale province of Ethiopia between 1960 and 1976 (Fröman, 1975). *Tylosema esculenta* (Marama bean) seems to be a promising fodder species as well as a staple food for humans (Bostid, 1979). Among the approximately 30 species of clovers in the East African highlands, several seem to have agronomic potential and have been studied (Kaharunanga, 1982); these include *Trifolium baccarinii*, *T. burchellianum*, *T. rueppellianum*, *T. semipilosum*, *T. simense* and *T. tembenese*.

In the dry tropics an American species, *Desmanthus virgatus*, from Texas and Mexico has become naturalized in West Africa. It is a herbaceous perennial with a woody basal part and seems quite promising for areas with a mean annual rainfall of less than 300-600 mm.

Further investigations are needed to select species and populations of such genera as *Indigofera*, *Crotalaria* and *Tephrosia* for their potential as fodder in the semi-arid and arid tropics, particularly in the areas where exotic species such as the stylos have not fulfilled earlier expectations. The extensive inventories, surveys and mapping carried out in Africa over the past three decades should be very useful in these investigations; to date, not enough use has been of the data from these surveys.

The local flora of Mediterranean Africa is rich in pasture species; some 250 of them have been tested in small-scale trials, and about 10% of the latter are being cultivated, often overseas, particularly in Australia (for example, subclovers and medics). The most commonly cultivated species number about 20 (Villax, 1963; Le Houérou, 1965, 1974a, 1977, 1985); these include *Hedysarum coronarium*, *H. flexuosum*, *H. carnosum*, *Lotus corniculatus*, *L. creticus* var. *collinus*, *Medicago sativa*, *M. littoralis*, *M. trunculata*, *M. rugosa*, *M. scutellata*, *Melilotus italica*, *M. albus*, *Pisum arvense*, *Trifolium alexandrinum*, *T. fragiferum*, *T. resupinatum*, *T. subterraneum* subsp. *subterraneum*, subsp. *brachycalycinum*, subsp. *yanninicum*, *Vicia sativa* and *V. villosa*. Variability between and within populations is usually high; in general, unimproved local populations have given much better agronomic results than cultivars of the same species imported from overseas.

Tests carried out on some other 'wild' species indicate that they seem to possess good agronomic potential (Le Houérou, 1985). These include *Lotus collinus* (= *L. creticus* subsp. *collinus*), *Hedysarum humile*, *H. naudinianum*, *H. perralderianum*, *H. carnosum*, *Onobrychis argentea*, *Medicago gaetula*, *M. tunetana* and *Trifolium hirtum*.

Some 20 cultivars of subclovers and about 20 medics have been developed in Australia; many more could be selected from local populations to meet the local ecological conditions (for example, cold and/or frost tolerance, which is usually not a selective criterion in Australian cultivars, but may be an important criterion locally in the North African highlands and southern Europe).

BROWSE

Some 130 main browse species from the arid, semi-arid and subhumid zones of West Africa (Le Houérou, 1980b) and 80 from Ethiopia (Le Houérou and Corra, 1980) have been listed. Lamprey et al. (1980) listed some 70 species from East Africa; Walker (1980) listed 70 from Southern Africa, while Lawton (1980) added another 70 species from the Miombo woodland of south-eastern Africa. Taking into account the overlap (fairly minimal) between these lists, and the fact that a number of good but fairly uncommon species have been overlooked, the

overall number of main browse species in continental Africa is about 400 (Wickens, 1980). Of course, many more species are occasionally consumed by livestock and game. These 400 species belong to about 55 families; the highest proportion of these are in Leguminosae (fairly evenly distributed among the three subfamilies), Capparaceae, Rubiaceae, Combretaceae and Tiliaceae.

Some species or groups of species have a high nutritive value; among these, the Capparaceae and legumes have a mean crude protein (CP) content of 20.7 and 15.8% respectively; the overall mean figure for African browse is 12.9%, based on data from 830 chemical analyses (Le Houérou, 1980d). Even apparent digestibility may be quite high; Mabey and Rose-Innes (1964, 1966) came up with figures of 60-70% for the dry matter and 70-75% for crude protein in the dry matter in *Griffonia simpliciflora*, *Baphia nitida* and *Milletia thonningii* in Ghana, as opposed to a mean browse value of about 50% in the organic matter (Le Houérou, 1980d). Some species are so rich in crude protein and non-silica minerals that they may be considered as concentrate feed, like cottonseed or peanut cake. Browse is also often rich in non-silica minerals. The overall mineral content is 11% in the dry matter, 7.5% for legumes and 12.2% for Capparaceae (Le Houérou, 1980d).

Among the particularly significant species with good to excellent nutritive value and palatability to livestock and wildlife are the following (Le Houérou, 1988b):

Acanthaceae	<i>Justicia slavioides</i>
Anacardiaceae	<i>Rhus natalensis</i>
Burceraceae	<i>Commiphora africana</i>
Capparaceae	<i>Boscia angustifolia</i> , <i>B. albitrunca</i> , <i>B. minimifolia</i> , <i>Cadaba farinosa</i> , <i>C. glutinosa</i> , <i>Crataeva adansoni</i> , <i>Maerua angolensis</i> , <i>M. crassifolia</i> , <i>M. oblongifolia</i>
Combretaceae	<i>Anogeissus leicarpus</i> , <i>Combretum aculeatum</i> , <i>C. zeheyri</i> , <i>Terminalia</i> spp.
Leguminosae	Caesalpinioideae: <i>Bauhinia rufescens</i> , <i>B. macrantha</i> , <i>Brachystegia</i> spp., <i>Colophospermum mopane</i> , <i>Cordeauxia edulis</i> , <i>Cordyla pinnata</i> , <i>Griffonia simpliciflora</i> , <i>Julbernardia</i> spp. Mimosoideae: <i>Acacia clavigera</i> , <i>A. ehrenbergiana</i> , <i>A. gerrardi</i> , <i>A. hockii</i> , <i>A. karroo</i> , <i>A. laeta</i> , <i>A. mellifera</i> , <i>A. raddiana</i> subsp. <i>raddiana</i> , subsp. <i>tortilis</i> , subsp. <i>spirocarps</i> , <i>A. senegal</i> , <i>A. seyal</i> , <i>A. xanthophloea</i> , <i>Faidherbia</i> (<i>Acacia</i>) <i>albida</i> Papilionoideae: <i>Baphia bequaertii</i> , <i>B. massaiensis</i> , <i>B. nitida</i> , <i>Milletia thonningii</i> , <i>Ormocarpum trichocarpum</i> , <i>Pterocarpus angolensis</i> , <i>P. erinaceus</i> , <i>P. lucens</i>
Meliaceae	<i>Khaya senegalensis</i>
Moringaceae	<i>Moringa oleifera</i>
Rhamnaceae	<i>Ziziphus mauritiana</i> , <i>Z. mucronata</i>
Rubiaceae	<i>Canthium</i> spp., <i>Feretia apodanthera</i> , <i>Gardenia</i> spp.
Simaroubaceae	<i>Balanites aegyptiaca</i>
Salvadoraceae	<i>Salvadora persica</i>
Tiliaceae	<i>Grewia bicolor</i> , <i>G. flava</i> , <i>G. villosa</i>
Verbenaceae	<i>Vitex doniana</i> , <i>V. madiensis</i>

Pellew (1980) reported browse dry-matter production of 5,000 kg/ha/yr from riverine plant communities of *Acacia xanthophloea* and 1,700 kg from ridge-top plant communities of

A. hockii-*A. tortilis* in East Africa. In West Africa the rule of thumb of 1 kg DM/ha/yr per mm of mean annual rainfall has been estimated as a result of a number of studies and surveys in arid, semi-arid and subhumid savannas and woodlands (Le Houérou, 1980c). From this amount, about 25%-30% is available to livestock and 65-80% to giraffe.

Browse species and fodder shrubs plantations may play an important economic role in agroforestry; significant agroforestry species in tropical Africa are *Acacia raddiana* subsp. *raddiana*, subsp. *tortilis*, subsp. *spirocarps*, *A. senegal*, *A. seyal*, *A. mellifera*, *Faidherbia* (*Acacia*) *albida* and *Pterocarpus erinaceus*. Other native species tried successfully in agroforestry are *Acacia karroo*, *A. laeta*, *A. mellifera*, *A. seyal*, *Bauhinia rufescens*, *Combretum aculeatum*, *Desmodium velutinum*, *Feretia apodanthera*, *Pterocarpus lucens*, *Moringa oleifera* and *Ziziphus mauritiana*.

In Mediterranean Africa and, to some extent, in the East African highlands, the following species have been widely used (Le Houérou and Pontanier, 1987): *Atriplex halimus*, *A. nummularia*, *Acacia saligna* (= *A. cyanophylla*), *A. karroo* and *Opuntia ficus-indica* var. *inermis*.

CONCLUSION

There is considerable diversity in forage species in Africa, particularly in grasses and browse species. Perhaps as many as 3,500 plant species play a significant role in feeding large African herbivores: 1,500 grasses, 600 herbaceous legumes, 400 browse species and 1500 others (forbs). By comparison, less than 150 cultivated plants species contribute in a significant way to human food requirements in Africa.

Genetic variability is apparently high, judging from the few species that have been subject to manipulation. The only agroforestry tree widely used throughout inter-tropical Africa, *Faidherbia* (*Acacia*) *albida*, seems to include a wide array of populations within which individual variability is also high and, seemingly, genetically controlled (some trees, for example, always bloom early, other always bloom late; some have a high pod yield, others none at all). Even species in which vegetative propagation is the usual multiplication system under cultivation exhibit a large variability. These include *Panicum maximum*, *Pennisetum purpureum*, *P. clandestinum* and *Opuntia ficus-indica*. Others, such as *Digitaria decumbens*, *Paspalum scrobiculatum* (= *P. commersonii*) and the *Brachiaria* seem much less variable.

The contribution of African species to the world tropical pasture development is very important for grasses (70%) and moderate for legumes (30%).

Browse potential for agroforestry is high but only a handful of promising domesticable species, out of several dozens, are actually being used on an empirical basis.

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PART 2

Ecogeographical Studies

2.1

Ecogeographical Survey of African Species

A. McCUSKER and J. TOLL

What are we striving for in undertaking an ecogeographical survey? In the International Board for Plant Genetic Resources (IBPGR), with its mandate to collect and conserve the germplasm of crop and forage species and their wider gene pools, we are concerned with documenting the different environments in which species grow, and the range of variation that species exhibit in those environments. Thus we are interested in the amount and distribution of genetic diversity in each species. With this knowledge we should then be in a good position to collect and conserve a widely representative range of this diversity.

Genetic diversity is an easy enough concept to understand in theory, but it is not so easy either to recognize in the field or to maintain in genebanks. With regard to field recognition of diversity, which is important for ecogeographical surveys, one tends to rely on features that look variable to the naked eye, such as the size and shape of the plant or the texture and moisture of the soil in which it grows, or other physical aspects of the environment. These surveys are usually carried out by botanists with a strong taxonomic leaning, so we have been generally much less attentive to differences that are not so visible on a herbarium sheet, such as early or late flowering, breeding system and pollinating vectors.

From the point of view of the users of plant germplasm — plant breeders in particular — these characteristics are of special importance and, in conducting an ecogeographical survey, we need to take full account of them. There is a lot of scientific work to be done in an ecogeographical survey which distinguishes it quite clearly from a collecting mission.

PROJECT BACKGROUND AND OBJECTIVES

Genetic diversity is believed to flourish where environments are diverse and selection pressures are low (or, to put it another way, where environments are favorable for growth). On this basis there should be considerable genetic diversity in Africa, and indeed there is. The tropical forests provide a good example.

In the Sahel, however, where IBPGR is planning its to undertake this survey, environments are apparently less diverse, and growing conditions are generally very harsh. Selection

pressure here is very high and, as a result, relatively few species are able to survive; among those that do, the best adapted individuals are strongly favored. Natural forces have selected the best gene combinations for the conditions. In other words, nature has done some pre-breeding for us. The plants resulting from this process, therefore, have particular value as genetic resources for use in similarly harsh environments, and IBPGR is concerned to ensure that they find their way into germplasm collections, accompanied by enough scientifically accurate information to make them as useful a resource as possible.

Nowhere is there a more urgent need to safeguard and exploit what remains of plant genetic diversity than in the Sahel. The region is afflicted by desertification, the causes and consequences of which are exacerbated by drought and are leading to a rapid loss of the genetic resources that have been adapted by nature over a long period of time. Yet it is this reservoir of diversity upon which measures to combat desertification depend.

It is known that the major cause of desertification is increasing human pressure on the land. This has already led to extensive overgrazing, deforestation and the cultivation of marginal areas, with eventual loss of vegetation, followed quickly by soil erosion. The erosion of plant genetic diversity which accompanies these events is one of the least documented but most catastrophic results of desertification. As habitats are destroyed and their ecotypes lost, so too are the distinctive adaptations, which could be the key to combating further desertification, lost.

The two interrelated strategies that are used to fight desertification — protection and rehabilitation of the environment, and development of sustainable crop and livestock production systems — both depend on the exploitation of the genetic diversity of plants.

Since 1984 IBPGR has fielded collecting missions in the Sahel in conjunction with various national institutions. Some ecogeographical information has been collected on these missions. The material and the data from the collection were deposited with the respective national institutes and designated genebanks for eventual evaluation and utilization. The evaluation could form the basis of a more extensive ecogeographical survey and analysis aimed at a better understanding of the genetic variation within the survey area. We would then be in a position to know how best to use the material that has been collected, and where the centers of variation are located — that is, where we would get the best rewards from further collecting efforts.

A more cohesive program, in which germplasm collecting is tied closely to germplasm evaluation, is called for if germplasm collected for long-term storage is also going to be made an effective resource for short-term use. Information on available germplasm must be assembled and correlated quickly in order to identify potentially useful variants to address some of the immediate problems in the area.

In the proposed project, a few selected species will be surveyed and collected across their geographical ranges and over several seasons. In this way, genetic variation resulting from differences in ecological and climatic factors in space and time can be sampled. To maximize the amount of genetic diversity captured, populations from many environments will be sampled. Seed or material for vegetative propagation will be collected where practicable.

Although much of the diversity in the genepools of the major crops has been collected already, relatively little attention has so far been given to the minor cereals, vegetables and legumes. Furthermore, there are numerous wild species that are gathered for food but whose value and potential are poorly known, and they are at risk of genetic erosion. A wide range of Sahelian species are also used for forage, browse, fuelwood, construction, medicines and other purposes.

PROJECT SCALE AND ORGANIZATION

The scale of the project we are proposing is potentially huge, but will be limited by resources. In setting priorities, IBPGR wishes to be guided by the needs of national programs in the Sahelian region for information on particular species, and by opportunities for collaboration with other institutions in carrying out the field work.

IBPGR proposes that the survey should start on a small scale with a limited number of priority forage species. This 'pilot study' could be extended later to include more species, depending on needs and resources. Trees are already receiving some attention, but herbaceous forages, particularly grasses and legumes, are still largely neglected.

The species listed below are suggested as likely candidates on the basis of their value as forage species, in dune stabilization, as windbreaks, and so on, and their susceptibility to further genetic erosion, but not all these species could be included initially. The aims and organization of the project and the selection of species must be compatible with the needs and on-going activities of the participating institutions.

Alysicarpus ovalifolius

Andropogon gayanus

Aristida sieberiana

Cenchrus ciliaris

Chrysopogon plumulosus

Dichanthium annulatum

Lasiurus scindicus

Panicum turgidum

Stylosanthes fruticosa

Tephrosia spp.

As everyone who has worked in the Sahel is aware, conditions are very difficult for field work, and it is in everyone's interests to work together where practicable. IBPGR is ready to foster as much collaboration as possible. That is part of our mandate. If several organizations are interested we are prepared to accept a coordinating role. We are raising this proposal today, rather than taking the opportunity to describe some of the work that IBPGR has already done in Africa, so as to make use of this excellent forum to exchange ideas and generate action. We are hoping for some constructive feedback before the end of this workshop.

PROJECT POTENTIAL

A project such as this has the potential to pull together many existing efforts and to promote cooperation on a wide scale. For example, gathering information from the literature, the herbaria and other sources would be the first step. Environmental monitoring and information systems such as those operated by the United Nations Environment Program (UNEP) could help pinpoint areas undergoing severe desertification for priority collection, monitor seasonal fluctuations in the vegetation and assist in the interpretation of the environmental data.

Knowledge of the reproductive biology of a species is critical to the selection of the appropriate collecting and maintenance strategy. In some cases the lack of information on the occurrence of apomixis in many grass species is a problem. Another research input could be on the patterns of intraspecific diversity using genetic markers. This would assist with the interpretation of ecogeographically related variation. Complementary research of this type could be contracted out to universities and specialist institutions.

The conservation of material collected would be undertaken by national institutions and relevant international centers, especially the International Livestock Center for Africa (ILCA) in the case of forage species. The 'users' of seeds and data would be the various developmental projects charged with introducing improved crop and livestock production systems or implementing environmental conservation measures. These projects may be operated by national, international or nongovernmental organizations. Feedback from these organizations on what species and which attributes are of use would assist in the selection of species and localities for priority attention. Furthermore, their on-the-ground observations on desertification and seasonal changes in the quantity and composition of the vegetation would be important for the planning of collecting missions.

Awareness is growing of the importance and urgency of safeguarding the plant genetic resources of the Sahel. All countries in the region are taking measures to protect this resource base, and several have initiated national genetic resources programs. The region and the wider community are responding by launching new programs at existing institutes and creating new organizations. These initiatives are occurring at all levels, including the grassroots. The involvement of developmental projects has particular importance for monitoring ecological changes and taking follow-up action.

Wild and semi-cultivated useful plants are receiving increasing attention. However, apart from multipurpose trees, the systematic survey and collecting of these species is not yet under way. Once it is set up, the project described here could provide the mechanism for starting field activities on minor crops and under-exploited species, thereby expanding the pilot study into a core project.

The short-term goal of such a project would be to help improve agricultural production and halt environmental degradation in the Sahel. It is in this area that the benefits will primarily be felt. However, as in the case of the Sahel, where trees and plants from Asia and South America are making an important contribution, there may well be a reciprocal benefit from the introduction of Sahelian germplasm into locations elsewhere in the world that have not yet been considered.

2.2

The Potential Use of the Global Resources Information Database (GRID) in Plant Genetic Resources Activities

A. BURRILL, H. CROZE and O. SIMONETT

Plants, like all living things, are a product of their environment. This applies not only to wild species, but also to domestic and cultivated plants. They are the product of their wild ancestors' environments, the peculiarities of which determined the evolution of certain traits. It is therefore no surprise that agriculturalists and scientists concerned with genetic resources often turn to environmental information in the course of their work.

The need to conserve genetic diversity is fundamental to the discipline of domestic plant genetics. The highly specialized food crops grown in many parts of the world yield produce that is large, tasty or has other special marketable qualities. However, in growing monocultures which have been selected for these qualities, the farmer leaves his crops vulnerable to pests, diseases or severe weather. Since the days of Vavilov, geneticists have realized the importance of maintaining the wild relatives of economic plants (Williams, 1987). It is only by the regular introduction of more resistant genes into domestic crops that high yields can be maintained, so this genetic base must therefore not be allowed to disappear. The conservation of genetic diversity is also important to pharmaceutical and chemical companies, for many of their products are derived from natural resources.

The conservation of genetic resources generally takes two forms. The first is the *ex situ* genebank, advanced centers where seeds and cuttings are held and archived under special conditions. The materials in these centers are collected in the field for future use; they come from both market crops and wild plants. Ideally, these centers would hold representatives of all cultivated and wild strains, but time and fiscal constraints naturally limit the size of the collections. Wild species are particularly difficult to collect and are typically under-represented in genebanks, frequently accounting for less than 2% of the acquisitions (Plucknett et al., 1987). In view of the importance of the genetic resources from these wild species, it is vital to ensure that those species which are collected for genebanks form as broad a spectrum as possible. One generally accepted method of doing this is to collect species

samples from a wide variety of environments. These plants will have evolved under very varied conditions and thus represent a diverse set of genetic material.

Genetic resources can also be conserved *in situ*, where species are maintained in their natural habitat. This method is ideal for many wild species that are difficult or impossible to maintain in a genebank (for example, many types of trees). It also allows the opportunity for continued evolution. Species in the wild will continue to change and adapt to the environment, developing new traits which potentially have commercial value. Species preservation in natural habitats thus forms an ideal complement to *ex situ* genebanks.

In situ conservation avoids the costs of collection and archiving, but requires that some safeguards be taken to maintain the sites in their natural condition. Over the past century, however, there has been an increase in the rate of genetic erosion among landraces and wild species. Land cover changes brought about as a result of human activities have been the major cause. Overgrazing and clearing of forests and grasslands have disrupted many natural habitats, and construction of human settlements has eliminated many traditional crop lands. As human populations grow and increase their impact on the landscape, it becomes increasingly important that areas which are host to essential genetic resources be protected and preserved as parks or reserves.

Just as there are limits on the resources available for collecting missions, the resources necessary for establishing and maintaining protected areas are clearly limited, and setting priorities for protection is a critical activity. First consideration is usually given to areas with unique resources, such as sites with uncommon environmental or ecological conditions in which rare species have evolved. Particular emphasis should be placed on those areas with unique species which are also under threat of development. This can best be determined by evaluation of the surrounding land uses and pressures.

Other prime candidates for protection are areas in which a large numbers of species occur. By conserving these so-called 'centers of diversity', a considerable amount of genetic material can be maintained at minimum cost. A number of international organizations, including the United Nations Environment Programme (UNEP), the Food and Agriculture Organization of the United Nations (FAO), the International Board for Plant Genetic Resources (IBPGR), the International Council for Bird Preservation (ICBP), the International Union for Conservation of Nature and Natural Resources (IUCN) and the World Wide Fund for Nature (WWF), have become involved in the identification of such centers. Information about known species distribution as well as data about environmental conditions are useful in this process.

The identification of areas for collecting missions and reserve establishment is thus a process which relies heavily on information on environmental factors. Researchers who are investigating the mechanisms of evolution and seeking to understand the processes which produce desirable genetic material are also interested in the environmental conditions in their study areas. The spatial correlation between genetic traits and environmental factors may point to critical causal links. For these reasons, collections of papers dealing with plant genetic resources are replete with maps depicting environmental factors, ranging from large-scale plots of trees to small-scale maps of rainfall and vegetation types across entire continents. Maps thus seem to form a useful source of information for many aspects of plant genetics. Working with map data, however, is traditionally a rather cumbersome process. The difficulties involved in integrating maps of different scales and projections can impose limits on their usefulness. Fortunately, advances in computer hardware and software capabilities in the past 20 years have obviated many of the difficulties.

GEOGRAPHIC INFORMATION SYSTEMS

The present generation of geographic information system (GIS) technology provides scientists and planners with a tool to make better use of spatial information, such as maps (Burrough, 1986; UNEP, 1988). GIS technology was developed with the recognition that the characteristics of a place are defined by the combination of many diverse attributes. For instance, by examining a variety of environmental factors, such as rainfall, soil type, altitude, slope and distance to market, one can map an area's suitability for growing a particular crop. Similarly, the carrying capacity of an area can be determined by evaluating a combination of environmental variables which can be mapped. GIS technology provides the facility to combine diverse maps, thus enabling one to study the interaction between variables, to understand the dynamics of their association and to evaluate an area on the basis of the sum of its features.

A GIS is actually a specialized computer program which allows for the input, manipulation, storage, retrieval, analysis and output of geographical data. GIS packages have been written for most mainframe and minicomputers, such as IBM PC-ATs with hard disks. Because of the special nature of geographical data, special input and output peripherals are often used with GIS packages; these may include electronic digitizing tables, scanners, color graphics monitors, plotters and laser printers.

Information can be entered into a GIS from a wide variety of sources, such as conventional maps, air photographs, satellite images and even field observations tied to specified locations. Basically, any data which can be mapped or which can be located in space can be entered into a GIS. Data not already in digital form must either be entered using a digitizing table or be prepared for reading by an electronic scanner. In either case, the process of data entry and verification is quite time-consuming and presents the major bottleneck in GIS processing.

Once the data have been entered into the computer, however, the advantages of a GIS become apparent. The system can transform the diverse datasets into a common projection and register them to a common coordinate system. Thus, datasets which have been stored in a GIS can be retrieved for comparison and analysis, in any combination, and used for any number of applications. Updating is also a relatively easy process. Data entry is thus a one-time cost which vanishes as the database is more widely used. For example, at the beginning of its pilot phase, UNEP's Global Resource Information Database (GRID) assembled a collection of small-scale thematic maps for Africa in connection with a project to assess desertification hazard. The digitizing was a substantial task, but the same datasets have been used repeatedly in other projects, including elephant population analyses (Burrill and Douglas-Hamilton, 1987), work on vector-borne diseases (Lessard et al., 1988) and studies of the Zambezi water basin (presently being undertaken by the International Institute of Applied Systems Analysis).

At the simplest level, a GIS allows the facility to retrieve datasets and display them 'on top of' one another for visual inspection (*see Figure 1 overleaf*). The analytic powers of the computer can also be used to actually combine datasets and investigate the spatial relationship between their attributes. Figure 2 (*overleaf*) illustrates how a GIS can be used to apply models and derive new datasets on the basis of existing information (UNEP, 1987c). In this example, the ecological suitability for growing coffee in Uganda was derived from maps of moisture availability and mean annual temperature. The GIS was also used to project the potential impact of global warming.

FIGURE 1 **Range of the African elephant (top left)**
 Protected areas in Africa (top right)
 Overlay of elephant range with protected areas (bottom)

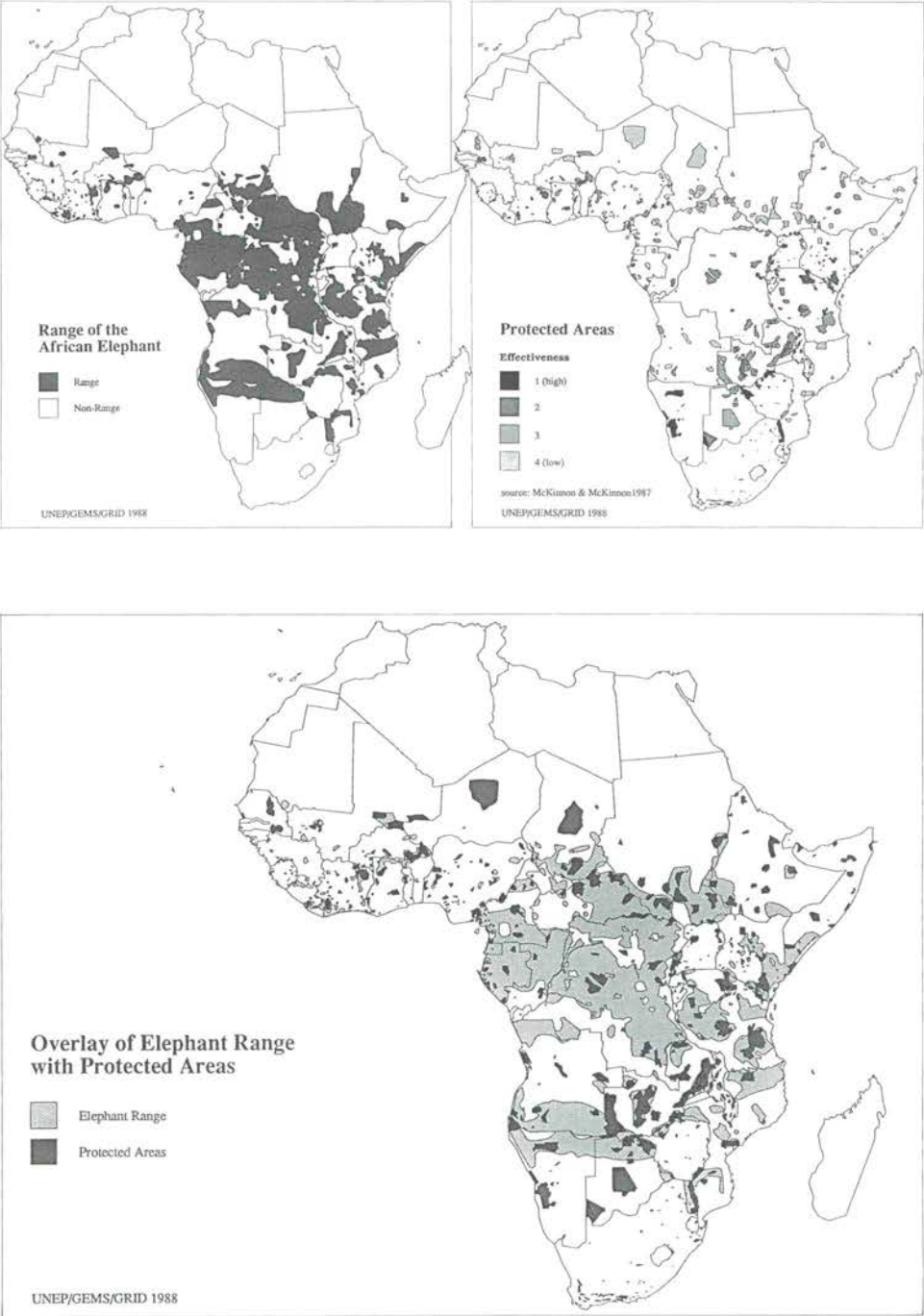
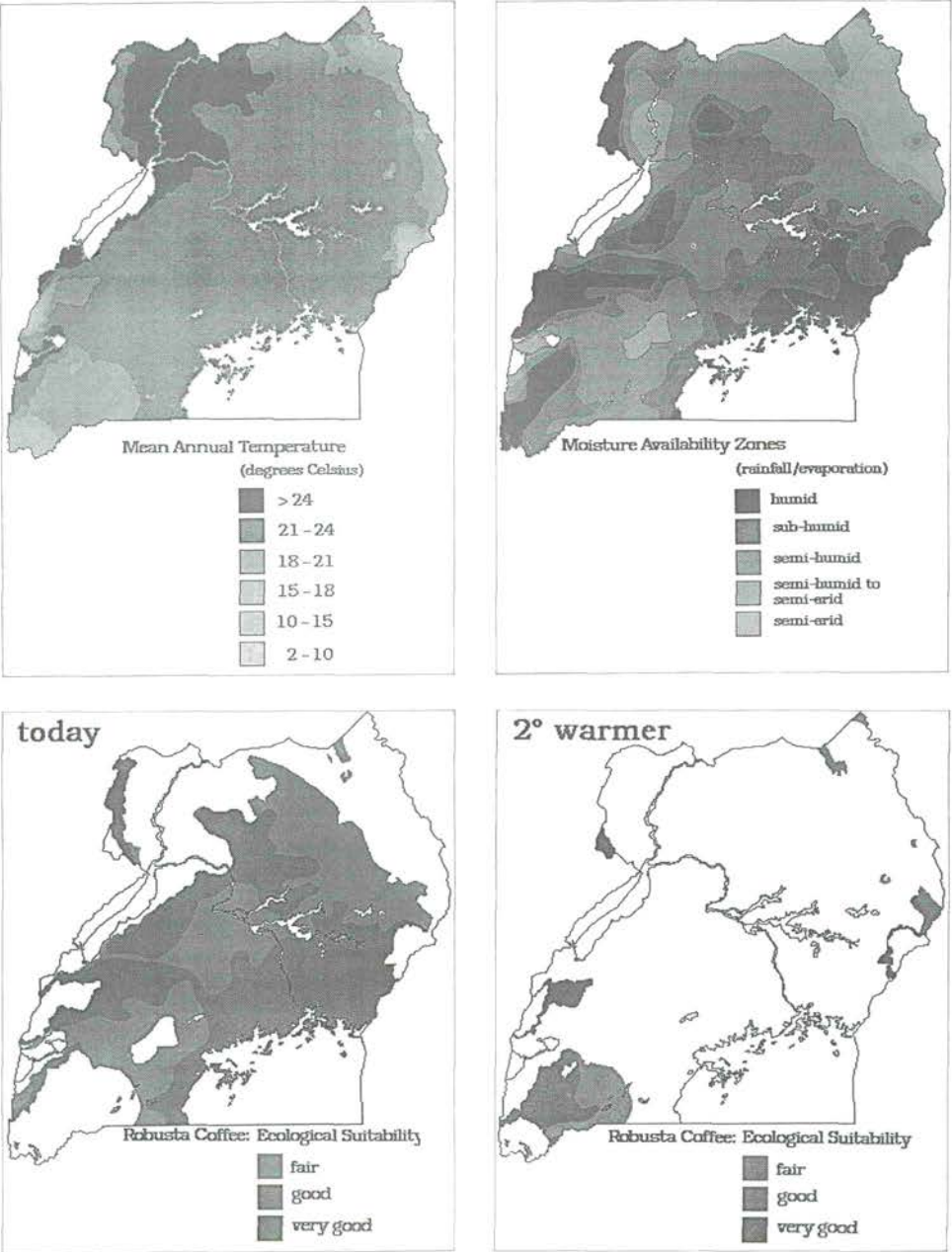


FIGURE 2 Mean annual temperature in Uganda (top left)
Moisture availability in Uganda (top right)
Robusta coffee: Ecological suitability (bottom left)
Robusta coffee: Ecological suitability at 2°C warmer (bottom right)



The GRID elephant project further illustrates some of the capabilities of a GIS, both for analyzing the relationship between known variables and in the application of a model to estimate an unknown variable. In this study, elephant density data were compiled from all areas in which elephants existed, comprising a total of about a third of the range of the African elephant.

These data were entered into a GIS from various large-scale maps and were then combined to form an elephant density dataset. This dataset was subsequently overlaid with data on various factors which were believed to influence elephant distribution, including human distribution, rainfall, vegetation type, protected areas and per capita GNP. Correlations were derived which substantiated some of the expected relationships, and these correlations were then used to develop equations to predict elephant density in areas which had not been studied. On the basis of these equations, elephant numbers were estimated across the continent.

As these examples illustrate, a GIS is a powerful tool for manipulating and analyzing geographic information. Like all tools, however, it must be used carefully and with the appropriate materials. High-quality input data and rigorous models are essential for producing reliable output. When used in combination with careful data collection programs and appropriate models, a GIS can play an important role in facilitating the handling of environmental data.

APPLICATIONS IN PLANT GENETIC RESOURCE ACTIVITIES

Given the importance of the distribution of both species and environmental features in plant genetic resource activities, GIS technology would appear to offer many potential uses. The scientist who is interested in understanding the processes of evolution, plant dynamics and genetic drift would find a GIS a good tool with which to investigate relationships. A researcher could, for instance, incorporate information on the distribution of genetic characteristics over successive generations for a study site into the computer, in combination with environmental data. The GIS could then determine the impact of the various environmental variables on the plant.

Similarly, a GIS could assist in determining and cataloguing centers of diversity. By integrating all of the existing information on species distribution, it would be possible to pinpoint known areas of high species diversity and to identify some of the characteristics which seem to determine these centers. The ICBP, based in the UK, has recently proposed undertaking a similar study using a GIS and bird distribution maps.

A GIS could also be used to locate areas which would be likely to harbor valuable genetic resources but which have yet to be investigated. By combining environmental maps and searching for characteristics which tend to co-exist with high species diversity, rich areas may be pinpointed. The same database could be used to highlight areas with unique environmental conditions. Through these techniques, GIS technology could assist plant geneticists to set priorities for collecting missions and for reserve establishment. The technology could not only help the geneticists to develop priorities but also to convince the policy-makers and general public of the importance of the priorities.

GIS systems could also be used to match species with environments. This type of application can take two forms. Agriculturalists working in one location, and searching for

species which could be bred with the local crops, might use a GIS to identify areas where such species might be found. In this case, the local conditions would need to be determined and a GIS containing the appropriate datasets could be used to locate other areas with similar conditions. Similarly, a collecting mission in one area might identify a particularly interesting tree with certain desirable characteristics. A GIS could assist in determining other areas where the tree could thrive. The Australian Government has begun using GIS packages for these types of applications.

Finally, a GIS provides a powerful output device. GRID has found that graphic output from a GIS is likely to make a greater impact on both planners and the general public than tables and lists. Plant geneticists could thus use a GIS to help not only in making decisions but also in convincing others of their merits.

While the establishment of a GIS at a gene research center would undoubtedly assist its work, the optimal use of such a system would be at the international level. By assembling all of the available information globally, not only on known species distribution, but also on the location of past collecting trips and the home ranges of species held in *ex situ* genebanks, global priorities could be established and information could be more easily exchanged between institutions in different countries. This would help to reduce the unnecessary duplication of effort and encourage better coordination and cooperation in conserving genetic resources.

THE ROLE OF GRID

GRID was established in 1985 as a component of UNEP's Global Environment Monitoring System (GEMS) (UNEP, 1988). Its initial purpose was to facilitate the use and dissemination of the data collected by the GEMS networks. As it has grown, GRID has archived numerous global, continental and regional datasets and has formed ties with other international organizations that are also involved in collecting or archiving environmental datasets.

GRID has assisted various national governments and international bodies to establish GRID-compatible facilities, and has helped develop plans for the structure, staffing and equipping of GIS centers (UNEP, 1987b). GRID has also participated in case studies with some of these institutions and provides training, both formal and informal, for their staff (UNEP, 1987a). By sharing datasets and giving advice, GRID could likewise play a role in helping an organization such as IBPGR to realize the potential of GIS technology.

CONCLUSION

Many aspects of work in the field of plant genetics, particularly in the area of genetic resources conservation, are inherently geographical. Plants evolve and differentiate in response to their surroundings and therefore preservation of genetic diversity is best conducted with regard to maintaining material from a variety of ecological and environmental conditions. For these reasons, recent advances in computer technology seem well suited for use in this area. GIS could provide an ideal means of integrating, analyzing and managing genetic resources data, and the establishment of an international database could provide a valuable tool for establishing global priorities and working toward the overall goal of the optimal preservation of genetic diversity.

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PART 3

Germplasm Conservation: *Ex Situ*

3.1

Long-Term Seed Conservation

N. Q. NG

The idea of genetic resources conservation has recently gained worldwide attention, for a number of reasons. The 'centers of diversity' of our crop plants seemed, until recently, to contain inexhaustable sources of genetic materials for plant breeding. However, they have been rapidly changing as a result of: human pressure on agroecological systems, leading to destruction of wild species; the introduction of improved new varieties which have replaced many landraces, leading to a loss of the genetic variability that had accumulated over a period of hundreds of thousands of years of natural evolution and was followed by mass selection by traditional farmers; and the introduction of new crops that have replaced indigenous crops, such as the gradual replacement of African rice, *Oryza glaberrima*, by the introduced the Asian rice, *O. sativa*, in West Africa.

There are several ways of preserving plant genetic resources of crop plants. The cheapest and most convenient is to store the seeds. However, not all crops can be preserved in this way, either because they may be vegetatively propagated or do not produce seeds, or because the period of the seed viability may be extremely short under storage.

Seeds are generally classified into two groups — the so-called 'orthodox' and 'recalcitrant' groups (Roberts, 1973). The longevity of orthodox seeds can be extended by storing comparatively dry seed at low temperatures. In general, the lower the storage temperature and seed moisture content, the greater the seed longevity. Most of our arable crop species belong to the orthodox group. In contrast, recalcitrant seeds, such as cocoa and mango seeds, generally cannot be dried without damage. Under ambient conditions, their viability periods are relatively short. Neither can they be stored under sub-zero temperatures without damage by freezing. Research at the National Seed Storage Laboratory in Fort Collins and at other advanced laboratories and universities in the USA or Europe on cryopreservation of dormant buds or shoots may provide guidance for the preservation on this group (Eberhart, pers. comm., 1988; IBPGR, 1988). There is not enough knowledge currently to make general recommendations for storing recalcitrant seeds for long periods.

This paper is therefore restricted to orthodox seeds, and aims to review the standards for conserving seed, processes of improving seed longevity and ways of predicting seed longevity. The system in use at the International Institute of Tropical Agriculture (IITA) for

long-term seed preservation is described, with special reference to cowpea and rice. IITA holds a world collection of more than 15,000 accessions of cowpea, over 12,000 accessions of rice, about 2,000 accessions of bambara groundnut and 1,500 accessions of soybean, among others.

STANDARDS FOR LONG-TERM SEED CONSERVATION

The terms 'base collection' and 'long-term seed conservation' are frequently used interchangeably when referring to preservation of germplasm accessions under storage conditions that ensure viability of materials for a period of between 50 and 100 years, before the materials are 'grown out' in the field for regeneration. The longer the seeds can be stored, the better it is for germplasm conservation, because of the cost of regenerating the materials and the risk of genetic drift or human error in the growing out.

In 1975, the Panel of Experts on Plant Exploration and Introduction, which had been established by the Food and Agriculture Organization of the United Nations (FAO), made recommendations on 'preferred' and 'acceptable' standards to be adopted in storing seeds for long-term conservation (FAO, 1975). Preferred standards specify storage at -18°C or less in airtight containers at a seed moisture content of $5 \pm 1\%$. Acceptable standards, on the other hand, specify storage at 5°C or less in airtight containers at a seed moisture content of 5-7%, or storage at 5°C or less in unsealed containers in a store atmosphere controlled at no more than 20% RH.

In 1976, the working group of the International Board for Plant Genetic Resources (IBPGR) on engineering, design and cost aspects of long-term seed storage facilities accepted, as a general recommendation, the preferred standards for long-term seed-storage installation (IBPGR, 1976). Since that time, IBPGR has encouraged institutions which are establishing base collections for long-term conservation to adopt preferred standards. The 1976 IBPGR working group also suggested that the preferred temperature standard could be 'relaxed' to -10°C if the seedbank was restricted to a few species with good storage characteristics. Ng and Williams (1979), in their world survey of the seed storage facilities for plant genetic resources, further relaxed the temperature standards to sub-zero temperatures ($<0^{\circ}\text{C}$). Stores operated at sub-zero temperatures were classed as long-term stores in the study.

The IBPGR advisory committee on seed storage, at its subsequent meeting in 1984, considered sub-zero storage temperature to be an acceptable standard for base collections and a single standard for moisture content of 3-7% was recommended as acceptable (IBPGR, 1985). These measures are justifiable and could even be further relaxed, especially for those species which have good seed storability and whose seed storability characteristics are fairly well understood.

With the current knowledge of seed storability, it is believed that the seed of many species can be stored for many decades or centuries under the relaxed standards. To achieve this, one must have a good knowledge of the relationships between seed longevity and storage environments, which are discussed later.

With regard to the size of the collection, it is generally believed that between 3,000 and 4,000 seeds of genetically homogeneous accessions and about 12,000 seeds of the genetically heterogeneous accessions should be preserved in a base collection (Hawkes, 1980; IBPGR, 1985).

STANDARDS FOR REGENERATION

It has been reported that when a decrease in the percentage viability of seeds occurs, there is an increase in the percentage of cells of surviving seeds that show visible chromosome abbreviations and in the incidence of mutant phenotypes in succeeding generations (Abdalla and Roberts, 1968; Roberts, 1975, 1978). The incidence of mutation in the surviving seed seems to be correlated with the percentage of the seeds that have died. One goal of plant genetic resources conservation is to maintain the genetic integrity of the conserved materials. In order to minimize the loss of genetic integrity resulting from mutation of the seed materials under storage, the materials should be regenerated as soon as a significant reduction of percentage viability is evident in storage. The working group of the 1976 IBPGR seed advisory committee recommended that accessions should be regenerated when a drop in their viability of 5-10% is observed under storage (IBPGR, 1976). The committee also recommended that accessions that are less than 80% viable at receipt should be regenerated before storage or, in species with typically low initial percentage viability, if the viability is less than 85% of the expected value. The 1984 IBPGR advisory committee on seed storage adopted an 85% regeneration level for all species (IBPGR, 1985).

There is no consensus among genebank experts regarding the recommended standards. Several genebank managers believe that the regeneration standard recommended by the 1984 committee is too high. Some Japanese experts believe that 75% or as low as 50% seed viability should be adopted as a threshold regeneration standard (Kumagai, pers. comm.). They believe that mutants would be selected out during regeneration. Chang (1988), head of the International Rice Germplasm Center (IRGC) in the Philippines, has agreed with the 50% seed viability regeneration standard for rice. He has argued that most temperate zone rice varieties may have only 85% germinability shortly after harvest in the humid tropics. The genebank at Wakehurst Place, in England, adopted 84.2% as the regeneration standard because the convenient probit value of this percentage is one and the standard is sufficiently high. Smith elaborated on this point during his lecture at the 1983 IITA/IBPGR training course in seed technology and genebank management at IITA. In the case of cowpea and rice germplasm, IITA has adopted 85% seed germination as the regeneration standard for its genebank (Ng, 1981).

Seeds of bambara groundnut, *Vigna subterranea*, produced from the same plant mature at different times because the flowering and podding period stretches over a period of more than 50 days. The pods are buried underground so they cannot be harvested as soon as they mature. If they are harvested early, many seeds will be premature. Seeds that are harvested are heterogeneous in quality. Bambara groundnuts that are harvested at the end of the growing season at IITA, Ibadan, generally have a low percentage of initial seed viability (70-90%). In such a case, a lower seed germination (50%) becomes the regeneration standard.

SEED LONGEVITY AND ITS QUANTIFICATION

Seeds begin to age or deteriorate soon after they reach maturity. The rate of deterioration is influenced by the environment surrounding the seeds from the time they reach maturity (even before they are harvested). Components of the field environments that affect seed viability include the presence of water or the relative humidity (RH) of the surrounding air, temperature, diseases and pests. It is difficult to quantify the effects of field weathering

because of the multiple factors involved. Generally, the longer the mature seeds remain exposed to field weathering in a humid region, the faster the seeds deteriorate. To produce large quantities of high-quality seed or seed samples, the crop must be planted at a time such that it matures during dry weather.

The most important storage factors affecting seed viability are seed moisture content and seed temperature. The effect of seed moisture content is far more important than that of temperature. The effect of storage temperatures in the range between -20°C and 50°C and seed moisture content between 4% and 25% have been studied extensively in many crop species (Roberts, 1960; Harrington, 1972; Ellis and Roberts, 1980; Ellis et al., 1982).

Harrington has formulated two rules of thumb to describe the relative influence of storage temperatures and seed moisture content on seed longevity. First, each percentage point in reduction of seed moisture content, within the range 4-14%, doubles the life of the seeds. Second, each 5°C reduction in seed temperature doubles the life of the seeds (Harrington, 1970, 1972). These simple and useful approximations emphasize the essentially exponential relationship between seed storage life and storage environment; however, they do not quantify the interactive effect of moisture content and storage temperature on seed longevity.

Roberts and his colleagues have proposed the viability model which is defined by the equation:

$$v = K_i - p/[10 \exp(K_E - C_w \log m - C_H t - C_Q t^2)] \quad (1)$$

This equation quantifies the combined effects of moisture content and storage temperature on seed longevity. It can be used to predict probit percentage viability, v , of a variety or species at any storage period, p (days), at any temperature, t ($^{\circ}\text{C}$), and seed moisture content, m (% wet basis), where K_i is the seed lot constant. It can be estimated by taking the probit value of the initial percentage viability or by measuring the standard deviation of the frequency distribution of death of the seed lot and K_E , C_w , C_H , and C_Q , the species constants (Ellis and Roberts, 1980; Cromarty et al., 1982). The equation was derived from the observations that: (a) the frequency of individual deaths over time in a seed population stored under constant conditions is described by the normal distribution

$$y = (1/\sigma\sqrt{2\pi}) \exp[-(p - \bar{p})^2/2\sigma^2] \quad (2)$$

where y is the relative frequency of deaths occurring at time p , $\bar{p}$ is the mean viability period (that is, time taken to fall to 50% viability) and σ is the standard deviation of the distribution of death time; (b) the survival curves, when probit percentage viability is plotted against time, are straight lines of negative slope $1/\sigma$ (see Figure 1); the survival curve, v , to be expected after a given storage period in days, can be described by the equation,

$$v = K_i - (1/\sigma)p \quad (3)$$

where K_i is a constant; it can be estimated by taking the probit value of the initial percentage seed viability for a particular seed lot, or measuring the standard deviation of the frequency distribution of death, and (c) that storage environmental effects have the following relationships,

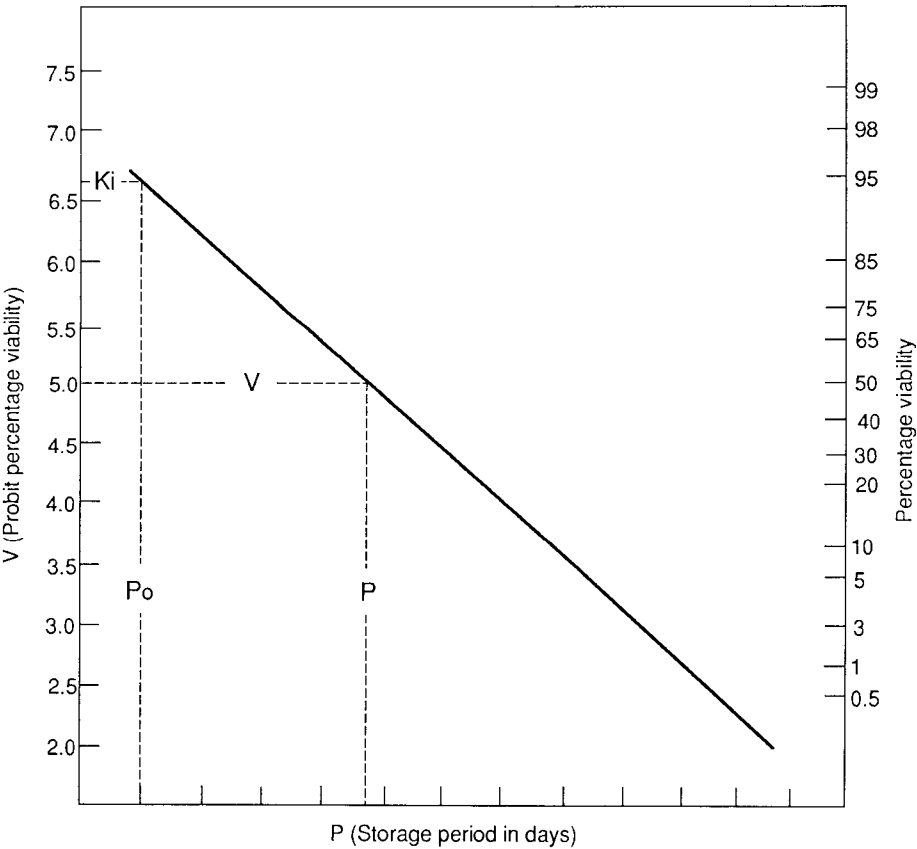
$$\log \sigma = K_E - C_w \log m - C_H t - C_Q t^2 \quad (4)$$

where m is moisture content (% wet weight basis), t is temperature in °C, and K_E , C_W , C_H and C_Q are constants for a particular species or variety. C_W indicates sensitivity to moisture content, and C_H and C_Q indicate sensitivity to temperatures. The equation (1) of the viability curve is obtained by combining equations (3) and (4). Ellis and Roberts (1980) give further details. The loss of probit viability can be estimated by rearranging the equation (1) thus:

$$(K_i - v) = p/[10 \exp(K_E - C_W \log m - C_H t - C_Q t^2)] \tag{5}$$

However, some researchers have pointed out that unless the temperature range is very wide, the quadratic temperature term ($C_H t - C_Q t^2$) could be simplified to linear term Ct (Tompsett, 1984; Dickie and Bowyer, 1985; Dickie et al., 1985). Ellis (1988) reiterates the validity of the temperature term of the viability equation (1), and argues that at least it was the case for barley, chickpeas, cowpea and soybean.

FIGURE 1 **Diagram showing that when percentage viability values have been transformed to probit values, the resulting seed survival curve has the slope $1/\sigma$, where σ is the standard deviation of deaths over time; thus $V = K_i - P(1/\sigma)$**



ACCURACY OF THE PREDICTION OF SEED VIABILITY

Accuracy in predicting seed viability under long-term storage is very important in germplasm conservation. This can provide guidance to genebank managers as to when the germplasm accessions under storage should be regenerated.

The viability equation (1) is currently one of the best means for predicting the viability of seed after any period of storage. Based on this model, the hypothetical times, in years, for cowpea seeds stored under various storage temperatures and seed moisture contents to decline from the initial viability of 95% to the final viability of 85% are shown in Table 1. According to these estimates, if cowpea seeds with a moisture content of 5% were stored at or below -10°C , more than 1,200 years would elapse before an accession with an initial viability of 95% would decline to 85%. Hence, the following sets of storage conditions could be chosen for storage of cowpea germplasm, which could fulfil the base collection requirement to ensure a 100-year viability of materials: 5% moisture content and 20°C ; 7% moisture content and 0°C ; and 8% moisture content and -10°C .

Nevertheless, care should be taken because the equation and species constants used in the estimates were derived from results obtained from a limited number of genotypes and conditions of storage over a short period of experiments. Species constants derived from rapid-aging treatments on seeds may not reflect the real relationships between seed survival and storage environments under the acceptable or preferred standards.

Results from seed germination which were obtained from experiments carried out under various storage conditions for a period of about two years at IITA, as well as results from 10 randomly selected cowpea samples which were stored for more than 5 years in IITA's base collection seed store (-20°C) are presented here for comparison. Table 2 (*opposite*) and Figure 2 (*overleaf*) show the percentage of seed germination after various storage periods of the cowpea cultivars VITA 4 and VITA 5, with seed moisture content ranging from about 7% to 15.7% (wet weight basis) and temperatures of $30^{\circ} \pm 2^{\circ}\text{C}$, $5^{\circ} \pm 2^{\circ}\text{C}$ and $-20^{\circ} \pm 1^{\circ}\text{C}$. The predicted viability of the seeds under each storage environment and storage period is also provided in the table for easy comparison. The results revealed the following facts: the observed viability for samples with low moisture contents (7.38% and 8.54%) that were

TABLE 1 Hypothetical time in years (to nearest 0.5) for cowpea seed viability to decline from the initial viability of 95% to the final viability of 85% under various combinations of seed moisture content and seed storage temperature

Storage temperature ($^{\circ}\text{C}$)	Seed moisture content (% wet basis)				
	5	7	8	10	12
-20	1761.0	331.0	170.5	56.5	23.0
-10	1253.0	236.0	121.5	40.0	16.0
0	711.5	134.0	69.0	23.0	9.0
5	493.0	93.0	47.5	16.0	6.5
10	322.0	60.0	31.0	10.5	4.0
20	116.0	22.0	11.0	3.5	1.5
25	64.0	12.5	6.0	2.0	1.0

Note: Based on the improved seed viability equation $v = K_i - p/10 \exp(K_E - C_w \log m - C_H t - C_Q t^2)$.

TABLE 2 Experimental and expected seed viability under storage

Storage temp. (°C)	VITA 4					VITA 5					
	MC ¹	0 ²	A	B	C	MC	0	A	B	C	D
30°±2°	7.38	98	83(97) ³	86(97)	84(96)	7.26	97	86(96)	84(95)	79(95)	90(94)
30°±2°	8.54	92	70(86)	80(83)	78(81)	8.46	99	84(98)	90(97)	91(96)	91(96)
30°±2°	12.46	96	65(32)	52(10)	47(3.6)	14.32 ⁴	98	68(1)	12(0)	25(0)	0(0)
30°±2°	15.45	98	59(0)	16(0)	14(0)	15.71	98	0(0)	0(0)	0(0)	0(0)
5°±2°	7.38	98	92(98)	90(98)	90(98)	7.26	97	93(97)	90(97)	89(97)	93(97)
5°±2°	8.54	92	86(92)	86(92)	86(92)	8.46	99	93(99)	94(99)	93(99)	96(97)
5°±2°	12.46	96	80(95)	74(95)	74(95)	14.32	98	80(97)	82(96)	75(95)	78(95)
5°±2°	15.45	98	68(96)	72(95)	72(95)	15.71	98	61(95)	78(94)	70(93)	85(91)
-20°±1°	7.38	98	94(98)	94(98)	94(98)	7.26	97	96(97)	96(97)	95(97)	92(97)
-20°±1°	8.54	92	90(92)	91(92)	90(92)	8.46	99	94(99)	96(99)	94(99)	80(99)
-20°±1°	12.46	96	85(96)	85(96)	88(96)	14.32	98	78(98)	78(98)	80(98)	84(97)
-20°±1°	15.45 ⁴	98	80(97)	80(97)	80(97)	15.71	98	52(97)	70(97)	75(97)	82(97)

1 Seed moisture content, % wet weight basis.

2 0 = initial seed germination, A = 12 months after storage, B = 16 months after storage, C = 19 months after storage, D = 23 months after storage.

3 Figure in parenthesis is the seed viability, estimated by the seed viability equation

$v = K_i - p/[10 \exp(K_E - C_w \log m - C_q t - C_0 t^2)]$, where $K_E = 9.102$, $C_w = 4.967$, $C_q = 0.0295$ and $C_0 = 0.000491$. K_i is estimated by taking the probit value of the initial viability.

4 Seeds with a moisture content above 14% might have been damaged by freezing.

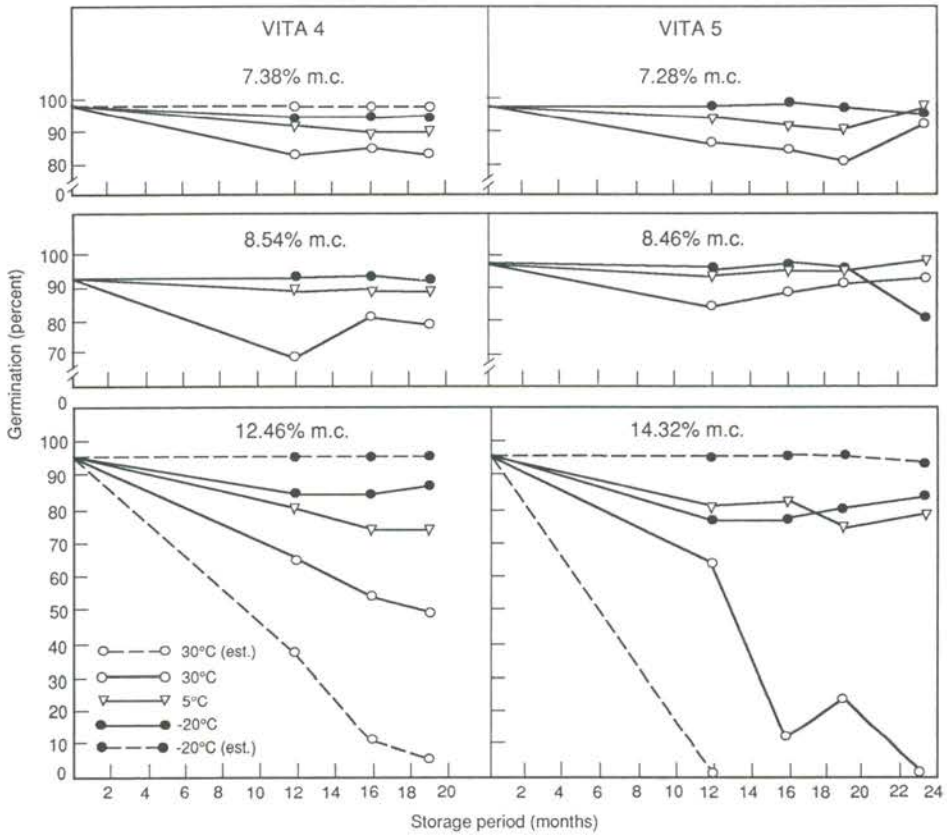
stored at high temperature (30°C) is generally much lower than the estimated viability; the observed percentage of germination of samples with low moisture content that were stored at -20°C are very close to the predicted values; and the observed seed germination of samples with moisture content exceeding 12% that were stored at -20°C or 5°C was much lower than the expected viability (this might have been caused by chilling or freezing injury, especially in those with a moisture content of over 14%).

Table 3 (*overleaf*) shows the observed percentage of seed germination of 10 cowpea accessions with a seed moisture content ranging from 6.5% to 7.5% that had been stored for more than 5 years in IITA's base collection seed store. The results indicate that all accessions except one (TVu 12393) showed germination rates very close to the expected values. This suggests that, under such low temperatures and low seed moisture content, most of the cowpea genotypes follow the seed viability model established by Ellis and his colleagues (Ellis and Roberts, 1980; Ellis, 1988).

Nevertheless, considerable genotypic differences exist among cowpea accessions (TVu 12393 and others) in terms of longevity. Similar evidence has also been observed in rice (*see* Figure 3 *overleaf*) (Chang, 1988). It is important that genebank managers take account of this fact.

Moreover, it is not certain that cowpea accessions in which the germination rate falls within the expected range will indeed continue to behave in the same way over such an extended period as 100 years. Evidence from the literature shows that some barley seeds (12%) that had been buried underground for over 100 years were viable (Ellis and Roberts, 1980). Some seeds can apparently be stored for over 100 years under conditions which do not meet the

FIGURE 2 Seed viability pattern of two cowpea varieties with different moisture content stored under different temperatures



preferred standard. Because of genotypic differences, the viability of seeds under storage needs to be monitored periodically, until such time as the longevity characteristics of each accession become clear.

The factors which account for differences in seed longevity of different genotypes of the same species are not yet clear. Seed dormancy, differences in physical structures, characteristic of starch and oil content and seed vigor may account for the differences in seed longevity of different germplasm accessions or seed lots.

MONITORING THE VIABILITY OF SEEDS UNDER STORAGE

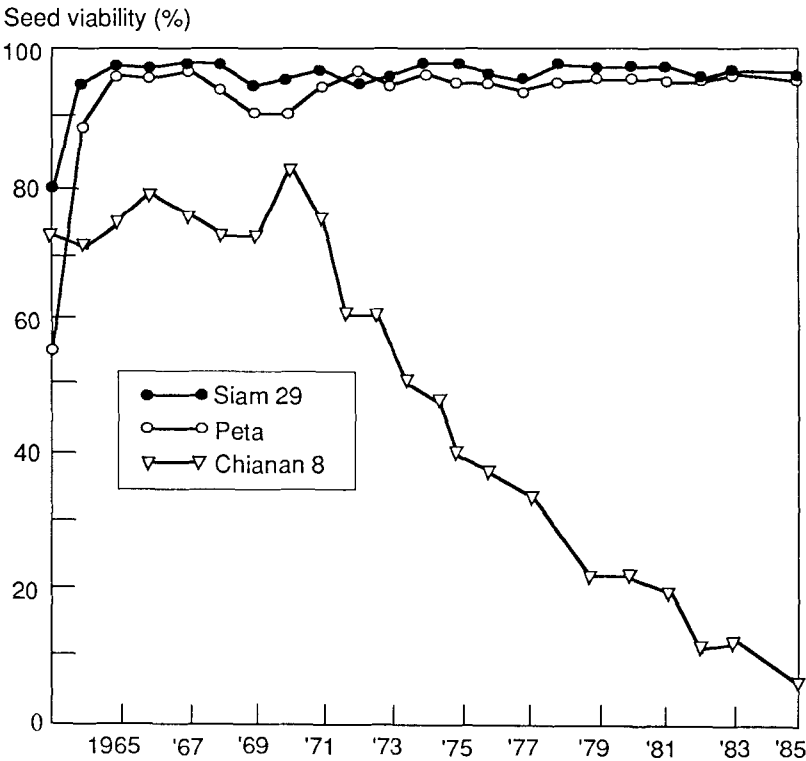
Genotypic differences exist within species in terms of seed longevity, and it is possible that errors, such as determination of seed moisture content or mechanical damage, may occur during the processing of seeds for storage. Seeds under storage must be carefully monitored

TABLE 3 Percentage of cowpea seed germination after more than 5 years of storage in IITA's base collection (-20°C) (November 1982-July 1988)

Accession No.	MC (%)	Storage period (years)	Germination (%)		
			Initial	Final ¹	Estimated ²
TVu 4133	7.5	5.67	94	95	93.8
TVu 4177	7.5	5.67	96	90	95.8
TVu 4337	6.5	5.67	94	98	93.9
TVu 9994	6.5	5.58	94	93	93.9
TVu 11392	6.5	5.33	100	95	99.8
TVu 703	6.5	5.42	97	94	96.9
TVu 4589	6.5	5.33	98	95	97.9
TVu 12393	6.5	5.33	91	80	90.9
TVu 12487	6.5	5.33	90	89	89.8
TVu 4601	6.5	5.25	94	96	93.9

1 Observed germination rate, based on 200 seeds, but for TVu 12393 it was based on 400 seeds.
2 Estimated by the equation $v = K_1 - p/[10 \exp(K_e - C_w \log m - C_H t - C_Q t^2)]$, where $K_1 = 9.102$, $C_w = 4.967$, $C_H = 0.0295$, $C_Q = 0.000491$ (Ellis, 1988).

FIGURE 3 Seed viability pattern of three rice varieties stored in the merdium-term room at IRRI (2°C, 5% RH, 8.5% moisture content), 1963-86



to prevent loss of valuable materials. A number of methods for seed viability monitoring have been suggested (IBPGR, 1985; Chang, 1986; Ellis, 1986). These include:

- testing all accessions at predetermined intervals;
- testing a number of accessions which are randomly sampled every year;
- testing a number of check varieties, which are representative of different genotypes or races of a species, at periodical intervals;
- a combination of any of the three preceding methods.

Testing materials at a predetermined interval depends on knowledge of the characteristic seed longevity of a species. The IBPGR advisory committee on seed storage recommended that under preferred storage conditions, the first monitoring test should be conducted after 10 years for seeds with a high initial germination percentage (IBPGR, 1985). The committee also indicated that species known to have a poor storage life or accessions of poor initial quality should be tested after 5 years. The interval between later tests should be based on experience. Ellis (1986) suggests the use of the seed viability equation to estimate the rejuvenation interval of every accession in a specific storage environment; he then sets monitoring intervals at one fifth of the rejuvenation interval.

At the genebank at IITA, we adopt a combination of approaches to monitor seed viability. These approaches include: testing a number of randomly selected accessions every year after 5 years of storage, and testing three test varieties every 2 years; and testing all accessions at one fifth of the predicted rejuvenation interval. The estimated regeneration interval for cowpea (depending on initial viability and moisture content of the seed) ranges from 133 years (90% initial viability with 7% moisture) to over 1,000 years (95% or greater initial viability and 5% moisture content) of storage. Using the lower limit of the regeneration interval (133 years), the monitoring interval for cowpea germplasm accessions at IITA is 26 years. We plan to conduct the first monitoring test on accessions 20 years after storage. Additional tests on randomly selected germplasm accessions and on test varieties will provide double checking of the seeds under storage. This will give better assurance of the safety of these seeds.

There is no set rule for the number of seeds to be tested during monitoring of the viability of seeds under storage. The standard of 400 seeds for testing seed germination rate, which was recommended by the International Seed Testing Association for commercial seeds, is viewed by many workers as impractical because many valuable germplasm materials will be wasted and only a limited quantity of seeds of each germplasm accession is stored. Instead of the standard of testing of 400 seeds, sequential germination testing (of a set of 40 or 50 seeds) is considered appropriate, although the test may sometimes exceed 400 seeds (Ellis et al., 1980; Ellis and Roberts, 1984; Ellis et al., 1985).

We are adopting two sets of duplicates of 50 seeds from each accession in order to assess the viability of the accession. If the result of the first test falls below 83%, the accession will be regenerated. If it is between 83% and 93%, a retest will be carried out. If the cumulative germination rate is 90% or more, the accession will be retained. If it is less than 85%, then that accession will be marked for regeneration. Arrangements would be made to regenerate the accession as soon as possible.

MEDIUM- AND LONG-TERM SEED CONSERVATION FACILITIES AT IITA

Success in seed conservation depends to a large extent on managerial skills and proper facilities. Good facilities for seed drying, threshing, cleaning, fumigating and packing are essential. The storage space requirements depend on the amount of materials that need to be preserved. When a large volume or number of germplasm materials or accessions is involved, a dry, cold and well-insulated storeroom is preferred. For a small number of samples, household refrigerators and freezers can be used to store seeds (Cromarty et al., 1982; Roberts, 1983).

Airtight seed containers which are made of glass, metal or aluminum foil package are essential for storing seeds and maintaining their moisture content after they have been dried to the desired level. If seeds are stored in open or non-airtight containers, the RH in their storage environment must be controlled, because seeds are hygroscopic and their moisture content will equilibrate with the RH of the surrounding air (*see* Table 4).

TABLE 4 Equilibrium moisture content of the seeds of some common crops at 25°C

Species	Relative humidity (%)					
	15	30	45	60	75	90
Barley (<i>Hordeum</i>)	6.0	8.4	10.0	12.1	14.4	19.5
Beet (<i>Beta</i>)		5.8	7.6	9.4	11.2	
Buckwheat (<i>Fagopyrum</i>)	6.7	9.1	10.8	12.7	15.0	19.1
Cabbage (<i>Brassica</i>)		5.4	6.4	7.6	9.6	
Carrot (<i>Daucus</i>)		6.8	7.9	9.2	11.6	
Cucumber (<i>Cucumis</i>)		5.6	7.1	8.4	10.1	
Egg plant (<i>Solanum</i>)		6.3	8.0	9.8	11.9	
Flax (<i>Linum</i>)	4.4	5.6	6.3	7.9	10.0	15.2
Groundnut (<i>Arachis</i>)	2.6	4.2	5.6		9.8	13.0
Lettuce (<i>Lactuca</i>)		5.1	5.9	7.1	9.6	
Lima bean (<i>Phaseolus</i>)		7.7	9.2	11.0	13.8	
Maize (<i>Zea</i>)	6.6	8.4	10.2	12.7	14.4	18.8
Mustard (<i>Brassica</i>)		4.6	6.3	7.8	9.4	
Oat (<i>Avena</i>)	5.7	8.0	9.6	11.8	13.8	18.5
Okra (<i>Abelmoschus</i>)		8.3	10.0	11.2	13.1	
Onion (<i>Allium</i>)		8.0	9.5	11.2	13.4	
Radish (<i>Raphanus</i>)		5.1	6.8	8.3	10.2	
Rice (<i>Oryza</i>)	5.6	7.9	9.8	11.8	14.0	17.6
Rye (<i>Secale</i>)	7.0	8.7	10.5	12.2	14.8	20.6
Sorghum (<i>Sorghum</i>)	6.4	8.6	10.5	12.0	15.2	18.8
Soybean (<i>Glycine</i>)	4.3	6.5	7.4	9.3	13.1	18.8
Tomato (<i>Lycopersicon</i>)		6.3	7.8	9.2	11.1	
Turnip (<i>Brassica</i>)		5.1	6.3	7.4	9.0	
Watermelon (<i>Citrullus</i>)		5.1	6.3	7.4	9.0	
Wheat (<i>Triticum</i>)	6.5	8.5	10.4	12.1	14.6	19.8
Winter squash (<i>Cucurbita</i>)		5.6	7.4	9.0	10.8	

Adapted from IBPGR Practical Manuals for Genebanks: No.1. Procedures for Handling Seeds in Genebanks.

During the first decade (1976-85) of the germplasm conservation activities of the Genetic Resources Unit (GRU) at IITA, most of the seeds for the active collection were stored in a room which was constructed of cement blocks; parts of the collections were maintained in a 5°C seed store with 55-70% RH. The room was about 14 x 7.5 m and 2.7 m high, and it was fitted with four window-type office air-conditioners, one split-type air-conditioner and a desiccant dehumidifier. The conditions in the room were about 20° ± 2°C and 30-40% RH. The seeds were stored in plastic jars with screwcaps; the jars were not airtight. Under such storage conditions, rice and cowpea seeds could be stored for about 4 years before they were rejuvenated.

Although the conditions were not ideal, the seed store served its purpose very well. The seeds were kept in screwcap containers, because of the very frequent retrieval of seeds from the store for distribution, characterization and evaluation. If the cowpea or rice seeds were dried to a 5% moisture content and stored in airtight containers, they could probably be stored up to 50 years or more, based on the estimate demonstrated earlier. Should the prediction be correct, then such a method of storage could be adopted for the base collection. This type of storeroom is easy to build and the equipment easy to maintain and replace. All national programs can afford to build such a storage facility. For those national programs that can afford to build better facilities, they should be encouraged to construct storage facilities and maintain germplasm materials according to the standard recommended by the IBPGR advisory committee on seed storage (IBPGR, 1976).

From mid-1982, the GRU began to process its germplasm for long-term preservation in a prefabricated cold store, 7.4 x 5 m and 2.4 m high, maintained at -20°C ± 1°C. Seeds were dried to 6-7% moisture content and were sealed in aluminum tubes. In addition, the GRU had in 1986 renovated, constructed and modernized its seed processing laboratory and storage facilities according to the standards recommended by the IBPGR seed advisory committee. The new facilities include three types of seed stores:

- a temporary seed store with a volume capacity of 68 m³ conditioned at 15°C ± 2°C and 20% RH;
- two active collection seed stores with a combined volume capacity of 410 m³ conditioned at 5° ± 1°C and 30-35% RH;
- a base collection seed store with a volume capacity of 132 m³ conditioned at -20°C ± 1°C.

The facilities include mobile shelves in seed stores, a seed germination laboratory and a seed canning room in which there are drying cabinets that can be conditioned to less than 10% RH at 20°C or lower. With these new drying facilities, we can dry seeds to 5% moisture content.

We place the seeds in the temporary seed store, soon after they are harvested dried and threshed, before they are sorted out and processed for banking into both the active and base collection. This temporary store room can also be used for drying. This facility will improve the efficiency of the work and the quality of the seeds.

Under our current storage facilities, we can preserve cowpea and rice germplasm in the base collection seed store in aluminum tubes for at least 100 years, and in the active collection seed store for 20-30 years. In the near future, the present plastic jars will be replaced by airtight containers in order to preserve the active collections.

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3.2

Conservation of Forest Species in Africa

J. B. HALL

The first obvious interest by forestry researchers in vegetation conservation on a pan-African scale, rather than a national scale, was shown about 40 years ago (Whyte, 1951), but it left little trace. There is no reference at all to this approach in what is widely regarded as the document which stimulated the present era of concern for forest conservation in its wide sense — the *Symposium on Conservation of Vegetation in Africa* (Hedberg and Hedberg, 1968). However, these early initiatives involved questionable emphasis on conservation as we now understand the term; in both cases the stress was on vegetation cataloguing and description, with little attention being paid to the need for rational and sustained resource management.

Fortunately, the wider implications of vegetation conservation were not being totally neglected. Following a range of initiatives and periodic discussions in the 1960s, a growing number of appropriately placed international agencies responded to the challenge of championing the role of vigorous conservation policies in national development. Among these, the Food and Agriculture Organization of the United Nations (FAO) stands out for its early actions and perseverance. The rapid progress of recent years, however, is a reflection of inter-agency cooperation.

Understandably, the first steps were to bring together the expertise of those who could describe the current state of affairs and suggest long-term aims and the strategies for achieving them. Key events in the early years were:

- 1968 — Panel of Experts on Forest Gene Resources established;
- 1972 — Forest Genetic Resources Information (Newsletter) launched;
- 1974 — Specific post within the FAO Forestry Department created to deal with Forest Genetic Resources;
- 1975 — Methodology pilot study report issued.

The debate and dialogue stemming from these modest measures have borne fruit. There is now in place a framework for action and coordination in the forest genetic resources field which includes:

- an international forum (the Commission on Plant Genetic Resources), established in 1983;
- a legal framework (the International Undertaking on Plant Genetic Resources), adopted in 1983;
- a financial mechanism (the International Fund for Plant Genetic Resources), established in 1987.

In a broader context these developments have been reinforced through collaboration with the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP) and the International Union for Conservation of Nature and Natural Resources (IUCN) (notably since 1984 through the Ecosystem Conservation Group, and specifically its Working Group on *In Situ* Conservation of Plant Genetic Resources). Related initiatives have been launched separately by all these organizations and by other organizations. Most significantly, conservation provisions are fully acknowledged in resource management programs in an increasing number of countries. Examples are the *Baikiaea plurijuga* forests in Zambia (UNEP) and the agricultural development and environmental conservation project for Tanzania's East Usambara Mountains (European Economic Community/IUCN). Indications that recognition will continue to grow are numerous. There are preparatory projects providing broad conservation frameworks for *in situ* conservation, such as: the Cameroon pilot study under the FAO/UNEP Conservation of Forest Genetic Resources Project (Roche and Dourojeanni 1984); IBRD consideration of natural forest retention linked with the forest rehabilitation project in Uganda; and various national conservation strategies, either available (for example, Zambia) or awaiting final clearance (for example, Nigeria). A tree genetic resource evaluation program has also recently been started by the International Board for Plant Genetic Resources (IBPGR).

FORESTRY CONTEXT

All developments enhancing conservation are as welcome for forest gene resources as for other plant genepools. Nevertheless, it is necessary to underline reasons for particular stress on *in situ* situations. About 10 years ago a timely state-of-knowledge comment appeared concerning African forest genetic resources (Willan and Harcharik, 1977) which noted four significant points:

- utilization of trees is centered on unimproved, so-called 'wild' populations, in contrast with today's key agricultural crop plants, many of which result from more than 10,000 years of selection and breeding;
- the value of a gene resource kept intact until attractive attributes can be located and selected for breeding and domestication is acknowledged and significance attached to populations at range-limits associated with high frequencies of genes (as for enhanced drought resistance) of value for marginal sites if new introductions are contemplated;

- broader use of genepools for the amelioration of agricultural environments is anticipated;
- several characteristics hamper refinement of domestication processes for forest trees, notably recalcitrance in maturation, seed biology and alternative propagation options and in unsuitability for use in conventional silviculture (that is, as even-aged monocultures).

All these points remain relevant, and the achievements during the past decade in harmonizing environmental concerns should boost confidence in progress toward solutions. We must, however, take note of the most recent global appraisals of where our current actions are leading us. Informed opinion is now readily available (World Commission on Environment and Development, 1987). For present purposes, we must note, in particular, the possible consequences of the greenhouse effect — with tropical temperatures likely to be 2°C higher by the second half of the next century. It is now clear that human activities have disrupted the environment on a scale and at a rate which does not allow nature to maintain or re-establish the balance (Palmberg and Esquinas-Alcázar, 1988). While technical advance raises confidence that in due course we will be in a position to draw on the resources of *in situ* genepools — selecting and applying genes to meet needs as they arise — the genepools and the variation stored within them are eroding rapidly. We may be left with the techniques but not with the genes!

If the prophesied temperature changes materialize, they will occur within the lifetime of forest trees already growing. Today's populations of forest species may be localized at considerable distances from where future climate will be most suitable, and within this short time-scale it is impossible to foresee a substantial resource surviving without management intervention. Skill in manipulating tropical forests and the species in them remains limited; past efforts have included conservation elements only where a handful of valuable timbers were concerned. No appreciable advance has been made since Willan and Harcharik's work, and revolutionary progress must begin in the immediate future if a potential resource is to become a real one rather than a lost one.

International and national political steps have, as indicated, generated an ideal atmosphere for constructive efforts to accommodate the climatic changes to which we must resign ourselves. The conservation provisions in the Tropical Forestry Action Plan (FAO, 1987) would seem a suitable reference framework. However, in my view even this does not adequately state the urgency of the case, because it seeks to rectify the faults of past and present resource use without additional measures to take account of pending climatic change. It is also pertinent that wherever ecological background awaits consolidation, there is a gulf between the best of administrative intentions and practical action on the ground.

PRACTICAL CONSIDERATIONS

It is in the context of the current gap between administrative measures and effective practice that the technical background for forest genetic resources conservation in Africa should be seen. Apart from the process of forging a united political approach, which culminated in the Tropical Forestry Action Plan, there has been a spate of valuable syntheses on a continental scale by: FAO/UNESCO (1977) — soils; UNESCO/UNEP/FAO (1978) — ecology; FAO/

UNEP (1981) — forest cover; Meteorological Office (1983) — climate; White (1983) — vegetation; and FAO (1984) — climate.

These six documents are the key to effective *in situ* conservation action for African forest plants. They represent a standardization of classifications and continental compilations of data. They enable resource expertise to view species throughout their ranges, a regularly stated need. It must be emphasized that decades of observations and records lie behind these publications.

The real advance is that by combining the older information with the new, syntheses distributions cannot be interpreted in environmental terms. It is this facility that permits the all-important range/habitat limit populations to be identified. Africa is favored in this respect — its more restricted flora is better known and documented than that of the American and eastern tropics.

There is much botanical work conducted at continental level through the Association pour L'Etude Taxonomique de la Flore d'Afrique Tropical and a complementary program of plant mapping (*Distributiones Plantarum Africanarum*). There is also an on-going register of African plant distribution maps (Lebrun and Stork, 1977; Stork and Lebrun, 1981). However, of some 2,500 African forest tree species, less than 10% are well mapped, and only for a much smaller percentage has any attempt been made to draw together monographic treatments of the kind reported in FAO (1986).

PILOT STUDIES

The capacity to use the knowledge now available has been examined in a number of studies incorporated in postgraduate training at the University College of North Wales (UCNW), Bangor, UK. These studies approached forest genetic resources conservation as species, national and locality centered studies. In each case, the objective was to assemble background information sufficiently comprehensive to produce proposals for practical conservation action. Without exception, satisfactory broad pictures emerged, but uncertainties arose when efforts were made to improve resolution from the coarse scale of a general distribution or a forest type classification to the population scale — the scale at which practical action must be taken. This, in turn, raises questions of the adequacy of institutional infrastructures for operating field programs.

Species studies

Species studies have concerned two timber tree species, *Maesopsis eminii* (Mondal, 1986) and *Nauclea diderrichii* (Irozuru, 1986), both of which feature in the FAO Panel of Experts on Forest Gene Resources priority lists, although FAO (1986) includes neither. Both species are fairly well known silviculturally but, apart from an annotated bibliography for *M. eminii* (Fenton et al., 1977), published information is fragmentary. *N. diderrichii* is a prominent plantation species in parts of Nigeria, and *M. eminii* is found in Uganda and, as an exotic, elsewhere in the tropics.

Distribution maps were compiled, and by relating occurrences to environmental conditions populations of interest could be identified which, as well as being at the geographical limits of the range, were associated with conditions which were extreme in other respects:

<i>Maesopsis eminii</i>	western limit (Sierra Leone) eastern limit (Kenya) southern limit (Angola) abnormal elevation (Kenya/Tanzania/Uganda >1000 m) low mean annual rainfall (Cabinda, Angola <750 mm) outliers (Sudan/Zambia)
<i>Nauclea diderrichii</i>	western limit (Sierra Leone) eastern limit (Uganda) southern limit (Cabinda, Angola) abnormal elevation (Cameroun/Uganda/Zaire >600 m) low mean annual rainfall (Cabinda, Angola <1000 mm)

Both species have proved amenable to domestication, and closer analysis of intraspecific variation could commence with minimal delay, given liaison among the countries represented within the natural range and the ability of field staff to collect seed. For *M. eminii* an added incentive should be clarification of conflicting interpretations of contrasting habit between the eastern (tall trees) and western (short trees) sections of the range. One interpretation concludes that two subspecies are involved; the other favors clonal variation.

National and locality studies

For studies at national and locality levels, the forest type is the working unit. Distinction between these approaches is essentially a matter of resolution and between *identifying* resource areas within a country and actually *managing* them.

National level study

Uganda was the subject of a review of overall forest conservation interest (Kahembwe, 1987). On a national basis, Uganda's forests had been classified into a number of types, most recently by Hamilton (1974), who had also provided up-to-date information on the forest trees known from the country, relating distributions to forest types. Kahembwe set out to link this information with older documents, principally a series of forest management plans concerning the forest in particular localities. It was possible to take account of existing conservation provisions in comparing forest types in terms of risk of genepool erosion, the diversity of the pool threatened and the extent to which Ugandan populations are peripheral to the main range or detached from it.

A reassuring link was evident between genetically important forest types (transition forests and *Cynometra-Celtis* forests) and designation of strict natural reserves. Concentrations of endemic species at high altitudes are covered by National Park or Sanctuary status. What emerged as the most vulnerable forest gene resource was the *Piptadeniastrum* forest type of the Lake Victoria area.

From the study, species of interest as recognized commercial timbers or other species at range limits were determined, the latter category by reference to floras after up-dating nomenclature to conform with present thinking. For each forest type, an indicative list of

species, showing which deserved special interest, was prepared. This list constitutes, in effect, the working list for the field forester whose task must now be to assess the species populations in the forest types and decide if their status is viable.

Locality study

At locality level, a study examines practical management much more closely. The protected forest area proposed for Mount Oku, Cameroon, is now being evaluated. Information about Mount Oku has been assembled from a variety of sources, none providing a definitive floristic account. Incomplete lists of trees available, such as that by the International Council for Bird Preservation (ICBP, 1986), were extended by adding casual records located elsewhere to produce an indicative list of about 25 species reaching 8 m or more in height, restricted floristics being expected at the elevations involved (greater than 2,000 m).

Afromontane elements dominate the flora, enabling the tentative application of information from parts of the ranges where the same species have received closer study. By topographic mapping, the area was partitioned according to slope and elevation categories; rainfall gradients were superimposed on the classification obtained. Provisional distribution patterns based on terrain features and inferences of site preferences indicate where forest diversity should be greatest and point to suitable indigenous species for rehabilitation in the different conditions present within an area from which 10,500 ha (55%) has been lost in 25 years and where a further 2,700 ha (15%) has been badly damaged.

READINESS AT FIELD LEVEL

None of the UCNW pilot studies has yet led to field action but this was not their immediate aim. However, the facilities, knowledge and expertise to put the findings to use were considered. It is clear that serious obstacles remain in the genetic resources conservation process in spite of the impressive advances at political level.

The species studies raise few difficulties because both examples relate to familiar successional trees already raised in plantations. It must be noted that this situation arises from past market interests, but current interest in conservation measures can be beneficial. For other species this will not necessarily be the case; in most countries where it occurs, a species may be unknown silviculturally. It would be wise to note those initiatives taken in conservation contexts, where management efforts in protected areas have been made to raise stocks of species thought to be disappearing. The option of enrichment planting is then available if the need arises.

Conservation action at forest level, local or national, poses more problems. The main one is lack of reliable assessment of current population status. Three problems contribute to this:

- *traditional restrictions of forestry interest to a few species*: increasing market flexibility, rising interest in services other than timber supply from forests (Roche, 1979) and recognition that resource stability depends on the complete genepool (not only the timber species part) surviving make the traditional view obsolete;
- *traditional concern with immediate or imminent harvests*: information routinely gathered about the growing stock ignores the small (and thus mostly younger) individuals in

the population. Many inventories still plan to evaluate stocking trees >30 cm or >40 cm dbh only, even if there is a tendency to include all species and not merely the 'listed' or commercial timbers;

- *training in traditional schools*: this results in too few foresters being able to recognize the full range of species in their forests. Even fewer are able to recognize them at the morphologically different seedling and sapling stages and when poles or mature.

These limitations tend to isolate the forest manager. There will be advantages in close collaboration with herbaria, where plant identification competence is broader. Many good herbaria are technically within forest services; others are government facilities available to support work on plant resources. Closer involvement with herbarium expertise would accelerate implementation of the more elaborate forest assessments essential to ascertaining the status of forests and of populations of particular species. Simultaneously, the herbarium would assume, appropriately, the more applied role little in evidence in recent years.

The question of forest stability will arise after assessment. Although past resource inventory has not been comprehensive, there are extensive archival legacies of data on timber species. Comparing current findings with these should be sufficient to show if extensive forest change has occurred as a result of exploitation and encroachment. With rapidly changing plant nomenclature, standardization of old data to current names will present problems but here, too, there is a role for the herbarium botanist.

Work on a more detailed level (that is, higher resolution) raises questions of rationalizing land use — even within forestry, when decisions are needed on terrain suitability for exploitation and the need to maintain the integrity of catchment cover — and, increasingly, rehabilitation. Managerial capacity to evaluate a site, relate its forests and their productive and protective roles to the terrain, and to predict consequences for different management actions, has traditionally been learned by experience. Today, these processes can be formally presented on the basis of principles and appropriate techniques in the course of training. There seems good reason to encourage training innovations for foresters to ensure this happens, and to ensure closer understanding between the herbarium as a service unit and the practical manager. Like everything else, all these steps are options that can be taken at national level. Most countries do have indigenous expertise, able to do everything that is necessary, and this knowledge should be passed on to trainees. Data needed for planning exist in the documents of FAO and other agencies, in floras that have accumulated over many years (and which cover almost every African forest tree species throughout its range) and in the archives. To coordinate and utilize these data is basically a matter of deployment of local staff. With government commitment to conservation measures now so much in evidence, we should be looking forward to a phase of rapid practical progress in the 1990s.

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3.3

In Vitro Conservation

T. J. RUREDZO and J. HANSON

The conservation of germplasm has relied on the principle that seed can be stored for long periods under cold, dry conditions. However, some plants that are vegetatively propagated seldom produce viable seeds. These include the tropical grasses *Cynodon*, *Digitaria* and *Brachiaria*, and some tropical starch crops such as sweet potato, *Ipomoea batatas*, yam, *Dioscorea* species, banana, *Musa* species and taro, *Colocasia esculenta*. Other vegetatively propagated crops are outcrossing and produce variable seeds which cannot be used to conserve material of the same clone. These include potato, *Solanum tuberosum*, and cassava, *Manihot esculenta*. Other species produce recalcitrant seeds (Roberts, 1973), which are physiologically damaged by drying and therefore cannot be stored for long periods. These include many of the tropical fruits such as mango, *Mangifera indica*, durian, *Durio zibethinus*, rambutan, *Nephelium lapacceum*, avocado, *Persea americana*, and some industrial plants such as cloves, *Syzygium aromaticum*, cinnamon, *Cinnamomum zeylanicum*, and cocoa, *Theobroma cacao* (Chin and Roberts, 1980).

Until recently the only means of conserving these species was in field genebanks, where the material is maintained in the vegetative state. The plants, especially trees, require considerable space and careful management, and are at risk from pests and diseases. With the recent advances of *in vitro* culture, many species have been successfully cultured (Sharp et al., 1984) and some maintained for long periods *in vitro*, thus allowing development of *in vitro* conservation as an alternative method for germplasm maintenance. This method allows conservation in minimal space with fewer inputs than in a field genebank, and cultures are protected from pests and diseases, including viruses. In genetic resources, the techniques of *in vitro* culture can also be used for collection, disease elimination, multiplication, creation of variability and distribution of material in aseptic conditions.

PRINCIPLES OF *IN VITRO* CULTURE TECHNIQUES

In vitro conservation relies on the fact that plant material can be kept alive indefinitely as *in vitro* cultures and that plant cells are totipotent. Theoretically, any part of the plant, from one

cell to groups of cells aggregated into higher levels of organization, can be kept for conservation purposes and plants can be recovered. Identification of the most suitable part of the plant (explant) and the optimum chemical and physical environments to control growth and morphogenesis is a prerequisite for the use of *in vitro* culture.

The explant

Apical shoots, axillary buds, embryos and gametes are suitable explants for *in vitro* conservation to maintain genetic integrity. These do not require an adventitious regeneration stage which might release somaclonal variation resulting in heterogeneous regenerants (Larkin and Scowcroft, 1981; Scowcroft, 1984). Meristems are ideal explants for *in vitro* culture for genetic conservation since meristem culture can also be used to eliminate viruses from plants (Kantha, 1986).

Chemical environment

In vitro plant cultures are grown in a complex medium, which consists of a basal medium, growth regulators, a carbon source, osmotic regulators and other physiologically active substances. There are several basal medium formulations, made up of different amounts of inorganic salts to provide essential minerals, vitamins for healthy growth and amino acids to supplement protein syntheses (Gamborg et al., 1976).

Culture media are usually supplemented with exogenous growth substances, such as auxins (which initiate embryogenesis and rhizogenesis), cytokinins (which initiate caulogenesis and promote shoot development) and gibberellins (which promote shoot elongation). The quality, quantity and relative proportions of the medium supplements determine the growth and morphogenesis of cultures (Evans et al., 1981; Krikorian, 1982; Skoog and Miller, 1957).

Since *in vitro* cultures are not fully autotrophic, simple sugars such as sucrose and glucose, which are relatively cheap and easily available, are widely used as a carbon source. Because of its osmotic properties, the carbon source also acts as an osmotic regulator. The osmotic potential of the culture medium affects the rate of uptake of the medium components by the explant. Non-metabolized substances such as mannitol or sorbitol can also be used to regulate the osmotic pressure.

Physical environment

While most cultures can tolerate a range of temperatures, some are very specific or have an optimum temperature. *In vitro* cultures are normally kept at the temperature of their natural habitat (20-30°C) for normal growth, at temperatures below 20°C for slow growth, and at -70°C to -100°C (in ultra-low temperature freezers) or -196°C (in liquid nitrogen) for cryopreservation.

Light is necessary for photosynthesis, photoperiodic reactions and the phytochrome responses of cultures. Light quantity, quality and distribution affect the morphogenetic response of *in vitro* cultures during regeneration (Krikorian, 1982). White fluorescent light

with an 8-12 hour photoperiod is usually used for illumination. Light intensity is usually kept high to encourage photosynthesis and hence autotrophy during normal growth.

In culture, plants are kept in closed vessels which maintain the humidity near 100% and allow free gaseous exchange. The gaseous composition inside the culture vessel can be manipulated to affect the rate of growth of cultures (Bridgen et al., 1978).

Plant regeneration

There are three basic pathways by which plants can be recovered (regenerated) from *in vitro* cultures:

- *non-adventitious organogenesis* is the production of shoots from the meristematic regions and the subsequent production of adventitious roots; the recovery of plants from embryos and haploid plants from gametes is non-adventitious if there is no proliferating (callus) stage;
- *adventitious organogenesis* is the production of adventitious meristems, either directly on the explants or from callus growing in culture from the explant;
- *adventitious or somatic embryogenesis* is the production of somatic embryos directly from explants or from callus tissue growing in culture.

Plants that are formed through non-adventitious regeneration are genetically identical to the mother tissue, while those formed through adventitious regeneration are usually genetically heterogeneous. Even so, direct adventitious regeneration gives rise to plants that are less heterogeneous than those produced from indirect adventitious regeneration.

IN VITRO CONSERVATION

Normal growth conservation

Once the optimum conditions for *in vitro* cultures are determined, they can be kept indefinitely under conditions of normal growth by replenishing the medium and subculturing. Cultures can then be regenerated and rapidly multiplied using micropropagation techniques.

However, with *in vitro* normal growth conservation, the cultures need a substantial amount of management from skilled technicians and the frequent subculturing allows potential entry points for contamination. The technique is suitable for situations such as maintaining endangered species, stocks for or results of *in vitro* manipulation, breeders' lines needing rapid propagation, and plants that cannot be conveniently conserved in any other way.

Slow growth conservation

The growth rate of cultures can be slowed down by using low incubation temperatures (Galzy, 1969; Dale, 1980; Henshaw et al., 1980), manipulating the components of the

medium (Henshaw et al., 1980), manipulating the carbon source/osmoticum ratio (Henshaw et al., 1980), reducing the gas pressure in the container (Bridgen et al., 1978) or manipulating the light regime (Mullin and Schlegel, 1976). For practical genebank purposes, low temperature has been widely adopted by *in vitro* active genebanks (IVAGs). Some genebanks are already using slow growth techniques for germplasm storage in IVAGs, such as the cassava genebanks at the Centro Internacional de Agricultura Tropical (CIAT) and the International Institute of Tropical Agriculture (IITA), the potato genebank at the Centro Internacional de la Papa (CIP), and the sweet potato genebanks at CIP, the Asian Vegetable Research and Development Center (AVRDC) and IITA. Experiments to develop suitable techniques and conditions for slow growth culture of *Cynodon* and *Digitaria* species are in progress at the International Livestock Centre for Africa (ILCA).

Most species show temperature preferences. Cassava, for example, cannot tolerate temperatures below 20°C (Withers, 1980), while potato requires alternating day and night temperatures (Henshaw et al., 1980). Combinations of optimum environmental conditions need to be determined for each species. When equipment is limited, the chemical environment may be adjusted to produce satisfactory growth rates for several species at standard physical conditions.

Cryopreservation

Cryopreservation is the longest-term type of *in vitro* storage. Storage in liquid nitrogen is the most common method, having the advantage that no highly sophisticated equipment is required.

The explants are treated with cryoprotectants to minimize cryodamage to membranes caused by ice crystals (Withers, 1980). They are then cooled to -196°C using 'slow' or 'rapid' freezing techniques to prevent damage from ice crystals by achieving extracellular freezing and protective dehydration or by inducing the formation of microscopically small intracellular ice crystals (Withers, 1980). The plant material can be kept indefinitely in sealed ampoules under liquid nitrogen. Freeze/thaw regimes and plant recovery procedures need to be established for each species (Withers, 1978, 1980). Investigations into the cryopreservation of several species are at an advanced stage.

PRINCIPLES OF *IN VITRO* GENEbanks

The concept of storing germplasm cultures *in vitro* is relatively new. Recommendations on the principles, design, planning and operation have been made by International Board for Plant Genetic Resources (IBPGR, 1986). *In vitro* genebanks can serve as medium-term IVAGs or as long-term base genebanks (IVBGs). The IVAG will hold material under slow growth for conservation or normal growth for collection, disease elimination and indexing, multiplication, dissemination and utilization. Several IVAGs are already operational, as noted above. The IVBG will hold cryopreserved material for long-term storage, with the material being sampled only for monitoring stability and replenishing the IVAGs, (IBPGR 1986). IVBGs are still in the experimental stage, but it is likely that techniques for cryopreservation of potato at CIP are sufficiently advanced to establish an IVBG in the near future.

IN VITRO TECHNIQUES FOR GENETIC RESOURCES

In vitro techniques are a valuable tool in genetic resources work for activities other than conservation. Current uses include those outlined here.

Elimination of diseases

Most plants carry diseases, which reduce productivity and present quarantine problems in the movement of plant germplasm. *In vitro* plant culture is carried out under aseptic conditions which exclude most bacteria and fungi. Viruses and other obligate endoparasites can be eliminated using meristem culture together with heat treatment (Kartha, 1981, 1986). Disease indexing is needed to confirm that the plants are virus free (IBPGR, 1988). This technique is currently being used for virus elimination in cassava at CIAT and in potato and sweet potato at CIP.

Micropropagation

Micropropagation is perhaps the most widely used technique for *in vitro* plant culture. It has been adopted commercially for the rapid multiplication of ornamental and crop plants and is used by plant breeders for the multiplication of elite lines in breeding programs.

In genetic resources work, it is used for the multiplication of cultures for duplication in different genebanks and for dissemination. The rapid rates of multiplication and the independence of *in vitro* multiplication from seasonal weather changes make micropropagation very useful.

Creation of variability

Indirect formation of shoot meristems (caulogenesis) and, probably, embryogenesis release variability, which may result in plants with enhanced desirable characteristics or reduced undesirable characteristics (Larkin and Scowcroft, 1981; Scowcroft, 1984). Scowcroft (1984) listed 28 species in which this somaclonal variation has been recorded for many different characters. Somaclonal variation has been found to be heritable (Scowcroft, 1984) and offers the plant breeder the opportunity to induce desirable characters to increase variation.

Plant *in vitro* culture techniques can be used for creating new genotypes of economic plants. *In vitro* fertilization can be used for plants that are incompatible at the pollination stage, while embryo culture can be used to rescue embryos that would otherwise abort. Somatic hybridization and genetic transformation can be used for the creation of new genotypes. In somatic hybridization, protoplasts of different genotypes are fused together to give rise to hybrid protoplasts which carry the genetic (heterokaryons) or cytoplasmic (cybrids) information of both parents. The heterokaryons and/or cybrids can be manipulated in culture to give plants that express the genetic and/or cytoplasmic information of both parents. This technique allows the crossing of incompatible lines, species or genera (Melchers et al., 1978; Melchers, 1982).

Genetic material can be inserted directly into plant calls using the tumor-inducing bacterium *Agrobacterium tumefaciens*. Plants which carry the new genetic material can be recovered from the transformed plant tissues by adventitious regeneration (Wullems et al., 1982). Genetic transformation to form new plant genotypes can also be carried out by directly inserting foreign genetic material into protoplasts. Plants can be recovered from the transformed protoplasts using protoplast culture techniques.

Haploid and dihaploid regenerants can be produced from *in vitro* anther and pollen culture. This has led to the release of new rice varieties in China (Sunderland and Cocking, 1978; Sunderland, 1979).

Germplasm collection

During collecting missions, some species cannot be conveniently collected as seeds. These include vegetatively propagated species such as cassava, potato and yam, species with bulky seeds such as coconut and palm, and species which do not produce adequate amounts of seeds, such as *Cynodon* and *Digitaria*. In 1984 IBPGR recommended the use of *in vitro* techniques for the collection of these species (IBPGR, 1984) and *in vitro* collection techniques have been developed. These may be in fully equipped laboratories, improvised laboratories or field laboratories for palm (Sossou et al., 1987), outdoor working areas for coconut (Assy Bah et al., 1987) and minimal facilities for cacao (Yidana et al., 1987) and wild species of *Gossypium* (Altman et al., 1987). A minimal facility method for the collection of *Cynodon* and *Digitaria* species is currently being developed at ILCA.

CURRENT DEVELOPMENTS

In vitro culture has proved a useful technique for genetic resources work and should become more widely used as methods are refined, problems resolved and new techniques developed. Many of the early concerns about the stability and genetic diversity of *in vitro* cultures have been resolved. Plants that are recovered from the non-adventitious growth of shoot tips, axillary buds, meristems, embryos and gametes have been found to be genetically stable (Scowcroft, 1984). Plants that are directly regenerated from non-axillary regions of the plant are also stable, although their genotype will depend on the mother tissue rather than the mother plant (D'Amato 1975). Indirect regeneration through a callus stage is believed to release somaclonal variation; these tissues exhibit genetic instability and should be avoided. Recently developed molecular techniques of 'genetic fingerprinting' will allow quantification of genetic variation in the regenerants and confirm that genetic integrity is maintained during conservation.

At ILCA *in vitro* culture techniques have a potential use for tropical forage grasses and browse, which cannot be handled easily by conventional methods. These are a major feed resource in sub-Saharan Africa, and collection, multiplication, maintenance and distribution of germplasm is an essential service of the ILCA Forage Genetic Resources Unit. Work at ILCA is centered on *Cynodon*, *Brachiaria*, *Digitaria* and some browse species to develop alternative *in vitro* methods to make this germplasm more widely available. *In vitro* culture requires specialist equipment, expensive chemicals and skilled manpower to develop unconventional methods, and although it is a useful tool in genetic conservation, considerable expertise and input is essential to develop suitable procedures for most species.

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PART 4

Germplasm Conservation: *In Situ*

4.1

In Situ Conservation of Plant Genetic Resources: The United Nations Educational, Scientific and Cultural Organization (UNESCO) program in Africa

W. J. LUSIGI

By the year 2000, the projected growth in human population can be expected to create enormous economic and political pressure for making more productive use of the world's remaining 'natural' ecosystems. With the increased needs of larger human populations for land and resources, is the conservation of large natural areas a realistic proposition? What sort of nature conservation will be possible in the year 2000?

One estimate suggests that we are now losing at least one species per day, and that by the end of 1980s we could be losing one species per hour. Another estimate indicates that, if present trends continue, at least 500,000 of the 3-10 million species of animals and plants now present will become extinct during the next two decades. The major cause of these extinctions will be the disruption and degradation or destruction of natural habitats, particularly in the forested areas of the tropics. To have any chance of preventing such predictions from coming true, two main problems must be tackled: first, that of providing a sound scientific basis for the planning and management of protected areas; and second, that of convincing land planners and resource users, particularly at the local level in developing countries, that conservation is not necessarily inimical to their daily social and economic needs.

Over the past few years, the Man and the Biosphere (MAB) Program has been testing some new approaches to conservation through the biosphere reserve concept, based on the conservation of sites representative of major ecosystem types. These sites are protected for the role they can play in research, monitoring of change, education and training, as well as for the long-term *in situ* conservation of genetic material. The biosphere reserve concept is not meant to replace other conservation efforts, but to support and complement them. An essential underlying theme views the development of resources as an important prerequisite for future conservation. With a rising population, increasing demands on land and tightening economic constraints, the intensification of agricultural production on one piece of land can be the means of ensuring conservation of another.

CHARACTERISTICS OF BIOSPHERE RESERVES

The main characteristics of biosphere reserves are outlined here.

- a) They are protected areas of representative terrestrial and coastal environments which have been internationally recognized for their value in conservation and in providing scientific knowledge, skills and human values to support sustainable development.
- b) They are united to form a worldwide network which facilitates the sharing of information relevant to the conservation and management of natural and managed ecosystems.
- c) Each includes representative examples of natural or minimally disturbed ecosystems (core areas) within one of the world's biogeographical provinces and as many of the following types of areas as possible:
 - (i) centers of endemism and of genetic richness or unique natural features of exceptional scientific interest (which may be part or all of the core area);
 - (ii) areas suitable for experimental manipulation to develop, assess and demonstrate methods for sustainable development;
 - (iii) examples of harmonious landscapes resulting from traditional patterns and land use;
 - (iv) examples of modified or degraded ecosystems that are suitable for restoration to natural or near-natural conditions.

Collectively, these types of areas provide the framework for carrying out the scientific and management functions of biosphere reserves.

- d) Each should be large enough to be an effective conservation unit, and have value as a benchmark for measurements of long-term changes in the biosphere.
- e) They should provide opportunities for ecological research, education, demonstration and training.
- f) The 'buffer zone' may consist of a combination of any of (ii) to (iv) of (c) above, which are areas suitable or used for research purposes. In addition, the 'buffer zone' may also include a large area which may not be delineated but in which efforts are made to develop cooperative activities in order to ensure that uses are managed compatibly with the conservation and research functions of the other areas of the reserve cited in (c) above. This multiple-use area may contain a variety of agricultural activities, settlements and other uses and may vary in space and time, thus forming an 'area of cooperation' or 'zone of influence'.
- (g) The reserves must have adequate long-term legislative, regulatory or institutional protection. Biosphere reserves may coincide with or incorporate existing or proposed protected areas, such as national parks or protected research sites. This is because some of these protected areas are often the best examples of the natural unaltered landscape or because they constitute suitable areas for carrying out the various functions of biosphere reserves.
- (h) People and their activities should be considered as part of a biosphere reserve. People constitute an essential component of the landscape and their activities are fundamental

for its long-term conservation and compatible use. If people are encouraged to participate in the management of a biosphere reserve, this ensures a stronger social acceptance of conservation activities.

- (i) Normally, there is no need for changes in land-holding or regulations following the designation of a biosphere reserve, except where changes are required to ensure the strict protection of the core area or of specific research sites.

The above characteristics, however, may give an insufficient impression of the breadth of the concept. Successful biosphere reserves constitute models of the harmonious marriage of conservation and development. They provide visible examples of the application of the World Conservation Strategy — sustainable development in action.

BIOSPHERE RESERVES IN AFRICA

The biosphere reserves were designated in 1976. Subsequently, the network has grown steadily. At present, it consists of 243 biosphere reserves in 65 countries. Some 36 of these reserves are found in 20 countries in Africa. Cooperation with other international organizations involved with conservation and sustainable development has been strengthened, particularly with the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP) and the International Union for Conservation of Nature and Natural Resources (IUCN). Representatives of these organizations meet together regularly under the auspices of the Ecosystem Conservation Group to coordinate action.

Biosphere reserves in Africa cover ecological systems which range from desert environments, tropical forests and savanna rangelands to marine biosphere reserves. They are sites of unique ecological qualities and form a basis of a variety of ecological activities. Research projects based on biosphere reserves have been a source of significant information on conservation, which is exchanged throughout the region at seminars and scientific meetings. Most biosphere reserves also encompass national parks and their closely related conservation activities.

An important aspect of the biosphere reserve concept is the inclusion of local people in conservation. Through research programs which are people-based, such as the Tai Forests project in Côte d'Ivoire and the IPAL Project in Kenya, the understanding of the role of people in conservation has increased significantly.

The training of specialists in conservation is another important feature of the biosphere reserve program in Africa and several seminars have been organized by the MAB program, facilitating interaction between scientists in the region. Administrators and resource managers have also been able to participate at these seminars in order to make the link between the scientific community and the management community.

CONCLUSION

In 1983 UNESCO, in collaboration with FAO, UNEP and IUCN, convened the First International Biosphere Reserve Congress, in Minsk, USSR, to review the experience of the

previous decade and to establish the general framework for the future development of the biosphere reserve network.

This conference noted with satisfaction the efforts that had been made by individual countries in establishing biosphere reserves. It made its recommendations in the form of the Biosphere Reserve Action Plan which has been endorsed by the UNEP Governing Council and IUCN. This action plan complements the decisions for the implementation of the biosphere reserve program. Since it is unlikely that many African countries will find new land to be designated as parks, the biosphere reserve system seems to be the only alternative to ensure the conservation of our natural ecological systems in Africa.

4.2

The Role of Indigenous Vegetation in the Conservation and Maintenance of Ecological Stability

W. J. LUSIGI

The Commission on Ecology Occasional Paper 4 (1984) contains the following statement: 'In order to ensure that human life is sustainable, it is necessary to adopt a forward looking approach to land management and nature conservation in particular. Since natural processes and natural systems play a vital role in maintaining living standards, such an approach must aim at preventing damage to them. Usually such damage is expensive or impossible to repair.'

The philosophy of conservation for sustainable development is discussed in the World Conservation Strategy, a conservation approach developed by the International Union for Conservation of Nature and Natural Resources (IUCN). The three main concepts of the strategy are: maintenance of essential ecological processes, preservation of genetic diversity and the sustainable utilization of species and ecosystems. They cover measures that range from ecologically aware industrial development to the preservation of natural ecosystems in protected areas such as national parks.

Another philosophical approach recognizes that the extinction of species and ecosystems by human intervention is undesirable. People have come to recognize that, in the long term, the natural heritage is as important as the cultural heritage.

Most natural vegetation communities found on the surface of the Earth are at some stage of succession. Either they are moving toward climax conditions that are relatively stable or they are moving away from the climax stage to a more unstable secondary stage. Indeed, what we observe in the real world are vegetation communities that are fragmented, harvested and polluted. All these different types of stresses are caused by man and his technology. It is important that we, as conservationists, try to understand how we should protect plant communities from these stresses.

In this short contribution I intend to first look at the various studies that have been carried out on community structure and stability, and then at some examples of loss of indigenous

vegetation in Kenya and the consequences of this loss. I will try to address the following specific questions:

- What happens to plant communities when they are stressed?
- What losses should be expected in structure?
- What is the vulnerability of certain species?
- What is the susceptibility of certain communities to invasion by other species?
- What are the chances of reverting to the original communities after a disturbance?
- What are the consequences of a disturbance to an indigenous community?

COMMUNITY STRUCTURE AND STABILITY

An understanding of the response of various indigenous communities to different types of stresses has been the concern of ecologists for a long time. One important approach has been the application of island biogeographic ideas (Lovejoy et al., 1984). These ideas have been valuable in understanding the changes in species richness during the fragmentation of natural communities when, for example, we convert continuous forest to isolated forest tracts surrounded by farmland. According to this theory, large islands hold more species than smaller ones with equivalent environments, which means that larger reserves will hold more species than smaller ones. Less obvious and probably of greater consequence is the loss of species from a reserve or an island after isolation. This follows from the theory of island biogeography because extinction and immigration rates vary with the size of an island or reserve, and different rates occur because of reduction in area when an island is created by rising water levels or a piece of natural habitat is isolated by fragmentation of previous continuous habitat. They result in a net loss of species until some equilibrium is achieved.

Another approach has been to look at ecosystem complexity and stability (Pimm, 1985). Many ecologists had a simple answer to what effects the complexity of a community structure should have on stability; more complex communities were likely to be more stable. Thus our goal in conservation should be to maintain complexity. The consequences of simplification should be to cause instability, species losses and further simplification; also, complex communities should be more robust than simple ones. Many authors have demonstrated the increased chance of pest outbreaks in agricultural systems, and others have shown the apparent absence of pest outbreaks in tropical (but not temperate) forests. They also note the ease with which species could invade small, remote (and hence species-poor) oceanic islands. Simply, the early studies used stability to mean four different things: resilience, persistence, resistance and variability.

Another set of studies, originating in the early 1970s, have tended to define stability in its strict mathematical sense (Pimm, 1985). These studies imply a different kind of comparison to those involving resilience, persistence, resistance and variability. If a system is not stable, we shall probably not observe it, except in transition to a new and stable equilibrium. Rather special dynamics are required to permit species to persist with population densities that do not return to an equilibrium but, instead, cycle indefinitely. Cycles cannot be of too great an

amplitude or species densities will fall to levels from which they cannot recover. Thus when we investigate the chance of stability and what system structures affect it, we are implicitly comparing existing systems with hypothetical or extinct systems. It is certainly interesting to compare the structures of systems that are likely to be stable, and hence occur in nature, with those likely to be unstable and not occur. This enables us to create a catalogue of food web structures to be expected in the real world. In contrast, we can ask whether existing systems are more or less resilient, persistent, resistant or variable; this approach seems to fit our concerns as conservationists and I will discuss their application a little further.

STABILITY AND SPECIES LOSSES

If we kill enough organisms, it is hardly surprising that we shall eventually cause species extinctions. We do not even have to kill all the individuals to cause extinctions but merely to reduce the numbers to such low levels that chance events and the other problems besetting small populations make recovery unlikely. Certainly, a major practical problem facing conservation is to halt continuing declines in population from increased pollution, loss of habitat and fragmentation of habitat. But some species losses may not have been readily predicted by extrapolating previous population trends.

For rangelands, where livestock consume grasses, we increase death rates of species, yet have reasonably good intentions to preserve the communities in something like an original state. Range managers talk of achieving maximum sustainable yield; at whatever population level it occurs, it is a level that may be naturally encountered by a population quite frequently.

When we ask how well resource managers have done in maintaining their populations, the picture is a gloomy one. This century has provided an extraordinary list of collapses of various ecological systems. For example, tropical forests contain far greater biotic diversity than any other biome. So far as we can discern, they probably harbor around half (or possibly more) of all species, although they cover only 7% of the Earth's land surface (Myers, 1985). It is all the more regrettable that tropical forests are being degraded and destroyed faster than any other biome. Already, sizable sectors are gone. If present trends of exploitation, or rather over-exploitation, persist — and the signs are that these trends are likely to accelerate — there may be little left, except for isolated remnants by the middle of the next century at the latest. The ultimate consequence will surely be that millions of species will become extinct. In terms of the number of species involved, and the compressed time-scale of the phenomenon, this could eventually prove to be as great a biological debacle as any since the first emergence of life on Earth (Myers, 1985).

Equally significant is the destruction of arid land systems across Africa, leading to widespread famine. Indigenous vegetation is lost and leads to erosion of the soil. The collapse of fisheries systems can be cited throughout the world. Some of these may have resulted from overharvesting, economic considerations which place little value on future resources, or ignorance of the damage being caused. Whatever reasons may be advanced for the collapse of the systems, there are definite break-points. For simple population models, densities may return to a high equilibrium, provided the population remains above a certain threshold. But densities will move to a low equilibrium, or even to extinction, if the density falls below a certain threshold. Such behavior poses a special problem for conservation because, without detailed knowledge of the population, it may be very difficult to predict when species are going to 'fall off the edge' and be lost.

Harvesting affects the resilience of the population. Increasing resilience can increase or decrease a population's variability, depending on the relative time periods of the perturbation and the population's recovery. The theory that increased harvesting leads to lower resilience and greater variability needs to be reconciled with the observed population patterns.

STABILITY AND SPECIES ADDITIONS

Just as natural communities are modified through species loss, they are also changed through the introduction of new species. The devastating effect of introducing various exotic species to some ocean islands has been observed so often that there has been widespread concern over the future of such trends. But the list of such introductions is so large that it is important in conservation to understand how long a community will last when it is subjected to a stream of attempted introductions and how a community will be changed by an introduction.

The literature on plant introductions is rather scarce. The first group of theoretical studies looked at species from all trophic levels when they assemble from a community with a few species. In the early 1980s, Post and Pimm modeled species assembly by starting with a fixed number of plant species and successively adding animal and plant species (Pimm, 1985). Each potential introduction was tested to see if it could increase from a low density when the existing species were at their equilibrium densities. The proportion of introductions unable to invade when rare was called 'invasion difficulty'. Invasion difficulty measures community persistence. If a species could increase when rare, the consequences of this invasion were determined: the invader could add to the community, replace an existing species or cause the extinction of one or more of the community's species. Following the determination of a community's new equilibrium, another potential introduction was tested, and so on.

As a community gains species, the number of potential ways a species can add to an existing community grows even faster. Yet, Post and Pimm found that invasion difficulty rose constantly as more species invaded. Moreover, such steady increases in persistence continued even after the number of species in a community leveled off. Thus, early successional communities should change rapidly, later ones more slowly.

In another set of studies using finite and infinite pools of invaders, Post and Pimm concluded that as species successively invaded, the number of species outside the community dropped. They also found a continual increase in the difficulty of an invader being successful, and, in time, the community structure attained configurations that prevented any of the species outside the community from entering. Other studies have dealt with the difficulties faced by an introduction in competing for resources within a relatively rich set of species at the same trophic level. Here, species that were too similar competed strongly, while communities with widely spaced species were invaded quite easily.

Clearly, the best way to evaluate the effects of community structure on the success rate of introductions involves knowing which species failed. Pimm has suggested that we might compare those species that are still restricted to gardens, plantations and arboreta — failures — with those that have spread from these sites into natural habitats.

CONSEQUENCES OF DISTURBANCE OF NATURAL VEGETATION

From the foregoing discussion it can be concluded that an ecologically stable plant community is one that is resilient (able to recover from perturbations), persistent (able to

resist and survive species introductions), resistant (able to withstand species removals and additions) and variable (has sufficient diversity). Although some man-made agricultural systems may be able to have the above qualities, they require high energy and chemical inputs. Natural vegetation which is indigenous to an area occupies a specific ecological niche within that area, which gives that vegetation community the above attributes naturally. Communities may be stable at either the local micro level or the broader macro level. Natural communities are complex and, through their functioning, affect the ecological balance of a whole area. When stable, this ecological balance is positive, but when unstable the ecological balance is negative and the life support mechanisms begin to fail. An example of this relationship may be seen from what happens to a tropical forest system when subjected to various forms of environmental stress.

In humid and wet zones, where trees are the dominant vegetation, deforestation is a prerequisite to high-yield agriculture. Trees must be cut down so that agricultural crops can grow. Following deforestation in temperate zones, the annual yield of the crops, in terms of usable biomass per unit area per year, is often higher than that of the forests. Even if total net primary production is considered instead of only production useful to man, annual plants often have higher yields than native forests (Jordan, 1985). Relatively high productivity on deforested temperate soils can continue for many years but eventually, of course, without fertilization, productivity will decline.

In contrast, in the humid tropics, deforestation followed by cultivation results in only one or two years of high crop yields. The rate at which deforested, cultivated soils in the humid tropics lose their fertility depends on the type of cultivation and the type of soils; total net primary production and crop yields decline sharply after 2-3 years to the point where cultivation is no longer worthwhile. The reason for the decline is that soils in the humid tropics are usually relatively infertile, and even fertile soils rapidly lose their nutrients following clearing.

Infertility in tropical soils results from heavy rains and biological processes which go on throughout the year, resulting in high annual rates of decomposition, leaching of soluble nutrients and fixation of phosphorus. Rapid loss and fixation of nutrients also could mean that once disturbance ends, recovery of forests may be slow, or may not occur at all.

Despite the potential that tropical deforestation holds for soil degradation, for reduction of potential productivity and for prevention of return to forest, not all disturbances are equally serious. Some disturbances, such as local tree falls, have little effect on productive potential and recovery, while others, including soil loss, may have a devastating effect. The seriousness of the disturbance is not necessarily related to the involvement of man. Many of the natural disturbances that occur in tropical forests are more serious than those caused by some types of agriculture.

Deforestation not only affects the productive potential of plants, but also eliminates plant species and species habitats, a problem which is particularly severe because of the high species diversity. In certain circumstances, deforestation may have climatic repercussions that will modify, if not impoverish, remaining forest (Myers, 1985). The hydrological cycling system in Amazonia, for instance, is such that the basin's moisture remains within the ecosystem. This means that as the forest expanse is reduced, the climate in the remaining portion may well become drier, on the grounds that surviving forest is less capable of evapotranspiring as much moisture through the system as before. Thus the process could make for a steadily desiccating ecosystem — with all that that implies for the survival prospects of remaining biotas.

CONSERVING INDIGENOUS VEGETATION

Conservationists have been searching for a long time for the most effective way of protecting natural plant and animal communities. The first most natural reaction in the early times was to set aside areas as national parks. This is perhaps the most effective way to protect natural communities. But there has been continuing pressure to use the sanctuaries for other purposes. This means that the value of natural habitats for the protection of species may not always continue to exceed their value for agricultural production. East Africa's population is growing fast (in Kenya by about 4% per year) and the need for food is also growing. If reserves and parks have land suitable for agriculture, it is conceivable that sooner or later the protected areas will go.

Since Kenya, for example, has no minerals or oil, the full potential of the land must be developed by every means. But development must take the form most suited to the prevailing circumstances and the purposes for which an area is best adapted. Development of flora and fauna resources is as important as the development of any other organic natural resource and should be undertaken to the maximum extent consistent with its perpetuation. The natural surplus can be legitimately used and tourism can be instituted without detriment to the continuation of the resources.

One far-reaching development in the conservation of natural systems has been the recognition of categories of protected areas other than parks and reserves. At present, there are 10 recognized categories of protected areas, as developed by IUCN. These range from strictly protected reserves on the one hand to cultural landscapes on the other. The recognition of these other categories of protected areas is important because of changing socioeconomic and political realities. We might not always have new land to set aside; this means that we must always conserve ecological diversity wherever it exists — in protected areas or outside them.

The guiding principle in any land development involving any effect on the natural habitat should be always to ask oneself whether that development is absolutely necessary. If it is absolutely necessary, then the next question should be how to go about it with the least damage to the natural habitat. This ecological consciousness should be the responsibility of everyone because it is critical for the survival of the human race.

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4.3

In Situ Conservation and Monitoring of Rangeland Genetic Resources

B. M. NDAMBUKI

In situ conservation is the preservation and protection of genetic resources in their natural habitat (Ford-Lloyd and Jackson, 1986). This conservation strategy aims at achieving stability by maintaining self-perpetuating populations in natural ecosystems. The genetic variability of species is preserved in a defined area as well as by preserving the complex relationships between members of the community (Gopalan et al., 1986).

The term 'genetic resources' encompasses both animal and plant resources. Here, plant genetic resources will be given more consideration than animal resources. This is because protection and conservation of wild animal resources has received much attention in the past. Plants need to be given greater attention in the conservation effort. Much has been derived from plant genetic resources in terms of food, fuel, medicine, chemicals, fibers and so on. Every plant is likely to prove useful to humans if more research work is done. Hence there is a need to conserve the resources with known uses and those without known uses which might turn out to be useful in the future.

Conservation of plant genetic resources on the rangelands involves the wise and sustainable use of natural resources. Rangelands receive low and erratic rainfall and are unsuitable for cropping. Two rainy seasons are separated by two dry seasons and sometimes the dry periods extend into droughts (Dasman, 1973).

Rangelands experience high rates of evaporation. This causes salts to be deposited on the topsoil, creating conditions favorable to plants with a high degree of tolerance to salinity and alkalinity (Dasman, 1973). Most of the soils in the rangelands are not fully developed and are poor in nutrients. The nutrients are locked up in chemical combinations, making them unavailable to plants. The soils are also characterized by mineral imbalances, resulting in excess or deficiencies (Dasman, 1973).

Rangelands are important in Kenya as they occupy 70% of the total land area. They are the homes of livestock, wildlife and pastoralists. Kenya benefits from its rangeland resources through the sale of proteins from the animals' products (animal biomass). The wildlife also

earns the country a considerable amount of foreign exchange through tourism. The rangelands are important in terms of plant resources, and these resources need to be conserved.

IN SITU CONSERVATION

In situ conservation is applied to wild plant species. The species are preserved and, at the same time, maintain genetic perpetuation in a natural state. Consequently, communities evolve that are stable within their own environment. Any conservation strategy must allow continued evolution and natural selection among the species in a natural environment. Hence, multi-species communities arise which have a high plant diversity and a wide genetic base. This leads to long-term stability in population numbers (Ford-Lloyd and Jackson, 1986)

However, *in situ* conservation is not always acceptable. Conservation of genetic resources in the natural habitat makes the land unavailable to people in the area (Gopalan et al., 1986). The general increase in demand for food is causing the replacement of natural habitat with modern cultivars. Wild plants are being replaced by crops of more economic benefit. From the economic point of view, it is logical to encourage modern agriculture. The replacement of natural habitat often results in genetic erosion through the replacement of plant diversity with uniformity. A balance must therefore be established.

THE NEED FOR CONSERVATION

Conservation provides a wide genetic base which is important in breeding or selecting better varieties and strains of crops for food, fuel and medicine.

Cultivated crops have a narrow genetic base that leads to vulnerability. They are more likely to be attacked by pests and diseases. For instance, the Irish potato blight disease, *Phytophthora infestans*, of 1846 destroyed many crops and caused mass emigration (Gopalan et al., 1986). Cultivated plants have lost some of their valuable biological properties through generations of continued agricultural inbreeding and selection. These properties can be restored by using wild relatives of the cultivated crops which have retained their advantageous biological properties (Ford-Lloyd and Jackson, 1986).

The wild relatives of crops have a wide variety of genetic traits. They continue to maintain this genetic variation through natural selection and random processes of genetic change. Through genetic engineering, the genes controlling certain plant characters can be manipulated and transferred from one plant species to another. The crops are then crossed with their wild relatives to yield plant varieties that are hardy, high yielding in different environments and resistant to diseases and pests, as well as requiring less input in terms of fertilizers and insecticides. Dwarf but high-yielding varieties of wheat, sorghum, rice and maize have been developed in order to meet human food requirements.

All these developments have led to an increase in international efforts to conserve plant genetic resources diversity.

HISTORY OF PLANT GENETIC RESOURCES CONSERVATION

As early as the 1920s, scientists were aware of the need to conserve plant genetic resources. The major contribution was by the Russian geneticist and plant breeder, N. I. Vavilov (Ford-

Lloyd and Jackson, 1986), often considered the father of plant genetic resources activities. He proposed that crops could be improved using the wide genetic variation of their wild relatives, the latter providing the genepools from which the cultivars could be bred.

Vavilov identified centers of diversity. These were areas in which genetic variation in cultivated species was concentrated.

In the 1960s international organizations were created to deal with the conservation of plant genetic resources (Ford-Lloyd and Jackson, 1986). The Food and Agriculture Organization of the United Nations (FAO) hosted the first international technical meeting on plant exploration and introduction in 1961. However, the real work began with the establishment of the International Board for Plant Genetic Resources (IBPGR) in 1974 (Ford-Lloyd and Jackson, 1986). IBPGR is involved with the promotion, collection, conservation and evaluation of plant genetic resources of species of major economic importance and their wild relatives.

CONSERVATION METHODS AND MATERIALS

The conservation and monitoring of plant genetic resources requires a thorough knowledge of the vegetation composition, structure and biomass production. This gives an indication of the current situation and trends regarding the rangelands. Several methods have been used for vegetation sampling. Kenya's Department of Resources Surveys and Remote Sensing, of which the Kenya Rangeland Ecological Monitoring Unit (KREMU) forms a part, has done a lot of work in the rangelands, as well as in the high-potential areas, using vegetation sampling methods. The sampling is carried out by KREMU's ground survey section. Data are also obtained using aerial surveys and satellite images.

Quadrat method

The quadrat method is used to measure the herbaceous cover. Kershaw (1973) shows that the method has been used for a long time. Usually, a 0.5 m x 0.5 m quadrat is used. Within the quadrat the different plant species are noted, and the percentage of species cover and bare soil exposure is estimated. The amount of litter, dung, forbs, rocks and pebbles, vascular plant cover and even bryophytes and lichens are estimated.

From this kind of information, the density, frequency and the abundance can be obtained. The amount or the extent of the bare soil can also indicate the grazing pressure.

Line transect method

The Department also uses the line transect method. Transects are important in giving a description of vegetative change along an environmental gradient (Kershaw, 1973). The method consists of laying out a line running across the zones to be sampled and then placing quadrats at known intervals along the line. Johnston (1973) recommended the line transect method for grassland and woody vegetation. For biomass production, clipping is done at known intervals to determine the weights.

Point center quarter method

The point center quarter (PCQ) method is used to determine the woody cover. This method is more accurate in assessing tree density in forest stands, but not as efficient in estimating woody plants in grasslands (Johnston, 1957). The method assumes a random distribution of woody plant populations. This assumption can, however, lead to wrong impressions on plant density.

Kuchar (1979) describes PCQ as a plotless distance method. The PCQ method gives data on species composition, density, frequency, stem diameter (base diameter), height crown, depth and crown diameter. At every sampling point, four individuals or multiples are evaluated. This is done by drawing two lines — a vertical line in the compass direction and a horizontal line at right angles to it. Sampling is then done in every quarter.

Aerial surveys and satellite images

The low-level aerial surveys undertaken for animal censuses are also useful for establishing the distribution of various vegetation communities. The flights follow parallel east-west transects, spaced 5 or 10 km apart according to the Universal Transverse Mercator (Norton-Griffiths, 1978). The pilot maintains a certain flying height above ground level and a constant speed. The pilot calls out at the beginning of each transect (Ottichilo et al., 1987), and the front-seat observer records information on vegetation habitats. The two rear-seat observers count the animals within the observation strips defined by parallel fiberglass rods attached on both sides of the aircraft. Some information is also recorded on tape.

Using satellite images, different vegetation communities can be delineated according to tonal differences. Changes in vegetation can also be noted. Studies on vegetation maps are made possible by the use of satellite images. SPOT imaging has high resolutions (20 m in the multispectral mode and 10 m in the panchromatic mode). These have the added advantage of providing a large synoptic view over wide areas of the rangelands on a repeatable basis. Landsat imaging is also used, although it has poorer resolution.

Role of national parks and the herbarium

In Kenya, a national park is created by an act of parliament and it is therefore protected government land. Usually, no human activities should occur in national parks, unlike national reserves where some human activities may take place. The establishment of national parks is geared mainly to the protection of wild animal resources. The plant communities are not accorded as much protection. There should be more attention to the plants, particularly where plants are damaged by wild animals, especially by elephants.

The Department's herbarium forms part of the National Museums of Kenya. The aim of establishing the herbarium was to help in identifying plants while working in the field. Most of the plant species in the herbarium have been collected from the rangelands where the majority of KREMU's projects are carried out. However, there are also species from other areas. Often, more than one specimen per species collected from different areas is preserved in the herbarium since specimens exhibit slight differences. The herbarium is therefore important in providing taxonomic and ethobotanical information whenever required.

LIVESTOCK AND GRAZING MANAGEMENT

Rangelands in Kenya and other countries support large numbers of livestock. Ranches have been established where, in general, beef cattle are kept, usually under good management. The rangelands are also homes for nomadic communities who keep large numbers of animals and move around with them in search of pasture and water (Dasman, 1973). This leads to overgrazing and hence degradation of the vegetation, leading to soil erosion. The increase in human population has also contributed to overgrazing and soil erosion.

The number of animals should be reduced and maintained below the carrying capacity to minimize overgrazing (Dasman, 1973). However, most pastoral communities, such as the Masai and Turkana, consider large livestock herds to be a sign of wealth or prestige. Such communities need to be encouraged to keep fewer animals so as to maintain a good ecological balance. Hence more extension workers are needed in the rangelands to intensify technical assistance to the pastoral communities.

Environmental destruction is accelerated by the uneven distribution of livestock. Grazing management is therefore needed to control this distribution. Livestock often concentrates at particular areas such as watering points and salt licks. Watering points in the rangelands should be decentralized to create an equal distribution and prevent heavy concentrations of animals. Dams, boreholes and water holes would provide water in the rangelands.

Fencing is another management tool. Although expensive, fencing is important in ranches in that it creates paddocks. The paddocks allow rotational grazing which controls and minimizes grazing pressure.

FIRE CONTROL

The occurrence of fires in the rangelands is a common phenomenon. Occasionally, fires occur naturally as a result of lightning. Most fires, however, are caused by human activities. Pastoralists set the vegetation alight to kill pests such as ticks. Cattle raiders may start fires to obscure their tracks. The careless activities of poachers and bee hunters also cause fires (Sinclair and Norton-Griffiths, 1979).

Fire may have an immediate fertilizing effect on the surface soil because of the release of nutrients. The grass vegetation resulting from a burn is more palatable, nutritious and attractive to herbivores (Dasman, 1973).

Rangelands can be affected negatively by fires which can inhibit or completely suppress the growth of trees into the mature age classes. Young trees less than 3 m tall are susceptible to fire damage (Sinclair and Norton-Griffiths, 1979). Trees more than 3 m tall are safer from fire and hence are considered part of the mature tree population. Thus fire causes an overall decrease in cover density. Fires in the rangelands should be reduced as much as possible since their damage is extensive. If burning has to be applied, its frequency, seasonality and intensity should be studied carefully and the results applied accordingly.

REHABILITATION OF RANGELANDS

An important method of *in situ* conservation of genetic resources involves the reseedling of rangelands by replanting trees. This type of rehabilitation is considered to be the most

effective way of improving range condition (Dasman, 1973). Usually, indigenous trees that are well adapted to the rangelands are recommended. The species selected for replanting should be those already doing well in the rangelands.

A scientific inventory should be undertaken in most of the rangelands to identify those plant species that not only survive well in these areas but can also be easily propagated.

Among the grasses, perennial grasses are the most suitable for reseeding rangelands (Pratt and Gwynne, 1977). The grasses intercept water and conserve the soil. The roots bind soil particles and prevent soil erosion. The creeping perennials provide long stolons which produce roots at the nodes and cover the ground. The grass *Chloris roxburghiana* has been successfully grown in Kitui (Pratt and Gwynne, 1977). Other grasses suitable for reseeding purposes are *Cynodon dactylon* and *Enteropogon macrostachyus*. Reseeding improves ground cover in a manner not possible by grazing management alone. However, reseeding can be a waste of time unless grazing is controlled while the new range plants are establishing. Thus almost complete protection is needed (Dasman, 1973).

UTILIZATION OF RANGELAND PLANTS

Rangelands house many plants of medicinal value. Often, the bark or roots of these plants are the parts used for extraction of the drug component. This is a wasteful method of harvesting since the plants are damaged or even die after debarking. Research should therefore be done on the possible use of the leaves instead of the bark, since leaves can be regenerated. However, the state and natural concentration of the drug compounds found in the leaves needs to be established in order to effect non-destructive extraction methods.

Cychoma bark, for instance, is used for making anti-malarial drugs. Quinine, which is the major component, treats even the resistant strains. *Moringa stenopetala* is another drug of medicinal value. It is found in the north-eastern areas of Kenya where it is known locally as 'bofara' or 'mawa'. Products of this tree are used to treat many ailments, such as tonsillitis, worm infections, skin infection, burns, swelling eye inflammations, syphilis and snake bites. This plant is also used in filtering water. The seeds are crushed into a paste which is put into a container of dirty water. When stirred, the paste traps the dirt and bacteria and sinks to the bottom of the container with the dirt.

Studies done by KREMU in Kajiado-Amboseli National Park and the surrounding area revealed a diverse use of plants for medicinal purposes. *Balanites aegyptiaca* is used by the Masai to treat malaria. The bark is crushed and squeezed in water. The resulting syrup is then taken. *Lycium europium*, known as 'olokii' by the Masai, is used for eye treatment.

MONITORING CHANGES IN THE RANGELANDS

The conservation of plant genetic resources alone would be inadequate unless changes in the rangelands were properly monitored.

Range condition

The condition of a range is the state and health of a range based on what it is naturally capable of producing (Pratt and Gwynne, 1977). Range condition can be classified as excellent, good,

fair or very poor (Dasman, 1973). The assessment of range condition depends on the ability to recognize symptoms of deterioration. These symptoms include the amount of ground cover, bare ground and dead vegetation materials and the amount of soil erosion taking place.

Humphrey (1962) suggested the site-potential approach, which focuses on potential range production, as a method of assessing range condition. Brown (1960) suggested the increaser and the decreaser concept of assessing range condition in East Africa. *Themeda triandra* and *Cynodon* are replaced by *Pennisetum stramineum* and *Aristida* before further overgrazing produces ephemerals. Heady (1966) suggested five successional stages resulting from grazing intensity: a tall climax grass stage dominated by *Themeda*; an intermediate stage dominated by creeping species, such as *Cynodon*; a short stage of annual grasses; a weed stage dominated by annual grasses; and a weed stage dominated by annual broadleaved herbs. For domestic livestock, the tall climax stage represents excellent range condition (Pratt and Gwynne, 1977).

Range trend

Trend is the direction of change in range condition and soil (Pratt and Gwynne, 1977). It establishes whether the conditions are deteriorating, improving or remaining the same (Dasman, 1973). A rangeland in excellent condition, but deteriorating, is an area that requires management. The range trend is indicated by the vegetation. If an area has older individuals of the palatable species and more younger plants of the less desirable species, this indicates a deteriorating trend (Dasman, 1973). The trend is considered upward or improving if over half the juvenile plants per unit area are of the desirable species (Pratt and Gwynne, 1977). Assessment of range trend is an efficient tool for indicating range condition by monitoring changes in vegetation structure, abundance and species composition (Kuchar 1979).

USE OF THE GEOGRAPHIC INFORMATION SYSTEM

The data collected on plant species can be stored in a more organized and standardized way by using the computerized geographic information system (GIS). KREMU and many other institutions now have this system. It is reliable, efficient and rapid, and allows easy access to and retrieval of data.

KREMU is undertaking a project on plant species documentation using a GIS package. Coding is being done on all the plant species that have been collected. In each case, the following are recorded: the first four letters of the genus name, the first four letters of the species name, the geographical place and altitude of collection, the name and number of the collector and the date of collection.

This kind of record will give a full checklist of plants collected in Kenya. The GIS will give information in map form, from which one can locate distributions, and in published form, all of which will help in assessing the condition and trend of the rangelands.

CONCLUSION

In conclusion, I stress that there is great need to conserve plant genetic resources in the rangelands. Conservation will ensure a high plant diversity which will act as a genepool for

plant breeding and other uses. There should be long-term monitoring of the rangeland resources. Kenya, with over 70% of its area comprising rangelands, needs to protect them in order to conserve genetic resources *in situ*.

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PART 5

Evaluation and Utilization of Genetic Diversity

5.1

Rice Evaluation in Africa

A. O. ABIFARIN

For many years, rice evaluation has been the main method of varietal improvement in many parts of sub-Saharan Africa. Most of the varieties in the region have been developed through evaluation of locally collected or introduced improved germplasms. This paper gives some highlights on the two types of rice evaluation in Africa, with special reference to West Africa.

GERMPLASM EVALUATION

Evaluation is essential if germplasm is to be useful. The task of thorough evaluation is demanding. Human and financial resources constraints are encountered in many of Africa's national institutions and research stations. In national programs, only modest evaluation of indigenous collections are carried out. The bulk of the work is usually passed on to international centers. Some information is given here on the roles that international centers play in the evaluation of rice germplasm.

IRAT/ORSTOM and national programs

The Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières (IRAT) and the Office de la Recherche Scientifique et Technique d'Outre-Mer (ORSTOM), in collaboration with many national research stations, were the front runners in germplasm activities in the region. The national programs participating in these efforts included those of Côte d'Ivoire, Cameroon, Senegal, Madagascar, Guinea, Burkina Faso, Guinea Bissau and Zambia. Most of their collections were evaluated in Côte d'Ivoire at the IRAT Station in Bouaké; this station is now a national institute, known as the Institut de Savane.

Goli (1980) reported on the genetic resources activities of IRAT and ORSTOM with regard to indigenous rices in Africa. He reviewed the collections made from 1930 to 1977. These collections were evaluated and characterized, and were later used in breeding programs in

many parts of Africa. The evaluated collections were made up of samples from *Oryza sativa*, *O. glaberrima*, *O. longistaminata* and the intermediate forms. ORSTOM put a lot of emphasis in their evaluations on defining the evolutionary relationships between cultivated and wild forms by studying enzyme polymorphism (Bezancon et al., 1977). IRAT, on the other hand, studied phenotypic variation in its evaluation activities.

IITA and national programs

In 1976, the International Institute of Tropical Agriculture (IITA) based at Ibadan, Nigeria, started an active genetic resources program in which rice is an important component.

According to Steele (1980), IITA, the International Board for Plant Genetic Resources (IBPGR) and scientists from other institutions were involved in the evaluation of the collections. IITA publishes crop germplasm catalogs regularly. Many descriptors are recorded in the rice catalogs.

In 1980, the IITA Genetic Resources Unit (GRU) evaluated 1,500 new accessions of Asian rice for botanical characteristics (IITA, 1981). These data, together with information about the provenance of each accession, form the basic documentation of the collections. The reaction of African and Asian rice germplasm to blast disease and rice yellow mottle virus (RYMV) was studied by the GRU and the Cereal Improvement Program. Preliminary results indicated that 54 accessions of *O. sativa* out of the 1,132 tested showed horizontal resistance to blast disease. On the other hand, very few *O. glaberrima* collections tested showed high susceptibility to blast; most showed hypersensitive reaction or no reaction. The yield potential of some *O. glaberrima* cultivars was comparable to *O. sativa* or better, particularly under low fertility levels. For example, *O. glaberrima* (Kolon Kalan) yielded 2.0 t/ha, compared to the OS 6 check yield of 1.25 t/ha.

In 1981, accessions with little or no blast symptoms were selected and retested for blast resistance (IITA, 1982): 661 accessions of *O. sativa* and 329 accessions of *O. glaberrima* under upland conditions were sprayed with blast inoculum; 125 accessions of *O. sativa* and 52 of *O. glaberrima* were severely damaged. The susceptible check and six of the blast index varieties, as well as the disease spreader, were seriously damaged. The remaining 536 accessions of *O. sativa* and 277 of *O. glaberrima* showed very low damage.

Studies were carried out on the agronomic performance of 526 African *O. sativa* accessions sown in two rows of 5 m plots under upland conditions at IITA for seed multiplication and botanical characterization. Some of these accessions appeared to be high yielding with good agronomic characteristics, but none of them gave as high a yield as the two control varieties, OS 6 and ITA 116.

Evaluation for resistance to RYMV was carried out in 1982 by the GRU and IITA's rice breeding program (IITA, 1983). Studies carried out earlier by the GRU on the reaction to RYMV of over 1,000 *O. sativa* accessions and 75 *O. glaberrima* accessions after artificial mechanical inoculation under normal field conditions indicated that whereas most *O. sativa* accessions were highly susceptible, most *O. glaberrima* ones were very tolerant of this virus.

Rice accessions that appeared to be highly resistant to blast in the 1981 test were retested in 1982 in the glasshouse and screenhouse. Sixty-five accessions of *O. sativa* and 30 of *O. glaberrima* were confirmed as being highly resistant. Two accessions of *O. glaberrima* appeared to be immune; serological testing by a virologist showed no virus after mechanical inoculation. The studies indicated that most of the tolerant accessions were upland varieties

collected in Africa. In 1982 the GRU carried out a field screening test that included 536 accessions of African *O. sativa* landraces, 287 of *O. glaberrima*, 20 varieties of *O. sativa* developed by the International Rice Research Institute (IRRI), 30 cold tolerant *O. sativa* varieties from Korea and 15 blast differential rice varieties. The test revealed that most of the Asian varieties are highly susceptible to the local blast disease at IITA: 17 IRRI varieties (85%), 21 Korean rice varieties (70%), 95 accessions of *O. glaberrima* (33%), 69 accessions of the African *O. sativa* (13%), and six of the blast differential varieties were found to be susceptible to blast.

In evaluation for resistance to stem borer, *Diopsis thoracica*, 32 accessions out of over 755 had less than 10% infestation by this insect. The best 20 of these and the sources from which they originated are given in Table 1.

TABLE 1 Twenty of the best cultivars selected for resistance to the stalk-eyed fly, *Diopsis thoracica*, in a mass screening test of rice cultivars at IITA, 1982

Designation/ IITA acc. no.	Source	Infestation (%) ¹	Designation/ IITA acc. no.	Source	Infestation (%)
TOs 5827	Liberia	1.2	ITA 121	IITA	3.1
TOs 3213	Côte d'Ivoire	1.8	TOs 5267	Côte d'Ivoire	3.3
TOs 285	USA	1.8	TOs 657	USA	3.3
TOs 372	Indonesia	2.0	TOs 373	Indonesia	3.3
TOs 3212	Côte d'Ivoire	2.2	X.2. D.T.	Vietnam	3.4
TOs 5792	Liberia	2.2	TOx 936- 153-5-3-3	IITA	3.5
TOx 916-6-1- 101-2	IITA	2.4	TOs 663	Nigeria	3.5
TOg 6390	Liberia	2.5	TOs 5734	Liberia	3.6
TOs 272	USA	2.8	TOx 891-212- 1-102-1-1	IITA	3.6
TOs 5677	Nigeria	2.9	TOg 6481	Liberia	3.8

¹ Infestation ranged from 1.2% to 66.7% in the mass screening test.

Source: IITA, 1982.

Every year a number of accessions are evaluated by IITA's GRU. In 1986, for example, 800 accessions were evaluated for up to 43 characters (IITA, 1987).

WARDA activities

Over the years, the West Africa Rice Development Association (WARDA) has evaluated many of its rice collections for tolerance to such stresses as diseases, insects, drought, salinity and iron toxicity.

In 1978, at its Mangrove Swamp Station in Rokupr, Sierra Leone, 350 accessions were evaluated by WARDA for tolerance to salinity, soil acidity, tolerance to tidal effects and other

traits (WARDA, 1978). Several accessions possessing desirable traits have been used in the breeding program.

At Fanaye, Senegal, in 1978-79, 164 accessions collected from the Casamance were evaluated under irrigated conditions (WARDA, 1978). Their reactions to cold temperatures and dust-laden dry harmattan winds, among other factors, were determined. Also in 1979, at the WARDA station in Suakoko, Liberia, 1,103 accessions were evaluated under inland valley swamp conditions. Some of the characters recorded were days to maturity, grain discoloration, and reactions to iron toxicity blast, leaf scald and white head (WARDA, 1979).

In 1981, 277 accessions were evaluated under the iron toxic conditions of Suakoko (WARDA, 1981). The entries were made up of 91 accessions of *O. glaberrima* and 186 accessions of *O. sativa*. Among the tolerant accessions were TOs 7725, TOs 7726, TOs 7769, TOs 5532, TOs 5354 and TOs 7454.

Thirty-one accessions from Guinea were evaluated during 1982 at the WARDA Rokupr Station under acid sulfate tidal-prone conditions (WARDA, 1982).

In the WARDA/IITA/Central Agricultural Research Institute (CARI) collaborative iron toxicity research project, some 543 accessions were evaluated for tolerance to iron toxicity in 1986 (WARDA, 1986). The accessions that proved to be tolerant are listed in Table 2.

In 1986, at the WARDA station in Bouaké, 19 West African upland rice varieties and 38 selections from germplasm collections were evaluated for tolerance to upland soil acidity. Average soil water pH at planting time was 4.9. Also in 1987, 20 West African upland rice varieties, 12 selections from germplasm collections and four introduced varieties were evaluated at Bouaké. Average soil pH at planting time was 4.7. Table 3 shows the reactions of some of the evaluated cultivars (Choudhury and Diatta, 1987)

TABLE 2 Accessions showing tolerance to iron toxicity at Suakoko, Liberia, 1986

WARDA accession no.	Cultivar	WARDA accession no.	Cultivar
913	Yanssinah 19	1136	Pa Mamoh Kamara 22
895	Pa Bintu IIA	1158	Banjul Bai 384
908	Cobui 190	1101	Pa Soro 125
1003	Pa Konday 241	1120	Pa Fant 213
1177	Pa Bundu 62	1023	Kiti Mano 368
1590	Ys 441	1029	Pa Rooko 271
1592	Ys 429	1034	Pa Mayaninie
1130	Pa Tok 278 A	1041	P.C. Wui 297
906	Pa Bai Tollie	991	Pa Bia Bureh
889	Pa Ronko 54A	1044	Samba 327
881	Pa Soro Kant 228	1046	Nyabo II 421
880	Pa Bundu 328	1115	Pa Sanasi 219
871	Pa Lamina 220	1013	Mani Fingo 456
863	Mathes 129	1006	Kumba Mano 380
832	Morasan 109A	1102	Cherno 391
1107	Sawani 217	1172	Gbondo Yakai 290
998	Kpeyei 192	1150	Alma Koyo I 417

TABLE 3 **Reaction to upland soil acidity (pH 4.9-4.7) of some upland rice varieties, Bouaké, Côte d'Ivoire, 1986 and 1987**

Resistant	Moderately susceptible	Susceptible
WABC 165	WABZI	B 3622F-TB-14-4
IAC 164	IRAT 144	
IDSA 6	IDSA 14	
IDSA 9	DOURADO PRECOCE	
MOROBEREKAN	OS6	
I. CATETO	LAC 23	
IRAT 136	ROK 16	
IRAT 156	IRAT 112	
IR 5931-110-1	IRAT 109	
B 3622G-TB-41	IRAT 107	
IRAT 104	ITA 257	
IRAT 13	ITA 132	
B 2997C-60-3-3	ITA 184	
IAC 1246	TOX 85410132011117	
	BS 20	
	IR 10110231	
	LAC 23 (white)	

EVALUATION OF IMPROVED INTRODUCED CULTIVARS

Many introduced rice cultivars have been evaluated in rice-growing countries for various types of adaptations to local conditions. The evaluated improved or semi-improved cultivars were used either directly, as recommended varieties, or in hybridization work. Africa is said to be unique in its use of introduced varieties, especially the *O. sativa* species (Chang, 1976).

Most varieties, currently grown or of former importance, were developed from local collections introduced many years previously and from recent foreign introductions (Abifarin et al., 1972; Monyo and Nwaruka, 1974). Varieties developed from local cultivars after evaluation include Gambiaka, Bontoubala, Moroberekan, IM16, Oma Rossa Lac 23, Kihoga red, Theresa and Gambi. Varieties recommended from introductions include BG 79 and D52-37 (Guyana); Sigadis (Indonesia); Neang Veng, Phar Com En and Madin Thang (Cambodia); Makalioka (Madagascar); Indochina Blanc and Doc Phun Lun (Viet Nam); Iguape Cateto (Brazil); SR 26, Jaya, Padna and Anethoda (India); Ikong Pao, Taichung Native No.1, Tainan 2 and TS 123 (Taiwan); SML Alupi and SML 140/10 (Suriname); the IR series (International Rice Research Institute in the Philippines — IR8, IR5, IR20, etc.); Palawan, C4-63 and Azucena (Philippines); and Durado Precoce (Brazil) (Jacquot, 1976).

The evaluation of exotic improved germplasm continues to play a major role in varietal improvement programs in Africa. National and international institutions collaborate in these evaluations to form various types of bilateral and collaborative evaluation networks. Many African countries participate in African testing programs, such as the variety trials coordinated by WARDA until 1984, and in global testing programs, such as the International Rice Testing Program (IRTP).

Role of the IRTP

The IRTP, coordinated by IRRI, was established in 1975. However, prior to its inception, many IRRI varieties and lines had been evaluated in many parts of Africa. The IRTP evaluation programs in Africa have identified several promising varieties. Table 4 shows some of the varieties identified from different types of evaluations in Africa in the early years of the program. Since 1985, there have been changes in the grouping and administration of IRTP. We now have IRTP-Africa, which is a joint IRRI/IITA/WARDA program involving over 22 national programs. Most of the cultivars being evaluated in the IRTP-Africa program are of African origin or have been grown or tried in Africa for a number of years. Results from these evaluations will directly or indirectly lead to new varieties in Africa.

Role of WARDA

From 1973 to 1984, WARDA had an elaborate and extensive network of varietal trials throughout West Africa. These consisted of Initial Evaluation Trials (IET), which was a mass

TABLE 4 Some of the promising or recommended cultivars emanating mostly from IRTP nurseries in West Africa

Cultivars	Countries of importance	Some IRTP nursery sources
1. BG 90-2	Nigeria, Sierra Leone Niger, Benin, Togo	1974 and 1975 IRON and 1974 IRYN
2. BG 34-8	Mauritania	
3. BR 51-49-6	Ghana	1975 IRON
4. BR 51-319-9	Gambia	1975 IRON
5. IET 2885	Mali, Niger	
6. IR269-26-3-3-3	Nigeria (TOS 78), Mali, Niger, Sierra Leone	1973 IRYN
7. IR442-2-58	Benin, Gambia, Ghana, Guinea-Bissau, Togo	1975 and 1976 IURON 1976 and 1977 IURYN
8. IR578-95-1-3	Ghana, Nigeria	1973 IRYN, 1974 and IRON
9. IET 1444	Togo	1979 IRBN, 1978 IURYN
10. IR1529-680-3	Benin, Gambia, Ghana, Côte d'Ivoire, Mali Niger, Togo, Burkina Faso	1975 IRON and 1977 IRBN
11. IR1561-228 3	Mauritania	
12. JAYA	Ghana, Côte d'Ivoire, Mali, Senegal	1973 IRYN and 1975 IRON
13. MAHSURI	Sierra Leone, Liberia	1975 and 77 IRON
14. VIJAYA	Burkina Faso	1974 IRON
15. ROK 11	Sierra Leone, Benin, Togo	1975 IRBN
16. ROK 12	Sierra Leone	1975 IRBN
17. IET 1976	Burkina Faso	
18. IR3273-p339-2	Ghana	1979 IURON
19. IET 1444	Togo	1979 IRBN
20. BW 78	Guinea-Bissau	1979 IRON

TABLE 5 Some of the varieties identified from WARDA coordinated trials being grown as varieties or being considered for production in WARDA member countries

Country	Ecologies			
	Upland	Irrigated and rainfed lowland	Mangrove swamp	Deep flooded/floating
Benin	D 52-37, IRAT 10, IRAT 10, Col. 38, C 74, IR 442-2-58, CR 1002, IR 937-55-3, IR 28, SML AWINI	BG 90-2, Col. 38, IR 3273-P339-2, BW 196, IR 9	IR 442-2-58, IR 1529-680-3	
Burkina Faso	IRAT 10, IRAT 144a, SE 302 G, Dourado Precocce, IRAT 147	IET 1996, IET 2885, IR 1529-680-3, Vijaya, C 74, IET 14418, IR 1529-680-3		
Côte d'Ivoire	Dourado Precocce, IRAT 10, IRAT 13, IRAT 110a, IRAT 112, IRAT 136	BG 90-2, IRAT 10a, Jaya, Bouaké 189a, IR 1529-680-3	IR 5	
Gambia	IR 442 2-58, SE 302 Ga, IRAT 112, ROK 5, I Kong Pao	I Kong Pao, IR 28, BW 78, BG 90-2, ROK 5, IR 1529-680-3, IR 442-2-58, IR 22	ROK 5, Phar-Com	ROK 5, Phar-Com-En
Ghana	IR 442-2-58, IRAT 112, Dourado Precocce, IR 20, IR5	IR 442-2-58, CICA 4, IET 2885, IR 2071-586-5-6-3, BG 90-2, IR 1820-210-2, IR 665-79-2, BR 51-118-2, IR 20		
Guinea	LAC 23, ROK 16, IRAT 109	IR 20, IR 442-2-58, IET 114 IR 5	ROK 5	BKN 6323
Guinea-Bissau	I Kong Pao, IRAT 109, IRAT 113, IRAT 9, 10, SE 302 G	BW 78, BG 90-2, I Kong Pao, IR 442-2-58	ROK 5	
Liberia	LAC 23a	IR 5, 2526 (Suakoko 8), Improved Mahsuri (Suakoko 10)		

TABLE 5 (contd)

Country	Upland	Ecologies		
		Irrigated and rainfed lowland	Mangrove swamp	Deep flooded/floating
Mali	IRAT 10, IR 442-2-58, IRAT 112, SE 302 G	IR 442-2-58, IET 2885, Sigadis, IR 1529-680-3		MSP 10a, DA 29, BKN 6323, ADNY 310, DM 16 DM 17, BKN 6985-105-P
Mauritania		IR 8, TNI, BR 51-118-2, I Kong Pao, Thiu Thio Way, BG 34-8, IR 1561-228-3		
Niger		BR 51-118-2, BW 196, IR 269-26-3-3, (TOs 78), NTU 770-7-2, IR 1529-680-3, IET 2885, BG 90-2, BW 5146-5, IR 22		T 442, FARO 7, BKN 6232, FRRS 43/3, Neang-Kiew 5, MALOBIAN, AA8A MALJONG, FARO 14
Nigeria	Sel IRAT, 195/1/2/OS 6a, IRAT 136, IRAT	IR 20, BG 90-2a, IR 1529-680-3, IET 2885, ITA 123, IR269-26-3a, (TOs 78), BR51-46-5, BR51-118-2, BR-49-6, IR665-79-2 (TOs 42)		FARO 14, BKN 6323
Senegal	I Kong Pao, SE 302 Ga, IRAT 110, DI 11-509a	I Kong Pao, IR 8, Jaya, BG 90-2, BR 51-46-5, IR 442-2-58, BR 51-118-2, D 52-37	ROK 5	ROK 5
Sierra Leone	ROK 16, LAC 23a	4414, IET 1996, BR 51-118-2	ROK 5, Djapon	
Togo	LAC 23, IRAT 10, ADNY 8, IR 442-2-58, IRAT 13, SE 304 G	IR 1529-680-3, IET 1444, IR 20, ADNY 11, BR 51-319-9, BG 90-2 IR 1416-131-6, IR 1442-2-58 IR 841, IR 1529-680-3		

1 Variety identified in the country before entering coordinated trials.

screening of newly introduced or developed varieties, and Coordinated Varietal Trials (CVT), essentially yield trials. These trials were carried out at WARDA's Regional Research Stations and in member countries to identify valuable genetic material and to develop appropriate technology suitable for the different ecosystems. Table 5 shows several promising cultivars which have gone through the WARDA-coordinated trial program and are now being grown as released varieties or are at the seed multiplication stage in some member countries.

CONCLUSION

Rice evaluation in Africa is an important aspect of varietal improvement activities. Many useful traits have been identified from local and exotic germplasm materials. Some of these traits have been incorporated into rice breeding programs. Evaluation of improved germplasm has produced many varieties now grown in Africa.

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5.2

Bean Evaluation in Africa

J. M. BOKOSI

The common bean, *Phaseolus vulgaris*, is one of the most important legume crops in many countries of Africa. The African continent is the world's second leading producer of the bean (after Latin America) and 110 million people in sub-Saharan Africa live in countries where beans are the leading non-cereal source of protein. According to figures produced by the Food and Agriculture Organization of the United Nations (FAO), Africa produced 1.64×10^6 t from 2.5×10^6 ha in 1984.

As defined by the International Board for Plant Genetic Resources (IBPGR), evaluation is a systematic study of the technical attributes of the collected materials in respect of such features as yield, quality, resistance to diseases and pests, adaptation to environment and cultural conditions (Jain, 1981). Evaluation is concerned with performance characters which are generally physiological, quantitatively variable and subject to genetic (G), environmental (E) and GE effects, and is of essentially local significance. Jain (1981) argues that systematic evaluation will lead not only to stimulating discoveries of useful genetic materials, but also to new ways of assembling plant materials and biosystematic and ecological information, which in turn will lead to an acceleration of the rate of discovery.

Africa has a large collection of bean germplasm, much of it in the form of landraces rarely influenced by crop improvement programs. These landraces offer a wide range of genetic diversity. Malawi, for example, has nearly 4,000 bean accessions exclusively as landraces. In addition to these local collections, Africa continues to receive bean genetic resources from other sources. The Centro Internacional de Agricultura Tropical (CIAT), with a collection of about 35,000 bean accessions, is a prominent source. But there is no use in collecting and storing such examples of genetic variation in crop plants unless some use is going to be made of the information. This, after all, is the whole reason for genetic conservation. The usefulness of any genetic variation can be identified only through proper evaluation of the available gene pool. Evaluation is an exceedingly complex operation. Screening results may be obtained in a variety of research institutions by agronomists, breeders, plant pathologists and others. This requires collaborative efforts at the institutional, national and international levels. Genebanks and international organizations have a role to play in such collaborative work.

Because the amount of information associated with evaluating beans is already so large, the establishment of a suitable computerized information storage and retrieval system is obviously essential. The system must provide data on the genetic stocks to plant breeders rapidly and reliably.

CURRENT STATUS OF BEAN EVALUATION IN AFRICA

Yield

Evaluation on yield has received the highest priority over the years, and the trend is likely to continue because of the consistently low yields associated with many of the African bean-producing areas. The objective is to evaluate the local bean genetic resources and as many of the improved germplasm materials from other sources as possible. Being a highly quantitative trait and subject to environmental influences, yield can be meaningfully evaluated only at local sites. Results are usually of local rather than international significance. With this in mind it, would be very difficult to identify varieties that could be termed as the highest-yielding varieties in Africa. However, certain varieties have been reported as being high yielding in specific African countries.

A number of lines from CIAT's Bean Program annual report (CIAT, 1984) have reached advanced stages of testing in certain countries: a bush bean line, ICA-Palmar, is being tested in on-farm trials in Rwanda as Rubona 5; and in Zambia, BAT85 and Carioca (the latter introduced from Brazil via CIAT) were the highest-yielding lines in Zambia's advanced bean varietal trial in 1983-84. In on-farm trials in Zambia's Central Province, Carioca yielded three to four times as much as local cultivars under all agronomic treatments. Table 1 shows the performance of the five best varieties from the Mexican highlands when tested in the Great Lakes region (Burundi, Rwanda and the Kivu region of Zaire) in 1984. But the most impressive results are those from the ISAR Rwerere advanced yield trial conducted in 1983 (see Table 2). In Tanzania, Magehema and Ndunguru (1984) reported that variety Kabanima yielded over 6000 kg/ha.

Disease and insect pest resistance

Africa suffers from a wide range of bean diseases and insect pests. The occurrence, severity, damage caused and importance of these diseases and insects varies with location and seasons. Among the most important diseases in East Africa are: anthracnose, *Colletorichum lindemuthianum*; angular leaf spot, *Phaeoisariopsis griseola*; halo blight, *Pseudomonas phaseolicola*; common bacterial blight, *Xanthomonas compestris*; rust, *Uromyces phaseoli*; and blackroot or bean common mosaic virus (BCMV). Among the common insect pests are: beanfly, *Ophiomyia* species; and bruchids, *Zabrotes subfasciatus* and *Acanthoscelides obtectus*.

Resistance to anthracnose has been identified in some Malawian bean landraces: C76-4, C76-2, C61-5 and C151-28 (Bokosi, 1986). In Kenya, the variety GLP-X.92 is reportedly resistant to halo blight (Smit et al., 1984), while GLP-X.806 is resistant to angular leaf spot and fairly resistant to rust. In Tanzania, TMO117, TMO 75 and TMO 91 showed moderate resistant to beanfly (Rwamugira and Karel, 1984). CIAT has also been evaluating bean

TABLE 1 Yields of the five best varieties from the Mexican highland IBYAN (group 45.000) and their control varieties at each of six sites in the Great Lakes region in the 1984B cropping season

Site	Variety	Yield (kg/ha)	Site	Variety	Yield (kg/ha)
ISABU, Imbo (860 msl)	Carioca	738	ISABU, Mosso (1,260 msl)	Carioca	1,501
	A 344	852		A 114	1,481
	A 409	782		BAT 1671	1,493
	A 442	619		A 439	1,436
	A 321	616		A 344	1,392
	Control varieties			Control varieties	
	Calima	274		Calima	1,402
	Karama	176		Karama	1,399
ISABU, Murongwe (1,470 msl)	A 411	1,371	INERA, Mulungu (1,731 msl)	A 321	1,877
	A 344	1,210		A 344	1,886
	A 114	1,197		A 262	1,817
	Carioca	1,110		BAT 1671	1,785
	BAT 1671	1,098		A 439	1,727
	Control varieties			Control varieties	
	Urubonobono	1,150		Munyu	701
	Local mixture	833		Muhinga	890
ISAR, Rubona (1,650 msl)	A 442	2,233	ISAR, Karama (1,300 msl)	A 439	1,760
	A 410	2,207		A 410	1,710
	BAT 1671	2,183		A 321	1,660
	A 344	2,143		A 411	1,490
	A 321	2,120		A436	1,490
	Control varieties			Control varieties	
	Rubona 5	1,910		Ikinimba	1,450
	Ikinimba	1,513		Var	1,380

Source: CIAT, 1984

TABLE 2 The ten best climbing bean varieties in the ISAR Rwerere advanced yield trial, September 1983 planting

Identification	Country of origin	Source	Average yield (kg/ha)
G 858	Mexico	CIAT	6,407
ICA VIBORAL	Colombia	CIAT	5,298
C 8	Zaire	Zaire	4,876
G 811	Mexico	CIAT	4,859
G 2373	Mexico	CIAT	4,854
G 2333	Mexico	CIAT	4,840
G 11820	Colombia	CIAT	4,698
C 10	Zaire	Zaire	4,590
URUNYUMBA 3	Rwanda	Rwanda	4,534
GISENYI 6	Rwanda	Rwanda	4,047
Cajamarca (control)	Peru	Gembloux	4,812

Source: CIAT, 1984

germplasm in the Great Lakes region and has identified some sources of resistance for several diseases (*see* Table 3). The necrotic reaction to BCMV has been a general problem in lines introduced from CIAT, but some lines have been identified which do not show either mosaic or blackroot symptoms to any significant extent; these include BAT 1386, BAT 1426 and VCA 81007. (CIAT 1984)

CIAT has set up several international bean nurseries for germplasm evaluation on diseases. Among these are the International Bean Rust Nursery (IBRN), the International Bean Anthracnose Test (IBAT), the Bean Angular Leaf Spot International Test (BALSIT), the International Bean Common Bacterial Blight Nursery (VIB) and the International Bean Web Blight Nursery (VIM). The principal objective of all international nurseries is to identify sources of genetic resistance. Some of the materials from these nurseries are already being evaluated in a number of African countries.

In Malawi, a CIAT/Southern African Development Coordination Conference (SADCC) subproject to screen for angular leaf spot is almost under way. Two of the subproject's objectives are:

- to screen the bean germplasm collection in Malawi (over 3,000 accessions of landraces), 20 promising resistant lines from BALSIT and five lines from each of the bean-growing countries in the SADCC region for resistance against the common *Pg* pathotypes in Malawi and the SADCC region;
- to establish an angular leaf spot nursery to serve the SADCC region.

Drought

It has become apparent in recent years that great fluctuations in total bean production in some countries in Africa result mainly from inadequate rainfall and its uneven distribution. This has resulted in increased interest in evaluating for drought tolerance.

In Kenya, several cultivars (GLP-X.806, GLP-X.92, GLP-X.1004 and GLP-X.1127) have been shown to be well adapted to the country's semi-arid areas (Floor-Press, 1984). CIAT, in collaboration with some African countries, has recently been involved in evaluating materials for tolerance to drought stress. The establishment of the Bean International Drought Adaptation Nursery (BIDAN) are examples of CIAT's involvement. In the near future, a drought nursery will be set up in the SADCC region.

Nitrogen fixation

Evaluation for increased nitrogen fixation is becoming increasingly important in Africa. The reason for this is that many of the smallholder farmers grow the bean crop in less fertile soils and are finding it difficult to obtain inputs such as fertilizers, which are expensive and often unavailable. These are contributing factors to the low yields associated with many of the African bean-growing countries.

Varietal differences in nitrogen fixation in dry bean-*Rhizobium* association has been detected in some field evaluations. This forms a basis for a continued search for lines that, in association with the right *Rhizobium*, can fix considerable amounts of nitrogen. A number

TABLE 3 Varieties with few or no symptoms to indicate diseases in the Great Lakes region, Africa

<i>Colletotrichum lindemuthianum</i>	G.H. ¹	<i>Isariopsis griseola</i>	G.H.	<i>Ascochyta</i> spp.	G.H.	BCMV (no symptoms)	G.H.	<i>Pseudomonas syringae</i>	G.H.	<i>Xanthomonas campestris</i>	G.H.
A 483	I	A 240	II	GUAT 196-B	IIIB	G 4449	I	BAT 1220	IIIA	XAN 42	IIIA
A 484	I	A 281	II	V 8010	II	G 7587	I	G 790	IVA	XAN 112	II
AB 136	IIIB	A 337	II	BAT 1225	II	A 480	I	Red Kote	I	XAN 125	II
Ecuador 299	IIIB	A 338	II	BAT 1486	II	A 482	I			BAT 1336	II
7290	IIIA	A 340	II	VNA 81006	IIIB	BAT 1373	I			BAT 1449	II
		BAT 431	II	VNA 81022	IIIB	BAT 1386	I				
		BAT 1432	II			PAD 41	I				
		BAT 1435	II								
		BAT 1510	II		I	PAD 43	I				
						PVA 721	I				
						PVA 783	I				
						PVA 1216	I				
						ORFEOINIA	I				

1 G.H. = Growth habit
Source: CIAT, 1984

of lines have already been identified (RIZ 10, RIZ 13 and RIZ 29) and have reportedly been performing well in international nurseries (CIAT 1984). Although much of the CIAT work and results on increased nitrogen fixation are based in Latin American countries, some of these materials could prove useful in Africa.

A CIAT/SADCC regional collaborative research subproject is almost under way in Malawi to screen the Malawi bean germplasm (mostly landraces) and some bean lines from other countries for nodulation in relation to nitrogen fixation.

FUTURE DIRECTION OF BEAN EVALUATION IN AFRICA

It is apparent that there are enormous and diverse bean genetic resources in Africa and that only a limited amount of this germplasm has been fully evaluated. It is also worth noting that the process of evaluation is a continuous one and depends very much on the demands and diversity of humans as well as the environment. What seem to be inferior and valueless genetic resource materials now could turn out to be superior and valuable later on.

The role played by the international genebanks will inevitably increase the bean germplasm collection for the African countries that grow this crop. This expansion in procurement of bean genetic resources has its own implications. It will require an improvement in seed storage systems, an expansion of local (national) genebanks, proper documentation, efficient data management and retrieval systems, and training of personnel, among other factors. Many African countries will need assistance in addressing some or all of these crucial factors. IBPGR has been involved, directly or indirectly, in the collection, preservation and documentation of the world's genetic resources, and its achievements are worth praising. Nevertheless, continued effort and support should be given to the evaluation of the *Phaseolus* crop, especially in Africa where current bean yields are low and hunger is more prevalent.

Special attention should be given to evaluating bean mixtures, bean lines which are adapted to mixed cropping and the usefulness of species of *Phaseolus* other than *P. vulgaris* and its wild relatives.

In East Africa, beans are grown mainly in mixed cropping systems. These mixtures offer some security against adverse environmental factors because, overall, they tend to be more stable. In addition, mixed cropping allows for maximum utilization of scarce resources, especially land. The average farm size in the Great Lakes region is less than 1 ha.

The usefulness of wild bean germplasm cannot be overemphasized. In a search for resistance to the pests, Cardona and Posso (1987), at CIAT, evaluated more than 8,000 cultivated bean varieties, but no adequate levels of resistance to the bruchids *Zabrotes subfasciatus* and *Acanthoscelides obtectus* (the most important pests of stored beans in Africa and Latin America) were detected. However, high levels of resistance to both species of bruchids were identified among some wild beans of Mexican origin. The wild resistant varieties so identified were small-seeded, dehiscent climbers that could easily be crossed with cultivated varieties. This example, among many others, stresses the need for increased effort in evaluating more of the unexplored bean genetic resources.

Another area of prime importance lies with the composition of the 'evaluation team'. In many East African countries, women play a major role in bean production. In Rwanda they play a predominant role in seed selection and seed storage (CIAT, 1984). In these circumstances, therefore, it is imperative that women be included in the evaluation team, especially when conducting on-farm evaluations. The acceptance of any new varieties/technologies

will depend largely on the perception of the grower and consumer, and such people should be incorporated into the evaluation process. In the past, much of the evaluation exercise was confined to biological scientists; consequently, there was little success in transferring their technology to the farmers. Inclusion of growers/consumers in the evaluation team will help formulate meaningful objectives and ensure success in the adoption of new and improved bean varieties/technologies. Social studies in Malawi (Ferguson and Sprecher, 1987) and Rwanda (CIAT, 1984) have already revealed valuable information on the selection and acceptability of bean line mixtures.

Finally, there is a need to explore the usefulness of a number of evaluation tools. Any that offer efficient and reliable results should be given more attention. For instance, electrophoresis has been used by Okiror et al. (1982) to determine genetic and/or biochemical variation among bean lines resistant and susceptible to anthracnose based on two enzyme systems — peroxidase and esterase. Furthermore, electrophoresis can be used for screening against unnecessary duplicates of bean genetic materials, thereby ensuring efficient utilization of genebank space, and for checking the loss of genetic diversity.

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5.3

The Regional Program on Beans, Phaseolus vulgaris L., in Southern Africa: Strategy and Progress in Plant Improvement

D. J. ALLEN and J. B. SMITHSON

The common bean, *Phaseolus vulgaris*, was introduced into Africa from the Latin American gene center by European traders during the past four centuries. Africa is now the second most important bean-producing region of the tropics, following Latin America. The total average annual production in Africa is estimated at about 2 million tons, but as a large part of total production is consumed locally and is thus not included in FAO statistics, this figure may be an underestimate. The area under bean production in southern Africa is shown in Table 1 (overleaf).

Although bean production in Africa has increased over the past decade, this has been achieved through area increases; productivity has been stagnant (at about 500 kg/ha). Production increases have not kept up with population growth rates, so that per capita consumption is falling. Beans play a critical role in human nutrition in many parts of East and Southern Africa, providing up to 45% of total protein consumption in Rwanda and Burundi and nearly the same proportion in Uganda and Malawi.

Small farmers are the principal producers of beans in most of Africa. Most of the crop is cultivated in associated cropping systems with maize or bananas. In Malawi, for example, only 1% of total production of grain legumes is estimated to be in monoculture. Most production is for subsistence, and the use of fertilizers and pesticides is uncommon.

Insect pests (especially bean fly), diseases, soil infertility and periodic water shortages are considered the principal agronomic constraints associated with low yields. The most important diseases include anthracnose, angular leaf spot, rust, common bacterial blight, halo blight and bean common mosaic virus, all of which are seedborne and occur wherever the bean crop is grown. As many of the same diseases occur in both Latin America and Africa, control measures developed in Latin America could be usefully transferred to Africa. However, there are factors that are not common to both continents. For instance, beanfly and scab are both found on beans in Africa but not in Latin America.

TABLE 1 **Bean production in southern Africa**

Country	Area (10 ³ ha)
Angola	67
Botswana	1
Lesotho	9-30
Malawi	133
Mozambique	40
Swaziland	1-2
Tanzania	400-500
Zambia	100

Nevertheless, there are many similarities between the bean production systems in these two continents, and the prospects for the effective transfer of technology to Africa appear to be promising, provided that it is appreciated that the transfer of 'finished' technology is unlikely to prove more than a short-term expedient and no substitute for the permanent strengthening of local research capability.

Bean research has a long history in Africa and has continued to increase in importance over the past few years. Many national programs are backed by a reasonable infrastructure, although seed storage equipment, field equipment and transport for on-farm research not available for purchase in local currencies are generally inadequate for efficient deployment of the available research manpower.

The adequacy of human resources available to these national research programs varies greatly. Tanzania, for instance, with an estimated average annual production of about 400,000 t of seed, has at least 12 graduate scientists (five with PhDs completed or in progress) who spend at least 50% of their research time on beans, among four separate national institutions. Not all countries are so well endowed. In recent years, agronomy in general appears to have received less attention than breeding and crop protection. All countries, however, place priority on improving the training of their research staff, both graduates and technical assistants.

OBJECTIVES, ORGANIZATION AND PHILOSOPHY OF THE CIAT REGIONAL BEAN PROGRAM IN SOUTHERN AFRICA

CIAT's activities in support of national efforts in bean research have the following broad objectives:

- to increase bean productivity and production by breeding and selecting higher-yielding genotypes identified from a more diverse germplasm base, from both introduced and locally adapted landraces; such cultivars are likely to be selected for yield stability, relying on resistance to biotic and abiotic stresses, and for consumer acceptability;
- to develop more productive cropping systems, using promising new cultivars and varietal mixtures when appropriate, but ensuring that such innovations remain acceptable to producers and consumers and do not disrupt existing farming systems adversely;

- to help strengthen national research programs, to a degree that is both appropriate and sustainable nationally, by giving substantial emphasis to training; training is offered to postgraduate scientists at universities within or outside the region, with or without periods of research with CIAT programs; short-term training is encouraged, within or outside Africa. On-the-job training is an important part of the first two objectives.

In the first meeting of bean researchers in Africa, held in Lilongwe, Malawi, in March 1980 (Anon., 1981), CIAT was asked by delegates from the main bean-producing countries of East and southern Africa to mount a regional program to support national bean research in Africa. After some years of negotiation, it became apparent that no single donor was prepared to support the entire East and southern African region. CIAT therefore sought to establish projects in geographical subregions, based on agroecological and/or economic factors, for which funding could be obtained.

By 1983 CIAT was in a position to set up a regional program for the Great Lakes region (Burundi, Rwanda and the Kivu province of Zaïre) with Swiss support, and a full regional team is now in operation, based at a coordinating center in Rwanda. Toward the end of 1984, funds from the Canadian International Development Agency (CIDA) and the United States Agency for International Development (USAID) became available for establishing operations in the rest of East Africa, including Uganda, Ethiopia, Somalia and Kenya. The regional coordination center for these countries is in Ethiopia. Further funding from CIDA has enabled CIAT to establish a third regional base, at Arusha, Tanzania, to serve the SADCC countries. Each of the three regional programs is located, by agreement with the respective national research institution, with a national bean improvement program. The southern African program is jointly operated by CIAT and the Southern African Centre for Cooperation in Agricultural Research (SACCAR), an arm of SADCC.

CIAT's philosophy in operating these programs is that their principal objective is to strengthen national programs in such a way that they become fully effective, practically orientated interdisciplinary research teams that remain effective after the withdrawal of external support (Laing et al., 1984). Each regional program is monitored by a steering committee that meets twice a year. The committee for the CIAT/SADCC project is composed of the national bean research coordinators, the regional coordinator and representatives from CIDA and SACCAR. The general functions of the steering committee are to guide CIAT in its implementation of support functions and to set priorities for the region. Chairmanship and venue of the meeting rotate among countries.

If the improved cultivars of beans which are now available to national programs are appropriately integrated within more productive but sustainable cropping systems, and if national and regional programs work more effectively together to establish a strong network of scientists, then we may expect to bring about a green revolution based on grain legumes in Africa. The need to do so is real enough.

STATUS OF BEAN IMPROVEMENT IN AFRICA: EXISTING CULTIVARS

The products of organized breeding programs are cultivated on a large scale only in Ethiopia, northern Tanzania, Kenya and the commercial lands of Zimbabwe. All rely on introduced cultivars for the production of canning, snap and other types of beans for export. In northern Tanzania, the multiplication of bean seeds for export to Europe is an important industry.

Elsewhere, the varieties being cultivated are the direct or indirect descendants of successive introductions from the Americas from the 16th century onwards. They are almost exclusively indeterminate, usually bush or semi-climbers. Climbers are found everywhere in compounds, scrambling over fences or other crops, but the only area where they are cultivated on a large scale is in the highlands of the Great Lakes region. Nevertheless, provided suitable staking materials are available, the replacement of bush types by climbers would be a means of making substantial increases in yield in many situations.

These local cultivars are usually cultivated as mixtures of seed types that vary in complexity from area to area. In the Great Lakes region, southern Uganda and Malawi they are exceedingly complex, averaging 10 or more components, ranging in color from white, through yellow and green to reddish-brown and purple and with varying color patterns, sizes and shapes. In northern Zambia and adjoining areas, mixtures are less complex, being based mainly on yellow and white seeds.

The reasons for the use of mixtures are not properly understood. Theoretically, mixtures should confer yield stability and, in the Great Lakes region, mixtures are deliberately composed for specific situations. In most areas, mixtures command reduced prices in local markets and their components are sorted into color categories for sale. Whether reconstitution is deliberate or because of seed shortage is not always clear. Whatever the reason, mixtures are common in Africa.

RECENT DEVELOPMENTS IN PLANT IMPROVEMENT

Recent plant introductions have pursued relatively similar courses in most countries. Crop improvement programs were established in the 1960s and led to a series of cultivars from generally limited local collections and introduced materials from Europe and the USA. In Tanzania, emphasis was on seed or canning beans for export; in other areas, such as Malawi, beans were for local consumption.

In Tanzania, work on crop improvement began in 1959, at the Northern Research Centre at Tengeru, and resulted in the release of two white pea bean types in 1965 and two other cultivars in 1979. Subsequently, another of these earlier introductions was released as Lyamungu 85. In on-station trials this cultivar has produced 38% more yield than the currently grown Canadian Wonder and 14% more on-farm (*see* Table 2). More recent introductions are showing improvements over Lyamungu 85 (*see* Table 3).

In Malawi, there was much greater emphasis on local collection. Organized plant improvement was started in 1969 by the agricultural faculty of the University of Malawi at Bunda College. Some 11,000 collections were made, covering three-quarters of the country. Six cultivars were released. In association with Michigan State University, collections in the late 1970s and early 1980s added a further several thousand accessions to the genebank. More thorough evaluation of this important collection is now under way (Mloza-Band, 1987).

From the 1970s onwards, programs have tended to expand, often with the help of overseas funding. Sources of variability have been expanded by further introduction and some collection, and the products are moving through national testing systems. During this period, CIAT has been the major source of materials for most national programs. For example, since 1982, when a World Bank-funded project was set up, nearly 3,000 different materials have been introduced and tested in Zambia (*see* Table 4) and three cultivars have been quickly released. These are Carioca, BAT 331 and NEP 2, which in large numbers of trials over a

TABLE 2 Seed yields of Lyamungu 85 relative to Canadian Wonder in northern Tanzania

Cultivars	Yield % check	No. of trials	No. of years
On-station			
Canadian Wonder	100 ¹	56	7
Lyamungu 85	138		
On-farm			
Canadian Wonder	100	25	5
Lyamungu 85	114 ²		

1 About 1093 kg/ha.

2 1190 kg/ha.

Source: Tanzania Agricultural Research Organization, unpublished reports.

TABLE 3 Seed yields of promising new lines relative to Lyamungu 85 in Tanzania

Cultivars	Origin/pedigree	Yield % check	No. of trials	No. of years
Lyamungu 85	T 23	100 ¹	7	1
G 5621	Diacol Calima	108		
LB 282		107		
Lyamungu 85	T 23	100 ²	2	1
LB 281		123		
LB 588		115		
LB 86		114		

1 About 1600 kg/ha.

2 2356 kg/ha.

Source: E.M.K. Koinange (unpublished data).

TABLE 4 Numbers of new bean materials introduced into Zambia from CIAT nurseries, 1982-87

Year	IBYAN ¹	VEF ²	Other advanced lines	Segregating populations	Disease/pest nurseries	Total
1982-83	8(1)	0	598	56	0	662
1983-84	26(1)	0	0	0	0	26
1984-85	55(9)	636	0	0	308	999
1985-86	91(9)	404	0	0	332	827
1986-87	15(3)	203	23	0	126	367
Total	195	1,243	598	56	766	2,858

1 International Bean Yield and Adaptation Nurseries.

2 Bean Team Nurseries (Viveros del Equipo de Frijol).

number of years have produced 1.5 and 2.5 times the yields of previously recommended cultivars (*see* Table 5). Others now moving through the national testing system are showing further improvements over the new cultivars.

TABLE 5 Seed yields of Carioca, BAT 331 and NEP 2 relative to previously recommended cultivars in Zambia

Cultivars	Yield % check	No. of trials	No. of years
Misamfu Speckled Sugar	100 ¹		
Carioca	231	26	5
BAT 331	159	16	2
Mexican 142	100 ²		
NEP 2	245	7	1

1 About 400 kg/ha.

2 287 kg/ha.

STRATEGIES FOR EVALUATION

From the foregoing it is clear that there has been long but sporadic introduction of bean germplasm into Africa. Although there is no doubt that recombination and selection will have resulted in novel combinations and sustained others that do not exist elsewhere today, the limited evidence that does exist is that such combinations are not frequent and that immediate substantial benefit can be directly gained from the large genetic resources and new breeding materials that are available through introduction from Latin America and elsewhere.

But how should we proceed? Bean genetic resources at CIAT now number over 35,000 and there are four breeders continuously producing novel recombinants. In addition, we face diverse environments, cropping systems and constraints in Africa, each with its own requirements. Obviously, we cannot evaluate all material in every environment, so for southern Africa we are adopting an ecological approach.

First, in collaboration with Agroecology Unit at CIAT, we are developing a classification of bean producing areas in Africa. So far this has been done for length of growing season and amount of rainfall and mean temperatures during that growing season. Locations in Colombia, where selection and evaluation are being practiced, have been characterized in the same way and areas in Africa that are environmentally similar have been mapped. These indicate, for example, that Darien is similar to Arusha and Mbala; and Popayan and La Selva resemble Lyamungu and Mbeya (*see* Tables 6 and 7).

There are also parallels among African locations, as shown in Table 6. For example, Lichinga in Mozambique and both seasons at Mbala are very similar in character. The same is true of Bunda in Malawi and Msekera in Zambia. It should be possible to exploit such ecological homologies to develop effective and efficient testing strategies.

We obviously now need to examine the reasons for these similarities and differences in greater detail, and to include other factors such as photoperiod and soil type in our analysis.

This environmental analysis is of use only if it enables us to interpret and perhaps predict genotypic behavior. Some information is available from earlier work but this tends to be

TABLE 6 **Characteristics of research stations in southern Africa**

Station	Latitude (°)	Altitude (m)	Rainfall per season (mm)	Temperature (°C) Max. Min.	
Tanzania					
Arusha	3 20	1,402	600	24.2	14.8
Morogoro	6 50	579	670	30.3	20.3
Lambo	3 16	1,067	786	27.2	17.2
Lyamungu	3 13	1,250	1,256	23.9	14.9
Mbeya	8 55	1,736	662	22.4	12.9
Malawi					
Bunda	13 58	1,134	785	27.0	17.2
Zambia					
Msekera	13 33	1,032	958	27.4	18.0
Mbala	8 51	1,673	786	24.8	15.0
			816	24.1	14.1
Zimbabwe					
Harare	17 50	1,470	773	26.0	15.5
Lesotho					
Maseru	29 19	1,528	367	26.3	12.2
Mokhotlong	29 17	2,195	353	22.6	7.6
Mozambique					
Chokwe	24 32	33	100	27.2	12.3
Umbeluzi	26 02	12	531	32.1	20.4
Lichinga	13 17	1,364	938	25.0	15.7
Swaziland					
Malkerns	26 32	730	646	26.0	15.6
Nhlangano	27 07	1,036	539	24.8	14.4

TABLE 7 **Characteristics of research stations in Colombia**

Station	Latitude (°)	Altitude (m)	Rainfall per season (mm)	Temperature (°C)	
				Max.	Min.
Cali	3 30	965	477	29.1	19.4
			390	28.9	19.0
Darien	3 49	1,360	464	24.7	14.7
			457	24.4	14.4
Popayan	2 25	1,760	697	23.0	13.0
			1,088	22.6	12.6
La Selva	6 20	2,200	826	21.9	11.2
Obonuco	1 12	2,700	530	17.4	8.3

incomplete and inconsistent. One approach is to relate the behavior of the same set of genotypes to environmental changes across a range of locations and seasons. This is one of the aims of the African Bean Yield and Adaptation Nursery (AFBYAN), established in 1987. AFBYAN comprises a set of 25 entries contributed by national programs involved in the regional projects. Its purposes are to initiate a regional nursery network, make the best materials more available, assist in the classification of environments for beans and interpret variations in performance across environments in terms of physical and biotic environmental factors.

So far we have grown AFBYAN entries at 10 locations and have conducted preliminary analyses of data for seven of them. Combined analyses of variance indicate that genotype $\times$ environment interactions account for substantial proportions of the total variation and are the same as, or greater than, genotype effects for several important plant characters. For seed yields this is reflected in dramatic changes in ranking of genotypes among environments. For example, K 20 was bottom in two seasons at Kawanda, the area where it was developed, but it ranked top and second in Rwanda and Zambia (*see* Table 8). Differences among entries in regressions and deviations from the regression were a factor in these interactions (*see* Table 9).

As shown in Table 10, we have environmental as well as plant character data. When we have more sets of data, we hope to begin clustering environments according to genotype behavior and interpreting observed variations in performance. Such a strategy should help considerably in directing flows of materials between Colombia and Africa, as well as within Africa, as a basis for effective and efficient breeding strategies for bean improvement in the future.

TABLE 8 **Seed yields (kg/ha) and ranks (AFBYAN 1986-87)**

Entry	Kawanda 6S	Kawanda 6F	Msekera 7F	Rubona 7F	Mulungu 7F	Mean
Black Dessie	1,633 (9)	1,363 (2)	957 (13)	1,251 (25)	403 (10)	1,058 (7)
G 13671	2,275 (1)	845 (11)	553 (23)	1,483 (20)	313 (14)	1,039 (10)
G 2816	1,650 (7)	908 (9)	928 (14)	1,826 (9)	2,543 (1)	1,387 (1)
K 20	81 (25)	271 (25)	1,580 (2)	2,400 (1)	0 (25)	956 (16)
Carioca	1,692 (6)	2,175 (1)	1,175 (7)	1,361 (21)	703 (4)	1,271 (3)
Urubonobono	2,192 (2)	888 (10)	284 (24)	1,851 (8)	280 (5)	1,116 (6)
Nain de Kiyondo	1,567 (20)	577 (21)	799 (18)	1,281 (23)	1,564 (2)	1,034 (11)
G 12470	1,317 (17)	593 (20)	464 (25)	2,165 (2)	652 (6)	968 (14)
XAN 76	1,908 (3)	1,093 (4)	2,049 (1)	1,572 (17)	453 (9)	1,344 (2)

TABLE 9 Stability analysis of seed yields (AFBYAN 1986-87)

Entry	Mean yield (kg/ha)	b	SE	R ² %
Black Dessie	1,058	0.70	0.296	58
G 13671	1,039	1.20	0.427	67
G 2816	1,387	0.20	0.771	2
K 20	970	1.39	0.566	60
Carioca	1,271	0.58	0.559	22
Urubonobono	1,116	1.35	0.356	78
Nain de Kiyondo	1,034	0.38	0.480	14
PVAA 563	916	1.14	0.098	97
G 12470	968	1.16	0.346	74
XAN 76	1,344	0.90	0.409	55

TABLE 10 Plant characters and yield components % total sums of squares (AFBYAN)

	Plant height	Ground cover	DFF	DM	Pods /M2	Seeds /pod	Seed wt	Seed yield
No. of trials	4	4	4	3	4	4	4	6
Environments (E)	19.3 *	27.0 ***	53.2 ***		25.3 ***	2.6 **	8.0 ***	49.9 **
Varieties (V)	10.9 ns	19.3 ***	27.4 ns		24.9 ***	57.3 ***	66.3 ***	5.8 ns
V x E	38.1 ***	21.7 ***	16.7 ***		23.4 ***	13.7 ns	9.5 ns	27.6 ***

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5.4

Food Legume Germplasm Evaluation and Utilization, with Special Reference to Moroccan Chickpea Landraces

L. HOLLY, M. SOHL and M. KAMEL

The International Center for Agricultural Research in the Dry Areas (ICARDA) is one of the centers in the Consultative Group on International Agricultural Research (CGIAR) system. Its main responsibility is to improve food production and sustainability by developing ecologically sound farming systems in areas with under 500 mm annual rainfall in West Asia and North Africa (WANA). Its crop mandates include cereals (barley, durum and bread wheat), food legumes (lentil, kabuli chickpea and faba bean) and pasture and forage legumes. Food legumes received special attention because of their role in complementing cereal based diet, because of their ability to fix atmospheric nitrogen and thus contribute to more sustainable cereal production in low-input agriculture, and because little, if any, research efforts had previously been devoted to the improvement of food legume production in WANA.

To obtain basic material for food legume improvement, diverse germplasm collections were assembled and evaluated by ICARDA's Food Legume Improvement Program (FLIP) soon after ICARDA was established. Later, in 1984, a Genetic Resources Unit (GRU) was established to explore additional sources of genetic diversity to preserve and make available for crop improvement purposes. In 1984-85, the geographic and genetic representation of gene pools of mandated crops in the collections was assessed and priorities for further exploration were assigned. The evaluation of germplasm collections is a joint responsibility shared with the relevant commodity programs. The GRU focuses more on descriptive characterization, while the commodity programs put more emphasis on evaluation for agronomic traits and germplasm enhancement.

FOOD LEGUME PRODUCTION IN NORTH AFRICA

Food legumes are traditionally important crops in dryland agriculture and daily diets throughout the North African region. These crops are grown on about 650,000 ha, which is

about 13% of the total food legume area in the whole ICARDA region. Morocco is the largest producer and accounts for about 66% of the total area planted with food legumes in the Maghreb countries.

Faba bean, kabuli chickpea and, to a lesser extent, lentil are the major food legumes in these countries. Depending on the country, the three crops cover 72-90% of the total food legume area. Morocco and Tunisia are self-sufficient in most food legumes, particularly faba bean, surpluses of which are exported. However, since the early 1970s, the area given over to the three major food legumes in the Maghreb countries has been reduced by 15% and total production has fallen by 36% (see Table 1). This negative trend appears to be continuing; there were extremely low yields in certain areas in 1987 and 1988, as a result of severe drought, the uneven distribution of rainfall and other production constraints.

TABLE 1 Changes in production of major food legumes in North African countries between 1971-75 and 1981-85

Country	Average area (10 ³ ha)			Average production (10 ³ t)			Average yield (kg/ha)		
	1971-75 ¹	1981-85 ²	Change ³	1971-75	1981-85	Change	1971-75	1981-85	Change
Faba bean									
Morocco	231	163	-29	268	119	-56	1167	716	-39
Algeria	32	46	+44	22	23	+5	686	323	-53
Tunisia	55	41	-25	38	36	-5	683	865	+27
Chickpea									
Morocco	98	59	-40	62	37	-40	606	592	-2
Algeria	30	37	+23	16	10	-38	519	258	-50
Tunisia	27	33	+22	16	25	+56	568	748	+32
Lentil									
Morocco	39	61	+56	23	27	+17	598	418	-30
Algeria	20	11	-45	18	14	-22	388	132	-66
Tunisia	3	1	-67	1	1	0	407	802	+97

1 Hammawi, 1979. Food legume production: The contribution of West Asia and North Africa to the world situation. In Hawtin, G. C., and Chancellor, G. J. (eds.) *Food Legume Improvement and Development*.

2 ICARDA/IDRC/FAO Production Yearbooks, 1983 and 1984.

3 Change as a percentage.

In view of the negative production trends and the very high population growth rate in the region, there has been keen interest to increase self sufficiency in major staple field crops including food legumes. ICARDA has a major role in assisting national institutions to develop and execute improvement programs on its mandated crops in order to increase food production in these countries. In earlier years, the national programs were not able to effectively utilize the genetic material and agronomic trials provided by ICARDA. This was partly because of the lack of funds and of a sufficient number of scientists in the national programs, and partly because genetic material and improved technology supplied by

ICARDA were not specifically targeted to the region. In order to assist the adaptation of improved technology and appropriate germplasm, improvement strategies both at national and regional level have been developed, and ICARDA scientists have been posted to strengthen national research and technology transfer in the North African countries.

FOOD LEGUME GENETIC RESOURCES IN NORTH AFRICA

A survey of the gaps in existing germplasm collections from the ICARDA region revealed that food legumes from North Africa are particularly poorly represented in ICARDA's germplasm collections, and very few accessions were available in other genebanks. The highest priority was therefore assigned to the exploration and collection of these crops in North Africa. It was also noted that landraces of food legumes were still extensively grown in these countries and the rate of genetic erosion was estimated to be much lower than that in cereals (Toll, 1984). (See Table 2).

TABLE 2 Food legume germplasm accessions in ICARDA collections originating from the Maghreb countries (1988)

Country	Faba bean	Chickpea	Lentil	Total
Algeria	33	22	9	64
Morocco	76	212	46	334
Tunisia	50	262	15	327
Total	159	496	70	725

In Morocco, a breeding program started at the Institut Nationale de la Recherche Agronomique (INRA) in 1943, with emphasis on assembling a germplasm collection through introduction, selection within local populations and mutation breeding. Further introductions have been made since 1979 from international agricultural research centers (IARCs) and from different countries. Collection of local material occurred in two phases: from 1945 to 1974, and since 1982, through ICARDA and the International Board for Plant Genetic Resources (IBPGR). Most genetic diversity in food legumes is maintained in the cultivated landraces and in collections, but there is a potential danger of genetic erosion and loss of the locally adapted material because of more work being devoted to introductions and because of the negative trend of food legume production. In 1987, INRA's food legume collection comprised 830 accessions, including 309 accessions of faba beans, 175 accessions of lentils, 178 accessions of chickpeas and 168 accessions of peas (Kamel, 1987).

The national program in Tunisia has also started to build up and maintain a food legume germplasm collection; 360 samples have been collected with the assistance of ICARDA and the Germplasm Institute at Bari, Italy. It has been recognized that further efforts should concentrate on developing a comprehensive national germplasm collection (Salah, 1987).

In Algeria, food legume improvement work has concentrated on the evaluation and selection of introduced germplasm, originating mainly from ICARDA. The local germplasm

is almost unexplored although ICARDA maintains a total of 64 accessions originating from this country. The availability of a dynamic germplasm distribution program has allowed rapid results which will improve the situation of food legume production at the farmer level, but there is much to do in collecting native germplasm since no major work has been done yet (Maatougui, 1987). Nevertheless, the collection of forage legumes has already started and a food legume collecting mission is planned for 1989 in collaboration with ICARDA and IBPGR.

COLLECTION, EVALUATION AND UTILIZATION OF CHICKPEA LANDRACES IN MOROCCO

The chickpea improvement project at ICARDA is a joint venture with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and it focuses on the kabuli type chickpea which is predominantly grown in ICARDA's region. Work to develop suitable genetic stocks for the Mediterranean regions, including North Africa, considers winter sowing where resistance to *Ascochyta* blight, tolerance to cold, suitability for machine harvesting and medium to large seed size are required, and spring sowing where resistance to *Ascochyta* light and *Fusarium* wilt, tolerance to drought, early maturity and medium to large seed size are required for improved chickpea production (Singh, 1987). The development of improved germplasm is based on the exploitation of a diverse genetic resources collection comprising of 6,804 accessions (in 1988). A total of 6,224 accessions have already been evaluated for morphological and agronomic traits as a joint undertaking between FLIP and the GRU.

The Morocco/ICARDA food legume improvement project, a component of the North African subregional program, is conducted by ICARDA and INRA. The chickpea improvement program focuses on the development of high-yielding cultivars adapted to winter and spring seasons, with good seed quality. Since the merits of winter sowing have been well established, the program puts more emphasis on winter and dual purpose types with resistance to *Ascochyta* blight, large and good quality seeds, and early maturity. ILC 195 and ILC 482 were officially registered and approved for release in 1987 as the first two winter chickpea cultivars in Morocco. (See Table 3)

Several other breeding lines are being tested; they show considerable promise especially for winter sowing. The successful adaptation of winter sowing chickpea lines in Morocco could contribute to a considerable increase of yield. At the same time, the expected spread of new cultivars with sufficient tolerance to *Ascochyta* blight and cold will replace native landraces traditionally sown in spring. Since relatively few local populations have previously been collected in Morocco and utilized either by the national program or ICARDA breeders, urgent action was needed to explore and collect landraces from the main chickpea growing areas before they disappear.

Collection of chickpea germplasm

A collection mission was organized jointly by INRA, ICARDA and ICRISAT in 1987 and covered most of the chickpea-growing areas in Morocco. The route of the mission is shown in Figure 1 (*overleaf*). A total of 122 chickpea seed samples were collected in addition to other

TABLE 3 Evaluation of Moroccan chickpea germplasm at Tel Hadya, 1987-88.
Mean, range and standard deviation of eight characters: days to flowering, flowering duration, days to maturity, canopy width, plant height, first pod height, seed/plant and seed pod

Germplasm	Days to flowering				Flowering duration (days)			
	Mean	Range	Standard deviation		Mean	Range	Standard deviation	
			Mean	Range			Mean	Range
Moroccan accessions	148.4	139-165	4.09	0.68-6.22	27.3	21-35	4.	1.43-7.78
Check 1 (ILC 482)	144.6	144-146	2.64	2.18-3.09	29.8	28-30	2.67	2.18-3.01
Check 2 (ILC 3279)	154.8	154-155	1.17	0.74-1.84	21.3	20-23	1.94	0.68-3.80

Germplasm	Days to maturity				Canopy width			
	Mean	Range	Standard deviation		Mean	Range	Standard deviation	
			Mean	Range			Mean	Range
Moroccan accessions	187.6	177-206	2.86	0.95-8.45	45.3	28-62	15.28	5.35-24.44
Check 1 (ILC 482)	183.5	183-184	2.15	1.69-2.55	43.3	35-49	10.98	7.50-14.67
Check 2 (ILC 3279)	187.6	181-193	2.63	1.83-3.08	37.2	28-43	8.83	7.53-11.13

Germplasm	Plant height				First pod height			
	Mean	Range	Standard deviation		Mean	Range	Standard deviation	
			Mean	Range			Mean	Range
Moroccan accessions	52.3	22-73	7.598	3.86-11.59	21.2	13-31	6.77	2.25-11.67
Check 1 (ILC 482)	48.8	46-52	5.371	2.99-07.99	19.7	16-22	4.48	3.06-6.02
Check 2 (ILC 3279)	64.3	61-69	5.552	5.00-06.36	37.9	35-43	4.95	3.27-6.02

Germplasm	Seed/Plant				Seed/Pod			
	Mean	Range	Standard deviation		Mean	Range	Standard deviation	
			Mean	Range			Mean	Range
Moroccan accessions	33.8	15-74	23.18	5.72-45.71	1.00	0.88-1.16	0.16	0.04-0.43
Check 1 (ILC 482)	47.0	44-56	23.71	18.70-31.66	0.95	0.88-1.03	0.08	0.06-0.11
Check 2 (ILC 3279)	36.3	29-42	14.62	9.62-18.68	0.93	0.87-1.01	0.09	0.06-0.14

FIGURE 1 Map showing route followed during the food legume germplasm collection in Morocco, June-July 1987

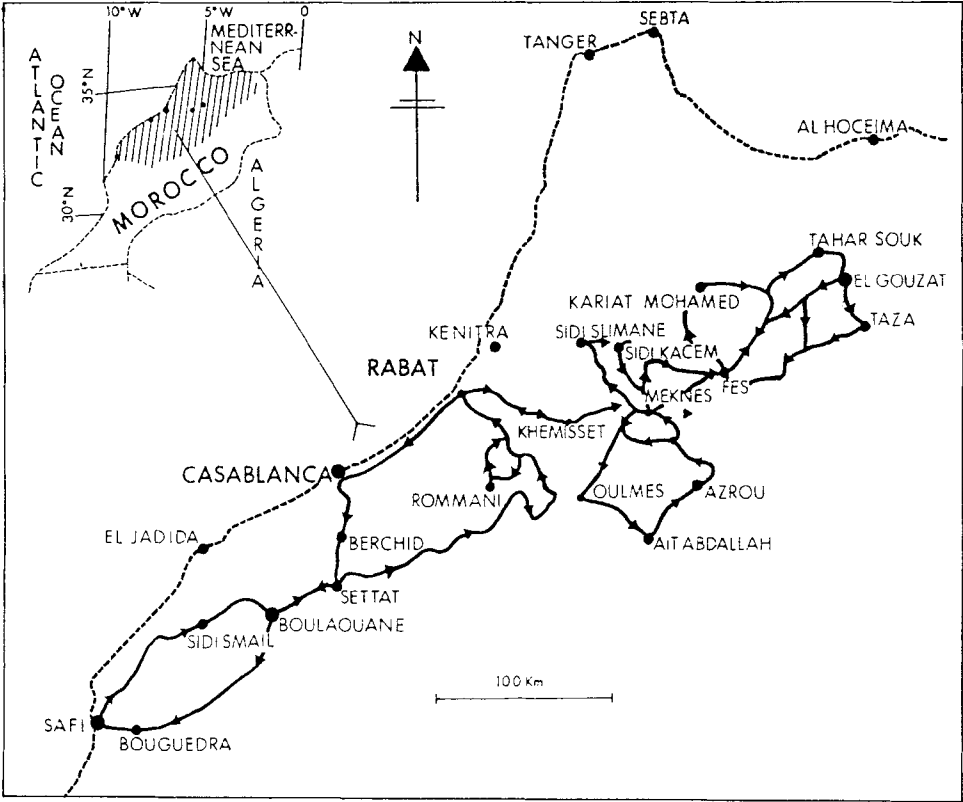
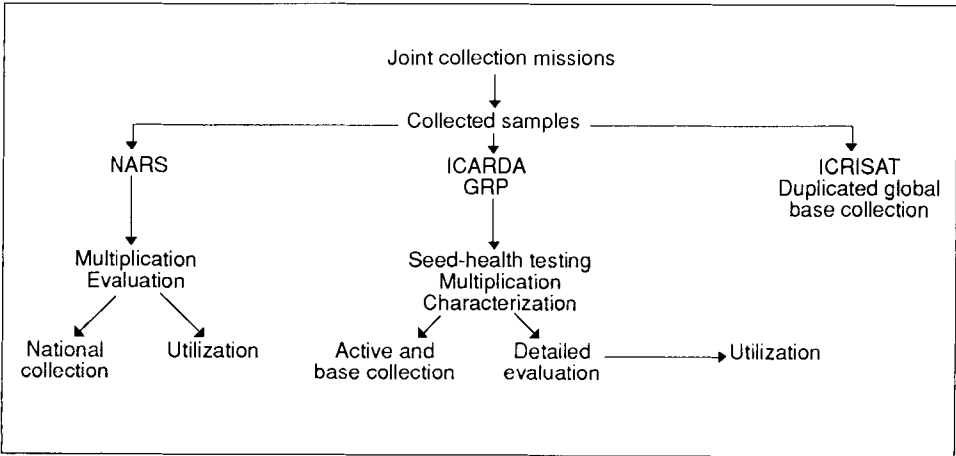


FIGURE 2 Chickpea germplasm management system at ICARDA



food legumes and subsequently shared among the participating institutes (Pundir et al., 1988). The collected germplasm represents a considerable addition to the food legume collections originating from North Africa.

Characterization and evaluation of the collected germplasm samples

The collected samples have been handled according to the germplasm management system developed at ICARDA (*see* Figure 2). Subsamples of the collected germplasm are preserved at ICRISAT in the global base collection and will be evaluated according to the priorities of the chickpea improvement program at ICRISAT. The subsamples left in Morocco were planted by INRA for multiplication and preliminary screening, with the main emphasis on comparing their performance with promising breeding lines developed for winter sowing. The multiplied samples will be preserved in the national germplasm collection and accessions with desirable traits will be exploited in the national chickpea improvement program.

A set of subsamples was planted at ICARDA's experimental fields at Tel Hadya, Syria, in an isolation area for multiplication, health status monitoring and initial characterization.

5.5

Premières investigations sur la diversité des mils pénicillaires sauvages de l'Ouest africain

L. MARCHAIS et S. TOSTAIN

L'équipe ORSTOM de Niamey a collecté depuis 1985 176 échantillons de mils pénicillaires sauvages, *Pennisetum glaucum* subsp. *monodii*, à travers le Sénégal, la Mauritanie, le Mali, le Burkina Faso et le Niger, ce avec le soutien du CIRPG et de l'ICRISAT. (Tostain et al., 1986; Tostain, 1986; Tostain et al., 1988).

La répartition géographique de mils sauvages observés par les prospecteurs permet de définir en Afrique de l'Ouest deux familles géographiques de mils sauvages. Une première famille de mils sauvages occupe de façon plus ou moins continue l'espace compris entre le nord de la Gambie, le sud d'une ligne Nouakchott-Tidjikja-Nema, jusqu'à la longitude de Nema et Nara (au Mali). La seconde famille occupe au nord les massifs de l'Adrar des Iforas et de l'Aïr et les vallées du Tilemsi et de l'Azaouak qui en descendent; cette famille s'arrête au sud sur le plateau du Gourma et les collines de l'Ader Doutchi. Ces deux familles que nous appellerons 'mauritanienne et nigérienne' sont séparées par le delta central nigérien et le désert au nord de Tombouctou.

La collection de mils sauvages commence à faire l'objet d'études morphologiques, enzymatiques, agronomiques et physiologiques associant plusieurs équipes différentes. Le présent document rapporte les premiers résultats acquis depuis un an sur les diversités morphophysiologique et enzymatique.

MATERIEL ET METHODES

L'étude morphophysiologique a été conduite sur un essai semé le 10 mars 1988 au Centre sahélien de l'ICRISAT près de Niamey, comportant des mils sauvages de l'Aïr (2), de l'Adrar des Iforas (8), de la zone pastorale couvrant le Niger, le nord-est du Mali et du Burkina Faso (15), de la zone agricole du Niger (11), du Sénégal (6) et de la Mauritanie (10), soit au total

52 échantillons. Chaque échantillon a été cultivé à raison d'une ligne de 10 pieds, notés pour la date d'épiaison, la hauteur de la tige principale, les longueur et largeur de la troisième feuille sous épi, la longueur d'épi, le diamètre du rachis de l'épi, la longueur du pédicelle d'involucre, la longueur des soies involucreales, la longueur de l'arête involucreale, la longueur de glumelle, le nombre d'épillets par involucre, les longueur et largeur de grain, la vitrosité du grain, le nombre d'épis et l'ornementation des soies. Au total, chaque ligne a été décrite par la date moyenne d'épiaison, les valeurs moyennes des pieds conformes au type sauvage, la fréquence des pieds chibras (intermédiaires entre les formes sauvages et cultivées).

L'étude enzymatique a traité des mils sauvages de l'Aïr (13), de l'Adrar des Iforas (8), de la zone pastorale du Niger et du nord-est Mali-Burkina Faso (29), du Niger agricole (16), du Sénégal (8), de Mauritanie (13) et de l'ouest malien (2). Ces échantillons ont été décrits pour les fréquences de 46 allèles, appartenant à 12 gènes exprimés par huit systèmes enzymatiques suivant la méthodologie utilisée pour étudier la diversité enzymatique des mils pénicillaires cultivés (Tostain et al., 1987).

RESULTATS

L'analyse en composantes principales du dossier morphophysiologique permet d'identifier sur le plan (1, 2) les 4 groupes suivants (*voir figure 1*):

- les mils de l'Aïr et de l'Adrar des Iforas caractérisés par une floraison précoce, des plantes de petite taille à épis petits et très nombreux, une végétation peu vigoureuse et une extrême sensibilité au *sclerospora graminicola*;
- les mils de la zone pastorale 'nigérienne' englobant la vallée du Tilemsi et le Gourma, plus ou moins intermédiaires entre les mils précédents et ceux du Niger agricole;
- les mils du Niger agricole (Tillabéri, Tahoua, Madaoua, Maïné-Soroa) caractérisés par une fréquence élevée de chibras, une floraison plus tardive et une morphologie qui les rapproche des mils cultivés;
- les mils du Sénégal et de Mauritanie caractérisés souvent par une floraison tardive, de hautes tiges et des soies involucreales peu ornées.

La distinction de ces groupes est confirmée par l'analyse factorielle discriminante (*voir tableau 1*).

Les caractéristiques des 4 groupes portées dans le tableau 2 montrent que les mils sauvages du Niger agricole sont clairement contaminés par incorporation de matériel héréditaire d'origine cultivée, dans ce sens où leurs traits morphologiques se rapprochent de ceux des mils cultivés. D'autre part, la distinction géographique des familles 'mauritanienne' et 'nigérienne' s'accompagne d'une différenciation pour la date de floraison et les caractères de végétation mais évidemment peu pour les caractères d'épi et de grain qui définissent la forme sauvage. Il n'est donc pas exclu d'observer à l'avenir d'autres différences, physiologiques par exemple, entre ces deux familles de mils.

La structure enzymatique des mils sauvages a été analysée en composantes principales en même temps que les mils cultivés sahéliens qui ont fait l'objet de précédentes publications

FIGURE 1

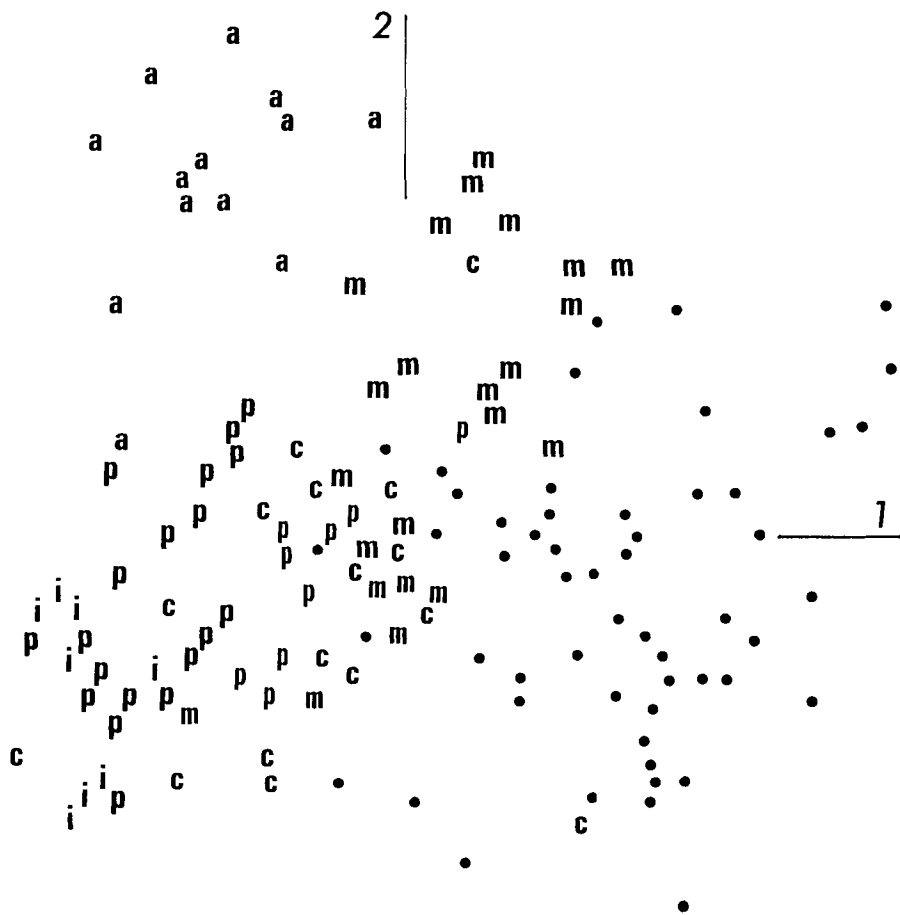


TABLEAU 1 Traitement des groupes morphologiques observés par analyse factorielle discriminante

Groupes morphologiques d'appartenance	Groupes morphologiques d'affectation			
	Air Iforas	Niger pastoral	Niger agricole	Sénégal Mauritanie
Air-Iforas	10	0	0	0
Niger pastoral	0	14	1	0
Niger agricole	0	2	9	0
Sénégal Mauritanie	0	0	0	16

(Tostain et al., 1987; Tostain et Marchais, en préparation). Six groupes enzymatiques apparaissent clairement sur le plan (1, 2) de la figure 2:

- les mils de l'Aïr;
- les mils de l'Adrar des Iforas;
- les mils de la zone pastorale Burkina Faso, Mali et Niger;
- les mils du Niger agricole;
- les mils du Sénégal et de Mauritanie;
- les mils cultivés sahéliens.

FIGURE 2

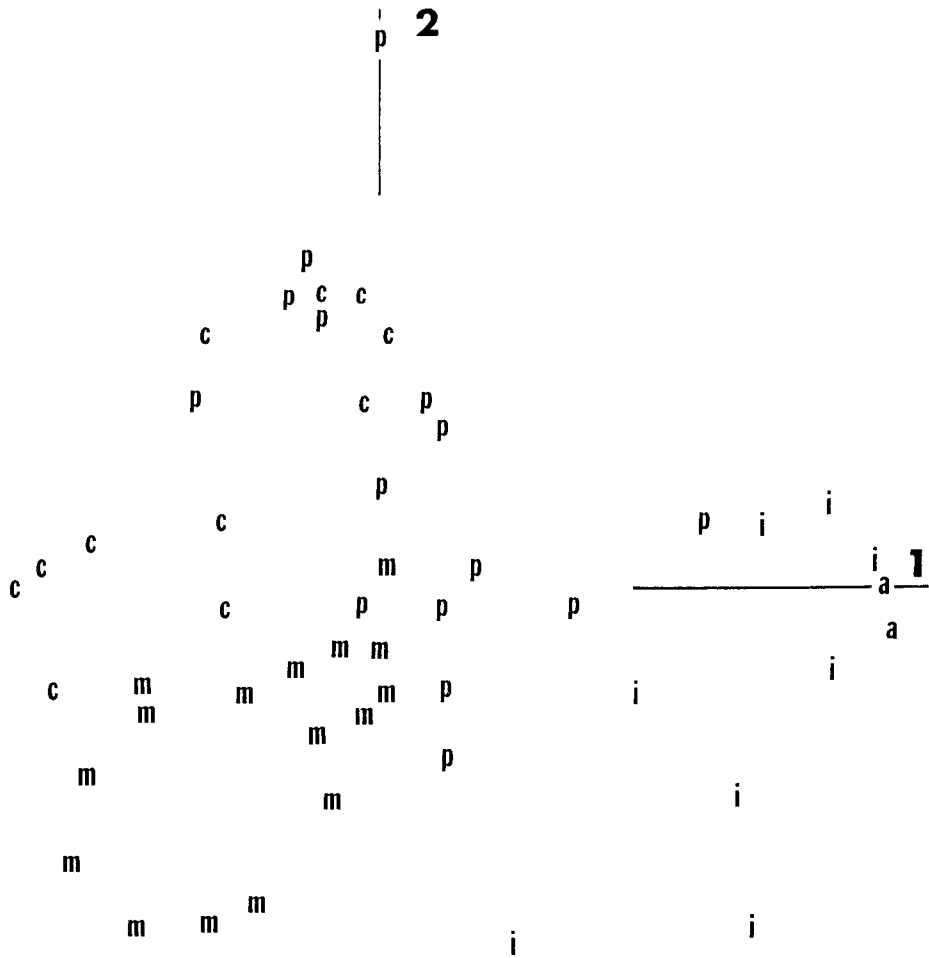


TABLEAU 2 Valeurs moyennes des caractères morpho-physiologiques discriminant les groupes

Groupes	Date floraison	Largeur feuille	Nombre épis	Longueur épis	Diamètre rachis	Longueur feuille	Hauteur tige	Hybrides (%)	Ornementation soies
Aïr, Iforas	35,3	7,4	77,5	8,0	5,7	26,9	92,3	0,0	2,5
Pastoral	47,0	17,0	36,7	11,6	9,9	40,4	128,4	5,3	2,8
Agricole	52,8	17,5	29,7	13,3	11,1	47,2	146,2	34,5	1,8
Sénégal Mauritanie	78,4	18,7	37,5	10,5	9,1	43,6	151,1	5,0	1,7

TABLEAU 4 Paramètres génétiques des groupes enzymatiques sauvages et cultivés de l'Afrique sahélienne

Groupes	Diversité de		Distances de Nei										
	Nei	2,73±0,045	Sauvages			Cultivés							
			Aïr	Iforas	Niger pastoral	Niger agricole	Mauritanie Sénégal	Mali	Mauritanie Sénégal	Niger	Est		
Sauvages													
Aïr	1,88	0,00	0,73	0,53	0,60	0,56	0,73	0,94	0,95	1,42			
Iforas	2,42	0,73	0,00	0,20	0,31	0,52	0,60	0,70	0,76	1,09			
Niger pastoral	2,71	0,53	0,20	0,00	0,05	0,25	0,33	0,50	0,48	0,88			
Niger agricole	2,81	0,60	0,31	0,05	0,00	0,19	0,22	0,33	0,28	0,63			
Mauritanie Sénégal	2,29	0,56	0,52	0,25	0,19	0,00	0,16	0,29	0,25	0,60			
Cultivés													
	2,93±0,061												
Mali	2,81	0,73	0,60	0,33	0,22	0,16	0,00	0,16	0,13	0,38			
Mauritanie Sénégal	2,79	0,94	0,70	0,50	0,33	0,29	0,16	0,00	0,05	0,11			
Niger	2,91	0,95	0,76	0,48	0,28	0,25	0,13	0,05	0,00	0,11			
Est	2,76	1,42	1,09	0,88	0,63	0,60	0,38	0,11	0,11	0,00			

Cette structure en groupes est pleinement confirmée par l'analyse factorielle discriminante (voir tableau 3).

Au sein de la famille Niger, on voit l'influence du mil cultivé sur la structure enzymatique du mil sauvage de la zone agricole: plus le mil sauvage se rapproche des cultures, plus sa structure enzymatique se rapproche de celle des mils cultivés.

TABLEAU 3 Traitement des groupes enzymatiques observés par l'analyse factorielle discriminante

Groupes enzymatiques d'appartenance	Groupes enzymatiques d'affectation					
	Aïr	Iforas	Mali Niger pastoral	Niger agricole	Sénégal Mauritanie	Cultivés sahéliens
Aïr	13	0	0	0	0	0
Iforas	0	8	0	0	0	0
Pastoral	0	2	21	3	3	0
Agricole	0	0	3	12	1	0
Sénégal Mauritanie	0	0	0	1	22	0
Cultivés précoces sahéliens	0	0	0	3	5	46

Comme pour les caractères morphophysiologiques, les caractères enzymatiques montrent qu'il y a échange de matériel génétique entre mils sauvages et cultivés. La figure 2 montre également l'originalité des mils sauvages du Sénégal et de Mauritanie par rapport aux mils sauvages de la famille nigérienne.

Malgré ces différences entre groupes sauvages, l'ensemble des mils sauvages présente des caractéristiques communes qui les distinguent des mils cultivés (voir tableau 4).

- Dans chaque pays, les mils sauvages ont une diversité inférieure à celle des mils cultivés. De plus, l'ensemble des mils sauvages a une diversité (2,73) significativement inférieure à celle de l'ensemble des mils cultivés (2,93). Les mils sauvages isolés dans les montagnes de l'Aïr ou des Iforas sont génétiquement pauvres.
- En règle générale, un mil sauvage est plus proche des autres mils sauvages ouest-africains que des mils cultivés et, réciproquement, un mil cultivé est plus proche des autres mils cultivés que des mils sauvages. En particulier, un mil sauvage du Niger agricole est plus proche d'un sauvage sénégalais que d'un cultivé nigérien.
- Les mils cultivés les plus proches des mils sauvages sont les mils précoces maliens alors que les mils cultivés les plus éloignés sont les mils précoces de l'Est africain (Tchad, Cameroun, Soudan, Somalie et Ouganda). Ce fait suggère que le Mali aurait été un pôle de domestication et que les mils cultivés maliens auraient été peu remaniés par des apports génétiques extérieurs.

CONCLUSION

L'isolement géographique a structuré les mils sauvages ouest-africains en différents groupes morphophysiologiques et enzymatiques: les mils de l'Aïr, les mils de l'Adrar des Iforas, la famille nigérienne et la famille mauritanienne. Le voisinage des mils cultivés a de plus introduit des éléments cultivés dans le patrimoine héréditaire sauvage. Il reste que cette structure sauvage est peu importante par rapport à l'ensemble des mils cultivés sahéliens, à savoir que l'ensemble des mils sauvages ouest-africains ne constitue qu'une seule et même source de diversité génétique, insuffisante pour avoir donné naissance aux mils cultivés.

Les résultats actuels conduisent à poser deux questions:

1. Où trouver des mils sauvages possédant une diversité génétique complémentaire de celle des mils sauvages ouest-africains, suffisante pour expliquer la diversité des mils cultivés.
2. Par quels mécanismes les mils sauvages du Niger agricole ou du Sénégal, contaminés en permanence par les mils cultivés locaux, maintiennent-ils une structure enzymatique différente?

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5.6

Conservation and Utilization of Wild Coffee

M. E. DULLOO and A. W. OWADALLY

There are various commercial sources of coffee. This paper discusses coffee obtained from the genus *Coffea*, family Rubiaceae. The entire genus is endemic to the tropics of Africa and Asia and most of the species are found in the Africano-Madagascar region, including the Comores and the Mascarene islands. The beverage that is widely drunk in the world comes from four main species — *Coffea arabica*, *C. canephora* (= *C. robusta*), *C. liberica* and *C. excelsa* — of which there are many varieties and strains. Several other plants have the word 'coffee' in their common names but do not produce a drinkable coffee. Examples include coffee berry, *Rhamnus californica*, coffee tree, *Polyscias guilfoylei*, wild coffee, *Psychotria nervosa*, and café marron, *Ramosmania heterophylla*. Café marron is a highly endangered plant from Rodrigues Island and is known only from one surviving tree in the wild.

We shall give a brief review of the taxonomy of wild *Coffea* species and discuss the conservation work undertaken on the wild species in the Mascarene region, particularly in Mauritius. Although no utilization work has been done on Mascarene species, the potential of the Mascarene species in deriving hybrids and possible lines of research work are proposed.

TAXONOMIC REVIEW

We do not intend to give a complete review of the systematic studies of the genus *Coffea* but only a short account of the number of species and their distribution. The taxonomy of *Coffea* is still rather confusing, and botanists over the years have not been consistent in listing the number of known species. Some botanists have listed 86 species (Houk, 1939); De Wildemann (1901) listed 36, but in 1910 suggested there were 80 species. Cramer (1957) claimed the existence of about 100 'good' coffee species, while Coste (1955) considered only 60 to be good ones. The recently published Flora of Tropical East Africa on the Rubiaceae family mentions 90 species. Whatever the number, there are probably some coffee species still to be discovered and our knowledge on this issue is still very vague. But it is certain that the entire genus is endemic to the tropics of Africa and Asia.

The genus *Coffea* has been divided into four sections: *Paracoffea* with 12 species; *Agrocoffea* with 9 species; *Mascarocoffea* with 15 species; and *Eucoffea* which is further divided into 5 sections totaling 23 species.

Several of the wild *Coffea* species in Africa are known to occur in Madagascar, and it has been reported that some 50 species are growing in the Madagascar native forest (Cabanis, 1970). Krug (1959) stated that a few representatives of the Madagascar species also occur on the Asian continent. Certain botanists have remarked on the close resemblance between Madagascar species *C. floreifolia* and the Indian species *C. bengalensis* (Leroy, 1962; Narasimhaswamy and Vishreshwana, 1963). Other African countries having wild *Coffea* species include Angola, Gabon, Cameroon, Togo, Côte d'Ivoire, Liberia, Réunion and Mauritius. Haarer (1956) and Wellman (1961) give some notes on the African species that are of economic interest. Many of these are closely related either to *C. arabica* or to the other cultivated species.

There are three species — *C. mauritiana*, *C. macrocarpa* and *C. myrtifolia* — in the Mascarenes. *C. mauritiana* Lam. is a shrub or small tree with verticillate branches and reaches a height of 5 m. The leaves are glabrous, leathery, obovate to elliptical, acuminate, cuneiform and decurrent. The leaves are 4-10 cm long by 2-6 cm wide with 6 to 8 pairs of secondary veins. The petioles are 3-10 mm in length. The stipules are deltoid (2-8 mm long). Inflorescences are axillary and upright. The fruit is ovoid to oblong, 18-20 mm long, and is yellowish-green, becoming purple at maturity.

C. macrocarpa A. Rich. is an evergreen shrub reaching 7 m high and having strong verticillate branches. The leaves are yellowish-green, glabrous, leathery and cuneiform with conspicuous veins; they measure 12-15 cm x 5-8 cm. Stipules are similar to those of *C. mauritiana* but larger (10 mm). The inflorescences are glomerulous and the fruits are ovoid, 25-30 mm by 13-15 mm, tapering at both ends.

It is believed that *C. macrocarpa* is very closely related to *C. mauritiana* and that intermediate forms exist between the two species (Bossier et al., in prep.). There has been a temptation to consider these two species as one, but in the absence of detailed taxonomic and ecological studies *C. macrocarpa* has been retained as a separate species and we tend to agree with this. There exists one distinct form obtained from a collection from Mt Bambous which Leroy (1962) considers to be a form of *C. bernardiana*. According to Leroy, *C. bernardiana*, and certain other species such as *C. campaniensis* should be considered as forms of *C. mauritiana* or *C. macrocarpa*. Chevalier (1947) placed these two species among the *Mascarocoffea* which, according to him, has great affinities with the *Eucoffea* group but differs from it mainly by the absence of caffeine in the beans.

The species *C. myrtifolia* (A. Rich and D.C. Leroy) also belong to the *Mascarocoffea*. It grows in the lowland forest of Mauritius. It is a small tree, reaching a height of 4 m, and has a compact bushy foliage. The leaves are elliptical, obtuse at apex, and sub-decurrent with a pink 3-5 mm petiole. They have 6 to 7 pairs of lateral veins. The stipules are caudate, and the inflorescences are not dense and sometimes occur in pairs. Fruits are ellipsoid, 11-12 mm by 6-7 mm and obtuse at the apex.

BOTANICAL EXPLORATION FOR *COFFEA* SPECIES

As we have seen, the taxonomy of the genus *Coffea* is rather confused and still very uncertain as regards the number of species, varieties and strains. It is important to undertake taxonomic

research in order to clarify these aspects. In addition, there is a need for studying the biology of the plant in the wild (on such aspects as its phenology, flower initiation and development, the number of florescences, seed germination and pollination) and also its ecological requirements, habitats, soil requirements, and so on.

In parallel with taxonomic studies, extensive field studies need to be done, especially in the areas of Africa where few botanical expeditions have been made. These areas may harbor additional *Coffea* species not yet known. As much material as possible has to be collected and, with the help of taxonomists, plants which differ from the cultivated species can be sought. The results obtained need to be documented in National Floras and, with international collaboration, a regional and a world monograph for the genus *Coffea* can be produced. This has become even more urgent considering the rate at which the forest areas in Africa are being cleared.

DISTRIBUTION OF WILD COFFEE IN MAURITIUS

First, it is useful to describe the different vegetation types where wild *Coffea* species are known to occur in Mauritius. Mauritius is third in the world in respect to number of threatened plants, after Hawaii and the Canary Islands. Of the 1,000 species of native plants, about 500 are endemic, including two *Coffea* species. More than 200 species are classified as endangered in the International Union for the Conservation of Nature and Natural Resources (IUCN) list of threatened Mauritian plants. Quite a number of these species are known from only one individual plant or from small localized populations. One of the endemic *Coffea* species, *Coffea myrtifolia*, is known only from a few scattered populations.

The main reason for such a high number of endangered native plants in Mauritius is that the natural forest ecosystems have been profoundly modified over a relatively short period of human impact. The early colonizers —the Dutch, the French and the English — considerably reduced the native forest areas, converting the land into agricultural fields, settlements, roads and other infrastructures. They also introduced a wide variety of exotic plants and animals. These alien gregarious and aggressive species are now causing havoc to the endemic flora and fauna. Owadally (1980) has reviewed some of the forest pests in Mauritius.

Most of the native plants are now restricted to the forests, which have been spared because of their inaccessibility. According to the studies undertaken by Vaughan and Wiehe (1937, 1941) and Vaughan (1968), several vegetation communities have been recognized in Mauritius. These may be divided into two main groups: the lowland dry forest, which receives less than 1,000 mm of rainfall annually; and the wet upland montane evergreen forest, which receives 4,000–6,000 mm rainfall annually.

The lowland forests have virtually disappeared. The few remaining areas which still exist are dominated by such species as *Mimusops petiolaris* (Sapotaceae), *Protium obtusifolium* (Burseraceae), *Diospyros tessellaria* (Ebenaceae) and *Elaeodendron orientale* (Celastraceae). *Coffea myrtifolia* is the wild coffee species which occurs there, but its population is very low indeed.

The upland forest has a very rich diversity of plant species. Although the dominant species —*Sideroxylon*, *Labourdonnaisia* and *Mimusops* species — belong to the Sapotaceae family, there are more species in the Rubiaceae and Myrtaceae families. Rubiaceae is represented by 30 genera with four or five species being endemic to the Mascarenes (Bossier et al., in prep.).

Two of the three *Coffea* species which exist in Mauritius, *Coffea mauritiana* and *C. macrocarpa*, are distributed in the upland forest.

IN SITU AND EX SITU CONSERVATION

Before we can achieve any result in the conservation of a species, it is important in the first instance that there is a willingness on the part of the State to conserve its flora. This willingness must be clearly enunciated as an objective in government policies. Mauritius produced a National Conservation Strategy in 1985 in which it stated its objectives with regard to conservation of natural resources in general. This strategy includes a number of projects, one of which aims at preserving our plant genetic resources. Such an initiative on the part of any government is essential to the success of any work on conservation.

Because of the rapid depletion of the forest areas in Africa, wild populations of indigenous plants are at risk and can disappear from our continent at any time. For this reason, it is important to ensure their survival by taking appropriate actions.

There are two measures which can be taken towards the conservation of *Coffea* species. These are *in situ* and *ex situ* conservation. These two approaches should complement each other so as to ensure the survival of the species. It has been argued that *ex situ* cultivation of species can be no substitute for *in situ* conservation (Ashton, 1985). While this may be true, it is important to undertake *ex situ* cultivation of *Coffea* species so as to obtain enough materials in a short time to enable breeding programs to be effective and to obtain more plants for reintroduction in the wild.

The *in situ* method is by far the most effective in conserving the wild *Coffea* species. In Mauritius, the least degraded areas of native forest, where wild *Coffea* species grow, have been carefully selected and small plots have been set up and weeded. This method is very tedious and expensive. Laborers have to return to the plots time and time again to weed out by hand the exotic plants, principally Chinese guava, *Psidium cattleianum*, privet, *Ligustrum robustum* var. *walkerii*, and *Ardisia crenata*. It is neither practical nor recommended to use mechanical devices and/or herbicides to eradicate the pests as this disrupts the fragile ecological balance.

The results we have been experiencing are very promising. Many native plants are now regenerating in the wild. In several plots in the upland forest situated in the Maccabée/Bel-Ombre and Mondrain nature reserves, quadrats have been established to monitor seedling regeneration and mortality. In several of them native *Coffea mauritiana* and *C. macrocarpa* have been observed to be regenerating (W. Strahm, pers. comm.).

As a complement to *in situ* conservation, *ex situ* conservation has been undertaken as well. This has involved the collection of seeds and cuttings for propagation in nurseries. Forestry records show that seeds of *C. mauritiana* and *C. macrocarpa* had been collected and sown in nurseries. Only *C. mauritiana* has been successfully germinated. Trials with *C. macrocarpa* have failed. Unfortunately, no seeds of *C. myrtifolia* have ever been collected. The plants of *C. mauritiana* obtained from the nursery propagation have been planted back in the native forest as enrichment planting.

In order to extend *ex situ* conservation work further, the Mauritian Government, assisted by the Universities of Dublin and Cambridge, the IUCN and the World Wide Fund for Nature (WWF), has established a plant propagation scheme for the conservation of all endangered plants. A propagation unit involving a mist bench was set up in the nursery of the Mauritius

Forestry Service, with the financial help from the Australian Government, the IUCN and the WWF. With this facility, several target endangered species, including the rare *C. myrtifolia*, were propagated by cuttings. *C. mauritiana* and *C. macrocarpa* were tried as well. Only the cuttings of *C. myrtifolia* rooted successfully (63% success rate). This is the first time that propagation of this species has been attempted, and it is believed that with improved techniques of cultivation better results will be obtained in future.

The plants obtained from propagation can now be planted in reserved plots in native forests as well as in botanic gardens and arboreta. From these plants, further plant materials can be obtained to establish plantations which can be used for research work on the utilization of these species.

Botanic gardens are now being asked to play an increasingly important role in the conservation of plant germplasm, and particularly wild relatives of crop species. Botanic gardens throughout the world have been behind the development of crops genetic resources programs (Heywood, 1985), but they have not been successful in conserving plant materials for research purposes (Williams and Creech, 1985). It is felt that they should contribute more towards plant conservation by keeping samples of provenances of wild coffee species which can be utilized for breeding experiments.

UTILIZATION

From time immemorial, coffee has been one of the most widely drunk beverages in the world. It is consumed by more than one third of the world's population. According to FAO sources, annual world production is around 5,000 million tons. More than 60 countries are coffee producers and this provides employment for some 25 million people. For many countries, coffee provides a very important source of foreign exchange earnings.

Although coffee is not native to South America, Brazil is the most important source of coffee in the world; other important South American coffee-producing countries include Colombia, Costa Rica and Puerto Rico. On the Asian continent, Indonesia is the largest producer; other producers include Sri Lanka, Java and India.

The African coffee-producing countries account for about 25% of world production. The most important countries are Angola, Kenya, Côte d'Ivoire and Uganda. The species utilized for making coffee are mainly *C. arabica*, *C. liberica* and *C. canephora*. In some African countries, particularly Ethiopia and Cameroon, wild trees of the cultivated species are still being utilized on a limited scale. The coffee produced, however, is of inferior quality and contains many imperfections. In Ethiopia, there are vast areas of wild *C. arabica* trees, mainly in the south-west regions where the beans are used for coffee making.

More attention should now be given to the utilization of other wild coffee species. This can take the form of breeding new hybrid varieties, given the new techniques of generating variability in cells and the potential now at our disposal for moving genes across sexual barriers. The pace of genetic improvement of coffee can be greatly accelerated by coupling new biotechnological methods with conventional methods such as grafting and artificial pollination.

Seeds of hybrid varieties obtained from the hybridization work have to be tested for their different characteristics. For an evaluation of the quality of the coffee produced, physical characteristics of the beans (size, shape, proportion of defective to wholesome beans and color), characteristics of roasting (rate of roasting and appearance of the bean surface) and

quality of the beverage (aroma, body and acidity) should all be considered. In breeding for quality coffee, these characteristics must be borne in mind.

This work has to be undertaken by specialized institutions with the equipment, experience and skills necessary to carry out these tests. Many African countries with a wild *Coffea* population lack such resources; most research work on utilization must be done in liaison with outside bodies. Small research stations have to be set up with the help of development aid agencies, so that some research work on the utilization of wild coffee may be carried out.

Work on wild coffee species should be treated as on any other crop, such as cereals, potatoes and sugarcane. New varieties must be sought with the following characteristics:

- high yield;
- resistance to diseases and pests;
- high plasticity;
- better taste, aroma and color qualities of taste;
- suitability as instant coffee;
- appropriate caffeine content (from high to low);
- suitability for advanced harvesting methods and storage.

In addition to the above characteristics, the coffee market has to be taken into consideration when new hybrids are developed. It is necessary to know which type and grade of coffee is in demand. For instance, there may be a demand for high-caffeine-content coffee as well as one for caffeine-free coffee. Decaffeinated coffee is gaining much popularity throughout the world as a result of certain ill-effects arising from the excessive consumption of coffee with a high caffeine content. However, the flavor in decaffeinated coffee is lost during the processing. There is thus a need for undertaking studies on caffeine-free coffee species. In this respect the Mascarene species, particularly *C. mauritania*, may have a role to play. The other species of *Mascarocoffea* should also be studied, as suggested by Chevalier (1947). These species have to be selected and hybridized to evolve strains possessing resistance to rust, yield and flavor, with little or no caffeine.

Besides the above, wild species may also play a role in blending with cultivated species and varieties, as most of the wild species are not suitable for consumption. Each type of bean has its special attributes and weaknesses. By combining several varieties together, one may seek to create coffee with a combination of desired traits.

CONCLUSION

The following recommendations are proposed:

- taxonomic research on the genus *Coffea* should be undertaken;
- botanic explorations in Africa should be made and wild coffee species should be collected to see how they differ from cultivated varieties;

- a regional and/or world monograph should be produced;
- areas where wild coffee plants occur should be protected; all conditions favoring their natural regeneration should be provided to ensure their survival;
- *ex situ* conservation work in botanic gardens in Africa should be developed;
- breeding programs involving cultivated varieties and wild species should be initiated;
- specialized institutions for undertaking breeding as well as assessment of coffee quality should be set up.

To put these recommendations into practice, it is necessary to set up a working group on coffee, perhaps within the framework of IBPGR. Competent manpower and grants from development agencies will have to be sought to enable the working group to perform properly. To this end, we hope that this workshop will make a significant contribution toward conserving wild species of coffee and improving the quality and demand for coffee.

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5.7

The Importance of the Herbarium in Plant Genetic Resources Exploration in Africa

J. H. SEYANI

People derive many of their basic needs from the plant kingdom (Fenton and Kitchen, 1956; Hyams, 1971; Ayensu et al., 1984). The types of food we eat, the clothes we wear, the wood we burn for energy, the timber that builds our houses — these are only a few of the many plant products on which we depend for our livelihood (Williamson, 1975; Anon., 1984).

Besides their direct value to us, plants are also a store of great biological diversity and provide a natural genepool for the selection and improvement of plants of economic value to humans and livestock. The high diversity found in plants — species, subspecies, varieties, etc. — form a genetic resource of immeasurable significance to the world, but the economic potential of the plant kingdom is as yet only partially realized (Anon., 1975; Anon., 1979; Seyani 1988a, 1988b). The wild species offer considerable potential for entirely new crops for food, fodder, fiber, shelter, fuel, medicine and raw materials for industry (Sauer, 1969; Anon., 1986).

In the world today, some 80,000 plants are edible, and only about 150 species have been cultivated on a large scale; 90% of the world's food is produced from less than a dozen plants (Ayensu et al., 1984; Smith, 1986). It can therefore be seen that our food base is narrow and that there is an urgent need to increase the number of food plants and other valuable species through the study of the world flora which at present contains about 300,000 flowering species (Takhtajan, 1969; Headstrom, 1978). Most of these are still growing wild in their various habitats while their potential is waiting to be tapped properly and rationally for the benefit of mankind. A number of national and international organizations are currently engaged in the regional collection and evaluation of plant germplasm for genebanks and ongoing breeding programs throughout the world. These include: the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) (maize and wheat); the International Board for Plant Genetic Resources (IBPGR) (general); the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (general); the International Institute of Tropical Agriculture (IITA) (general); and the International Rice Research Institute (IRRI) (rice). Such

programs have produced positive nutritional and yield results in many crop plants — cereals (maize, sorghum, etc.), pulses (*Phaseolus* beans, cowpeas, soybeans, etc.), roots and tubers (yams, cassava, sweet potatoes, etc.) — which are lessening the degree of famine in many developing countries.

My aim here is to discuss the importance of the herbarium in exploring plant genetic resources in Africa.

THE ROLE OF THE HERBARIUM

An herbarium is both a collection of dried plants and an educational and research center. As a basic source of systematic botany and related studies, the herbarium serves as a reference center, a documentation facility and a data storehouse. It is a special kind of museum that can also be regarded as a data bank with vast quantities of raw data. Each specimen is a source of information and its value depends on the completeness of the specimen, its data and the source of the material. Each specimen has information about the vegetation of an area, a population, the taxon to which it belongs, notes on uses and, often, common names. The herbarium collection therefore represents a source of primary information about man's explorations and observations of the world's flora and vegetation, and documents the results of many past inquiries into the nature and relationships of plants. The ancient herbals were mere compilations of the local medical folklore, with crude illustrations which were based mainly on herbarium materials.

The importance of the herbarium in plant genetic resources exploration must be viewed in terms of the full utilization of the national plant collections and expertise of its systematic botanists for the documentation, taxonomy, distribution and conservation of plant resources.

Documentation

An herbarium with its rich collections of plant specimens, including carpological materials and spirit collections, is a vast store of information concerning plants of each country or region. The specimens, along with their accompanying labels (of both cultigens and wild plants) provide the plant explorer/researcher with abundant useful raw data for documentation purposes. The data that has been summarized by Rogers et al. (1975) as being most used in genetic resources centers can easily be extracted from the herbarium specimens: information on 'finding' (date of collection, collector and number, locality, scientific and common names, etc); environment (altitude, vegetation, plant association, special growing conditions); organisms (morphology, variation, etc.); uses (medicinal, fiber, food, etc.); and ethnobotany (local knowledge about plants). Such primary information is extremely helpful to anyone embarking on field exploration work of a given plant group; it might be useful also in checking against field collection data.

Plant taxonomy

Plant taxonomy deals with the identification, classification and nomenclature of plants, and is important in research and communication. Most of the plants used by people are known by their common or vernacular names, and this causes a number of problems of identity,

usage and discussion of the plant in question. All these problems can easily be taken care of by correctly identifying the plants by the use of their universally accepted scientific names.

Taxonomy also provides the current taxonomic and nomenclatural status of plant taxa. It lists the synonyms of the correct names for easy communication, especially in research publications. Unless the plant genetic resources we are interested in can be identified or defined or named, it is difficult to refer to them either in *ex situ* or *in situ*.

Furthermore, plant taxonomy gives high predictive value of plant taxa. Since related plants have many characteristics in common, a well delimited or defined taxonomic group has a high predictive value. This is a very useful principle in the evaluation of plant genetic resources because if one species in a large genus or any plant group has a valuable character/trait, it is likely that the rest or some of the members of that genus or plant group when studied will exhibit similar or better character states. With these resources — the herbarium with its rich plant collections, the botanist with her or his expertise in systematic botany, the plant breeder with his knowledge of genes and crop improvement — our plant genetic resources in Africa could produce a wide range of new crops and products.

Distribution and ecology

The distributional data of plants in any geographical unit (region, country or continent) is very important to the field botanist or plant collector. It enables field workers to locate the desired plants in a precise area, thus saving time and scarce resources. The phytogeographical information can easily be compiled from the herbarium specimens whose labels include the locality from which the specimen was collected, as well as habitat features. Distribution maps of plants enable researchers to evaluate the spread of particular taxa in a region, showing both well and under collected areas. Such data, which are easily obtained from herbarium specimens, are important in the study or collection of germplasm. As more forests and wild areas are cleared for gardens and development projects, more and more plant resources will disappear, and unless there is a record of the geographical distribution of an important plant species it will be difficult for collectors or researchers to collect such a plant again once its former known habitat has been destroyed.

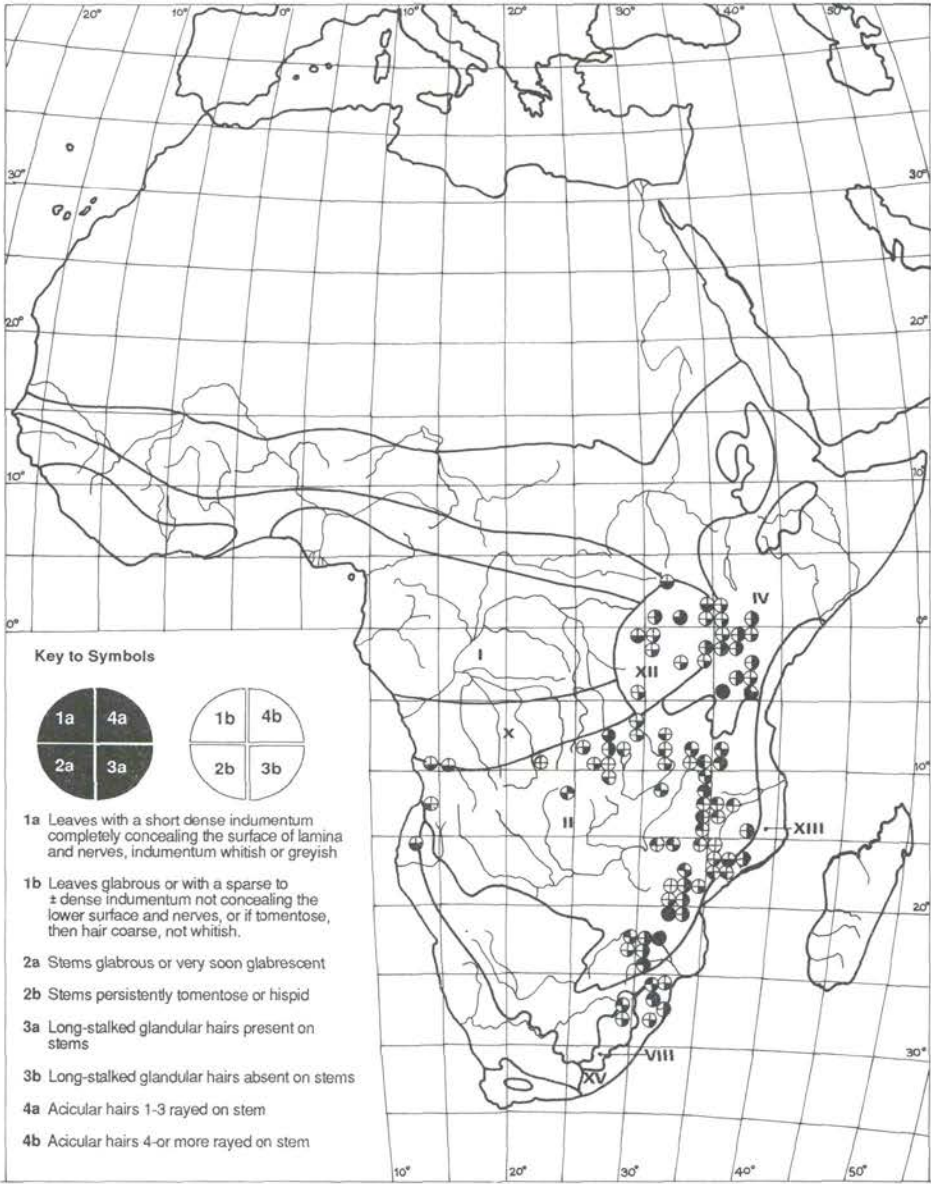
Figure 1 (*overleaf*) shows the present known distribution of the *Dombeya burghessiae* complex in Africa (Seyani, 1988c). It also shows the variability of this complex where the analysis of four indumentum characters showed no specific correlations or any patterns on the map. Such approaches could be used in the study/evaluation of some valuable plant genetic resources — defining or delimiting taxa through analysis of variation.

Apart from phytogeographical data, herbaria are a source of ecological information about the plant species. The label data on habitat, altitude, vegetation or rainfall can assist collectors/researchers in searching for the plants in similar environments elsewhere, or can be valuable data when carrying out *ex situ* propagations. Furthermore, if we know of the environmental needs of a given valuable plant, then we shall be able to understand the behavior when conditions of its habitat change or when it is brought under cultivation.

Conservation

The plants that people use are part of the national floras which, in developing countries, are disappearing at an alarming rate. It is estimated that tropical forests are being lost at the rate

FIGURE 1 **Distribution of *Dombeya burgessiae*, showing variation in four indumentum characters**



Note: I - XV = the phytogeographic regions of southern Africa (White, 1976, 1982).

Source: Seyani, 1988c

of 11 million ha per annum (Lanly, 1982). This means that each year several useful and potential plant species are being lost or their habitats reduced or damaged. This will lead to species becoming rare, endangered or extinct, depending on the levels of the ecological pressures that are being exerted on the habitat. Some valuable species will be lost before their blueprints for new active compounds or new genetic traits can be analyzed scientifically.

The herbarium has an important role in monitoring the conservation status of plant taxa or vegetation types. Using its plant collections and records as baseline data, the herbarium can indicate whether a particular plant group or vegetation type has a wide, restricted or rare distribution in a particular area/region/country. This information can be used to advise a government or its conservation agency on the conservation status of a plant species or vegetation type for some strategic actions. Unless there are some mechanisms for monitoring the conservation status of plant genetic resources and vegetation in Africa, many valuable genes and habitats are going to become scarce in the near future.

CONCLUSION

The great variety and diversity of the plant kingdom are very important for the survival of man and livestock. Plants are a source of food, fodder, fiber, shelter, fuel, medicine, raw materials for industry and many other items. Besides providing people with their basic needs, the plant kingdom, whose size for the flowering plant species is estimated at 300,000, is a store of great biological diversity and a natural genepool for the selection and improvement of plants of economic value to mankind. Today, various international organizations are involved in the collection, conservation and evaluation of plant germplasm resources in different parts of Africa.

Herbaria have a great role to play in such work in Africa in terms of the utilization of the national plant collections and expertise of taxonomists for the documentation, taxonomy, distribution, ecology and conservation of the plant resources. There is a great need to develop national herbaria and to establish closer cooperation between herbaria, genebanks and plant explorers for the future survival and benefit of mankind.

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PART 6

Collaborative Programs

6.1

Countries' Activities Summary

G. N. W. THITAI

Africa, the third largest continent, has great variations in climate, soils and topography which favor the growth of a wide range of plant species. As a result, there are several centers of genetic diversity for crops such as grain legumes, cereals and forage crops. However, the picture now emerging is that genetic erosion is threatening the survival of the landraces and their genepools. The main factors responsible for the genetic erosion include the manipulation of the living habitats as a result of man's quest for new land to cultivate, to graze animals and to build various types of infrastructures. Selection pressure caused by the widespread use of improved high-yielding varieties and the consequent neglect of many landraces has also led to genetic erosion. Coupled with the above is the threat from natural phenomena such as floods and droughts.

In order to curb and reduce the loss of plant genetic diversity, several countries in Africa have taken some measures which will be reported in volume 3 of this series (Country Reports). However, the following brief report is an indication of what is happening on the continent.

CONSERVATION ACTIVITIES

Several countries started their conservation activities by establishing forest departments at the beginning of this century in order to cater for the indigenous and exotic forest trees which were in the forest or natural reserves. The Ministries of Agriculture, however, were the ones that took the lead in conservation activities by encouraging collection of crop plant species. In all the countries reported, the active participation of the Ministries of Agriculture was noticeable. For instance, in Sudan, Mauritius and Kenya, horticulture production was promoted by those in charge of agricultural activities. In addition, exotic plant species were introduced by those ministries.

The conservation of plant germplasm in an organized manner, however, is a recent development. In many countries there are now a number of organizations, such as national research stations, research institutes, universities and plant quarantine stations, involved with

conservation work. However, where there is no plant genetic resources unit or a genebank, then the coordination of conservation activities is difficult because the different organizations tend to collect and maintain only those crop plants that are of immediate interest. In addition, exploration and collections are done in isolation by the various interested groups.

Until recently, most countries in Africa had some collections (mainly breeders' stock) composed mainly of exotic improved materials and a few indigenous species. Almost no wild or weedy relatives of cultivated crops were collected. The plant collections were kept in all sorts of places, including drawers and shelves, because cold storage facilities either were not available or were in need of repair.

Such problems have prompted the establishment of genetic resources units in the past five years, with the exception of Ghana and Ethiopia, which had set up such units in 1964 and 1976, respectively. Egypt, Kenya and Mauritius established their genebanks in 1987, while Nigeria established the National Centre for Genetic Resources and Biotechnology in 1986. Tanzania has no national genebank, but it has set up a National Genetic Resource Programme for coordinating and enhancing germplasm conservation activities. Zambia is planning to have a genebank in the near future. Other countries, such as Comores and Swaziland, have yet to start planning the establishment of such units.

In most countries the functions of plant genetic resources units can be summarized as follows:

- to organize germplasm exploration and collection missions at national level;
- to coordinate international exchange activities concerning rejuvenation, multiplication, characterization, preliminary evaluation and utilization;
- to coordinate and facilitate international exchange of plant germplasm and relevant information;
- to serve as a national authority for the validation, registration, naming and release of new crops.

Plant genetic resources units or genebanks must plan their activities according to the priorities of the country.

Several methods, either separately or in combination, could be used in the conservation and maintenance of the germplasm. The recommended method for conserving orthodox seeds is to store them in cold rooms at -20°C with a moisture content of 5% wet weight. However, few countries are able to maintain the cold rooms at -20°C , and thus these rooms are maintained at various temperatures, ranging from $+15^{\circ}\text{C}$ to -20°C . Many countries prefer to use deep chests rather than cold rooms because of cost and ease of maintenance.

The other commonly used method is to leave the plants in their natural habitat or to grow them in plantations. In Ethiopia and Liberia, such field genebanks have been established.

The use of *in vitro* cultures in conservation is done on a limited scale for some crops.

Characterization and rejuvenation

Many countries, despite having large plant collections, have not characterized them because of a shortage of trained personnel and insufficient funds. The few plants that have been

evaluated properly are those with the potential to increase the yields of crop plants and increase the resistance to such stresses as diseases, drought and salinity. Among the plants that have received reasonable evaluation in several countries are coffee, soybean, cowpea, maize, rice and some fruit trees. In Kenya, Ruiru II, a high-yielding coffee variety resistant to coffee berry disease, has been developed through intensive research. In Nigeria, Ife Brown, a cowpea variety which is photoperiod insensitive, disease resistant and high yielding has been developed. In Egypt, barley varieties adaptable to poor soils have been bred.

In several countries where horticultural crops and fruit trees have assumed great importance because of their role in commercial trade, bulking of seeds is a routine exercise. In Liberia, Sierra Leone and Zambia, rejuvenation of accessions is carried out in order to save the seeds which have been collected and cannot be conserved in the genebanks because of the lack of storage facilities or poor storage conditions.

Utilization

The whole purpose of conservation is ultimately to make use of the genetic diversity available in the genebanks. To achieve this goal, each country has set its own priorities on which its various programs, such as the crop improvement programs, are based. The aim of crop improvement programs is to improve the traditional subsistence and cash crops and to create new elite varieties.

Afforestation programs have also been in the limelight as far as utilization of germplasm is concerned.

Documentation

Field documentation aimed at providing the passport data is vital in a properly managed conservation program. It not only gives the accession an identity but also shows the geographical location of a species. In addition to passport data, it is also necessary to have characterization and evaluation data for utilization and conservation strategies.

Descriptor lists developed by the International Board for Plant Genetic Resources (IBPGR) have proved useful in evaluation exercises and many countries now make considerable use of them. However, because of some specific needs of certain countries, the collectors have developed their own descriptor lists.

In some countries the information and data obtained for each plant accession are stored in microcomputers. However, only a limited number of countries have microcomputers for this work. In many African countries, information is kept in manual files.

As for the quality of data, many countries have insufficient information regarding the accessions which have been collected and stored. This is because, in the past, many people were not trained in documentation and retrieval of information. This situation is now gradually changing.

Training

In many African countries there are few people trained to man the genetic resources units. In several countries, such as Kenya, Egypt, Rwanda, Burundi, Zaire, Mauritius, Zambia and

Sierra Leone, there are less than five people trained up to MSc level in genetic resources conservation and utilization. Ethiopia has 11 research officers trained up MSc level and one Senior Research Officer with a PhD. Middle cadre staff are also in short supply, and there is a need to train many people who can handle routine work efficiently.

It is noted with appreciation that IBPGR has assisted enormously in training many of the staff in the above countries; however, there is still a demand for more trained people. High-level refresher courses and short courses for the research officers who man the genebanks would enhance conservation efforts. The training of genebank managers is also essential.

CONSERVATION PROBLEMS

The main problems found today in African countries as far as plant germplasm conservation and utilization is concerned can be summarized as follows:

- *Availability of funds.* Some countries have no special budget from their government for this activity and there is a general tendency to rely solely on international organizations. Others have insufficient funding from their governments and this has hampered their plant genetic resources activities.
- *Personnel.* Several countries have very few people trained in germplasm conservation. Many report that fewer than five persons are trained up to MSc level. In other countries there are no full-time curators, and the technicians are few. There are also frequent changes of personnel in the Ministries.
- *Equipment and storage facilities.* A shortage of the facilities and equipment needed for conservation work is found in many of the African countries. This is perhaps because many of the plant genetic resources genebanks or units have been set up only within the past 5 years and are thus still acquiring the necessary resources. The lack of vehicles and seed driers is particularly noticeable. In some institutions, there is no electricity and water is not always available.
- *Available experimental land.* For rejuvenation, multiplication and evaluation, ample land is crucial. A few countries have difficulties in getting enough land for this activity, as well as for *in situ* conservation.
- *Security-sensitive areas.* Political problems in some countries have meant that there security-sensitive areas where collecting can be risky.
- *Descriptor lists.* Some countries have had problems because there are no descriptor lists.
- *Pest and disease problems.* These problems have led to considerable loss of genetic resources.
- *National conservation policies.* Several countries lack national policies on plant germplasm exploration, collection, characterization and documentation.
- *Perception of the need for conservation.* Unawareness of the problems facing plant genetic resources conservation is a factor in some countries.

COLLABORATIVE EFFORTS

IBPGR, which has the mandate to help organize a global network of plant genetic resources centers, has featured prominently in many activities concerning rehabilitation of cold storage facilities and exploration and collecting missions. The main purpose of these collections is to rescue the endangered species and to meet the expressed needs of users of the germplasm.

Some of the collections are organized by the IBPGR secretariat, while others are organized by national, regional and international centers, particularly the international agricultural research centers such as the Centro Internacional de Agricultura Tropical (CIAT), the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), the Centro Internacional de la Papa (CIP), the International Center for Agricultural Research in the Dry Areas (ICARDA), the International Crops Research Institute for the Semi-Arid Areas (ICRISAT), the International Livestock Center for Africa (ILCA), the International Institute of Tropical Agriculture (IITA) and the International Rice Research Institute (IRRI). Other international organizations that feature in collection and evaluation activities, as well as in sponsorship for workshops and training, include the United Nations Environment Programme (UNEP), the Food and Agriculture Organization of the United Nations (FAO) and the United States Agency for International Development (USAID). There are also a number of specific donor countries.

NATIONAL ACTIVITIES

The following is a brief report on each country's genetic resources activities. Table 1 (pages 256-60) shows the collection of crop genetic resources in Africa.

Burundi, Rwanda and Zaire (Economic Community of the Great Lakes Countries)

Under the aegis of IRAZ, the collection in this region is made up principally of traditional crops or those species introduced a very long time ago but widely used in the three countries concerned. They include sorghum, beans, cassava, peas and forages.

The orthodox seeds are conserved in freezers, while other types of plants are conserved as living collections. Some characterization work is being carried out for beans and sorghum, and the information is documented for future use in crop improvement programs.

Comores

In the three islands which form the Federal Islamic Republic of Comores, very little has been done in terms of conserving the plant genetic resources because of the lack of funds and personnel. However, the need to conserve the germplasm in these islands exists because certain tuberous crops and root crops, such as the cassava variety known locally as 'Idudu' and the sweet potato variety known as 'Kawaji' are disappearing as a result of selection pressure. In addition, a tree species, *Khaya comorensis*, has disappeared from the Grille forest because of over-exploitation.

Côte d'Ivoire

Interest in Côte d'Ivoire is directed at the improvement of varieties of several of the plants used in this country. Numerous research institutions have been created, each concerned with one plant or a group of plants.

Egypt

There are over 33,000 accessions kept by breeders in Egypt, and these include wheat, barley and rice. A genebank with long-term storage facilities was built recently in order to coordinate the conservation activities. Among the activities already initiated are the evaluation studies of the accessions; the evaluation of world barley collections and wheat, in particular, is well under way.

There are certain constraints, such as insufficient manpower and funds, although five people have been trained at the genebank.

Ethiopia

A plant genetic resources center was established in 1976 with the objectives of exploration, collection, multiplication, characterization and documentation. The center has both long- and short-term storage facilities and is maintaining over 45,000 accessions which have been collected through 140 organized collecting missions. On average, 8,000 accessions of different crops are being characterized each year.

Conservation efforts in Ethiopia are also being undertaken by farmers who are being encouraged to maintain germplasm through the strategic seed reserve project. Attention is also being focused on little-known plant species, including *Vernonia galamensis* and *Cordeauxia edulis*.

Gambia

Groundnuts, millets, sorghum and forage species have been collected in The Gambia. This has been followed by evaluation of the agronomic characteristics of the species.

Plant accessions are stored in an air-conditioned room, but because of the lack of constant electric power, conservation of these accessions has not been satisfactory.

Ghana

Organized germplasm collection missions have been ongoing since 1976. At present, many of the plant accessions are conserved in the 25-year-old Plant Genetic Resources Unit at Bunso. The unit has two deep freezers in which temperatures are maintained at -20°C.

Most of the accessions collected have been multiplied for seed storage and some have been conserved in the orchards and the arboretum.

Using the IBPGR descriptor list, several accessions have been characterized and evaluated. They are being used by universities and research institutes in crop improvement programs. Fruits and seeds of the sweet berry, *S. dulcificum* and those of *D. cumminsii* and *T. daniellii* have been used extensively in the research on the manufacture of sweetening agents.

The future is bright for genetic resources activities in Ghana as long as the transport problems can be solved.

Kenya

Several organizations in Kenya (such as universities, research stations and nongovernmental organizations) are engaged in one or several aspects of plant germplasm conservation. Recently, a National Genebank was established in order to coordinate all crop plant genetic resources activities such as collection, characterization, storage and introduction of new crop plants. Rehabilitation of cold stores in the various research stations is now in progress.

Many of the 50,000 accessions housed in the cold rooms and in field genebanks are under short-term or medium-term storage. Because of the particular needs in the country, several accessions have been incorporated in the crop improvement programs. Coffee, maize, beans, sunflower, rice and cassava are rated as being moderately utilized.

The level of characterization and documentation is generally low or poor because of the shortage of funds, facilities and trained manpower. However, every effort is being made to characterize many of the accessions.

Liberia

The pressure exerted on the land by the rapidly increasing population and the traditional farming practices, involving slash-and-burn fallow techniques, is already noticeable. As a result, collections of rice, root and tuber crops, indigenous vegetables and legumes were initiated and this was followed by varietal improvement programs on some of the species. The collected species were maintained in a field genebank, since there is no genebank for conservation of orthodox seeds.

Madagascar

In the light of socioeconomic priorities and the danger of the extinction of plant genetic resources, the search for and collection of plants is receiving attention. Emphasis has been placed on safeguarding rare forest species renowned for their socioeconomic value and establishing genetic banks for programs to improve plants cultivated for food, industrial use and forage.

Mauritius

Serious conservation activities in this country were started in 1985 under the Horticulture Division of the Ministry of Agriculture, Fisheries and Natural Resources. A genebank was

established at Barkly; it has two deep freezers which are maintained at -18°C for long-term conservation of orthodox seeds. Before storage in the genebank, the moisture content of the seeds is reduced to $5 \pm 1\%$ using silica gel. Apart from the large number of sugarcane accessions, only a few other species have been collected so far; these are *Abelmoschus esculentus*, *Lycopersicon esculentum*, *Amaranthus* species, *Solanum* species, *Brassica* species, *Allium cepa*, *Zea mays*, *Phaseolus* species and cucurbits.

The genetic resources activities in this country have been hampered by a shortage of land for conservation activities and by a shortage of trained staff.

Morocco

Systematic collection of cereals, forages and food legumes began in 1980. The seed samples were conserved in deep freezers and in cold rooms at the Hassan II Institute of Agronomy and Veterinary Medicine. Morphological and biochemical evaluation of the alfalfa is being carried out and the data documented. Corn, barley and oats are also being evaluated.

Niger

Because Niger has to cope with frequent drought, it has placed emphasis on the need to list species that are of value for food, forestry and forage and can tolerate long periods of drought.

Nigeria

Conservation of natural vegetation and modified ecosystems started in the 19th century when attention was focused on forestry. These conservation activities were later intensified, leading ultimately to the establishment in 1986 of the National Centre for Genetic Resources and Biotechnology, which now contains 9,000 plant accessions. In addition, several organizations, especially universities and national agricultural research institutes, are involved in conservation and utilization activities.

There are several reasons why attention is being paid to plant genetic resources activities. One of them is the realization that there is a lot of genetic loss attributable to the disturbance of the natural vegetation, advance of the Sahara and, most important of all, the selection pressure caused by widespread use of genetically improved crop varieties. Examples of plant species that are slowly being relegated to low priority status include: *Oryza glaberrima*, the red rice that is indigenous to West Africa and which is now being replaced by *O. sativa*, the white rice; the upland variety of *O. sativa*, known locally as 'Ofada,' which is also disappearing from the farmers' fields; and less popular species of the edible yams.

Hybridization and extensive selection for maize, soybean and cowpea has produced advanced varieties such as 'Ife Brown', a high-yielding and disease-resistant cowpea variety.

Senegal

'Genetics and variety improvement' is the heading under which collections of plant material are made with a view to augmenting or stabilizing the productivity of different crops and to proposing the cultivation of alternative crops.

Somalia

The Ministry of Agriculture has initiated research programs on sorghum, maize, rice, wheat, grain legumes and oil-seed crops such as groundnuts and sunflower. The collection of sorghum varieties was recently undertaken but as there are no storage facilities in the country the samples were sent to ICRISAT for storage. The main constraint faced in agricultural research is a shortage of qualified manpower and funds. In addition, there is no genebank in the country and, therefore, plant genetic resources activities are minimal.

Sudan

In Sudan, much emphasis is given to the conservation of the horticultural crops which feature in the crop improvement programs. A small genebank at the Horticultural Research Section of the Agricultural Research Corporation at Wad Medani has been established, and activities such as characterization, multiplication and documentation of the collected accessions has been going on for the past 2 years. However, the shortage of funds to meet running expenses, coupled with a shortage of proper storage facilities, has hampered the activities of germplasm conservation.

Swaziland

As is the case elsewhere, Swaziland's indigenous plants are faced with the danger of genetic erosion because of the influx of exotic plant species. Examples cited include groundnuts, bambara groundnuts and cowpeas. The country badly needs a national genebank to collect, conserve and utilize the local landraces and exotic genetic materials. There is no genebank for conservation of orthodox seeds.

Tanzania

Several organizations in Tanzania have now teamed up to establish a National Genetic Resources Program. This program stemmed from the realization that there was a vast diversity of genetic resources which was threatened by the introduction of modern crop cultivars, changes in land-use patterns and the disappearance of large areas of natural vegetation. Many of the collections of crops are scattered in various institutions and are conserved in cold stores. While some cold stores are in good working order, others need rehabilitation. The main constraint is shortage of funds, equipment, vehicles and expertise.

Zambia

The Department of Agriculture and the Department of Forestry have initiated some minor plant germplasm conservation activities. Over 4,000 accessions have been collected, but these are not properly conserved because of the problems related to maintenance of the cold stores. Evaluation and utilization of the accessions is limited and is not conducted systematically. As a result, a national committee is expected to be established to oversee and coordinate plant genetic resources activities.

TABLE 1 **The collection of plant genetic resources in Africa (only species with more than 20 accessions are reported)**

Country	Cereals	Food legumes	Roots and tubers	Vegetables
Benin	sorghum millet rice maize fonio	beans niebe voandzou lentils pigeonpea	cassava sweet potato yam	—
Burundi	sorghum rice millet	beans niebe garden peas pigeonpea groundnuts	cassava sweet potato	—
Chad	—	—	—	—
Côte d'Ivoire	sorghum millet rice maize	—	yam cassava	pepper okra eggplant tomato sesame onion
Egypt	<i>Oryza</i> maize wheat sorghum barley	bean chickpea soybean lentils	—	onion
Ethiopia	<i>Triticum</i> sorghum <i>Hordeum</i> <i>Pennisetum</i> <i>Eleusine</i> <i>Eragrostis</i> <i>Zea</i>	<i>Phaseolus</i> <i>Vicia</i> <i>Pisum</i> <i>Lathyrus</i> <i>Lens</i>	—	<i>Allium</i> <i>Brassica</i> <i>Capsicum</i> <i>Cucurbita</i>
Ghana	<i>Oryza</i> sorghum maize	lima bean cowpea bambara groundnut	<i>Dioscorea</i>	eggplant
Guinea	rice millet sorghum fonio maize	beans niebe voandzou peas	—	okra
Kenya	<i>Eleusine</i> <i>Setaria</i> <i>Echinochloa</i> <i>Oryza</i> <i>Zea</i> <i>Hordeum</i>	<i>Phaseolus</i> <i>Cajanus</i> sorghum <i>Vigna</i> <i>Pisum</i>	<i>Manihot</i> <i>Solanum</i> <i>Ipomoea</i>	<i>Citrullus</i> <i>Lycopersicon</i> <i>Capsicum</i> <i>Brassica</i> <i>Allium</i>
Liberia	rice	lima bean	cassava <i>Ipomoea</i> yam cocoyam	okra pepper bitterpall eggplant

TABLE 1 (contd)

Country	Cereals	Food legumes	Roots and tubers	Vegetables
Madagascar	rice maize	beans niebe groundnuts soybean voandzou	cassava	pepper
Mauritania	sorghum millet	—	—	—
Mauritius	<i>Zea</i>	<i>Phaseolus</i>	—	<i>Lycopersicon</i> <i>Amaranthus</i> <i>Solanum</i> <i>Brassica</i> onion cucurbits <i>Abelmoschus</i>
Morocco	corn barley wheat oat	faba bean	—	—
Niger	millet rice sorghum fonio	niebe voandzou	sesame	—
Nigeria	<i>Avena</i> <i>Echinochloa</i> <i>Hordeum</i> <i>Oryza</i> <i>Panicum</i> <i>Paspalu</i> <i>Pennisetum</i> <i>Secale</i> <i>Setaria</i> sorghum <i>Triticosecale</i> <i>Triticum</i> <i>Zea</i>	<i>Glycine</i> <i>Phaseolus</i> <i>Vigna</i>	<i>Canna</i> <i>Catimbium</i> <i>Colocasia</i> <i>Cyperus</i> <i>Daucus</i> <i>Dioscorea</i> <i>Ipomoea</i> <i>Manihot</i> <i>Xanthosoma</i>	<i>Amaranthus</i> <i>Abelmoschus</i> <i>Allium</i> <i>Basella</i> <i>Brassica</i> <i>Capsicum</i> <i>Citrullus</i> <i>Corchorus</i> <i>Cucumis</i> <i>Lycopersicon</i> <i>Solanum</i> <i>Trichosanthes</i> <i>Vernonia</i>
Rwanda	sorghum maize millet	beans garden peas groundnuts soybean	cassava sweet potato cush-cush	potato and other nonspecified introductions
Sao Tomé and Príncipe	—	—	—	—
Senegal	millet rice sorghum maize	niebe groundnuts	cassava	various crops

TABLE 1 (contd)

Country	Cereals	Food legumes	Roots and tubers	Vegetables
Sudan	—	<i>Phaseolus</i>	<i>Abelmoschus</i> <i>Allium</i> <i>Lycopersicon</i> <i>Capsicum</i> <i>Citrullus</i> <i>Cucumis</i> <i>Cucurbita</i> <i>Raphanus</i> <i>Anethum</i> <i>Hibiscus</i>	—
Tanzania	rice sorghum millet	beans grain legumes cowpea soybean	—	groundnuts
Tunisia	barley wheat millet	—	—	—
Zaïre	sorghum rice millet maize	beans niebe groundnuts pigeonpeas	cassava sweet potato yam taro cush-cush	potato and other nonspecified introductions
Zambia	<i>Zea mays</i> sorghum <i>Eleusine</i> <i>Pennisetum</i> <i>Oryza</i>	<i>Phaseolus</i> <i>Vigna</i> <i>Voandzeia</i> <i>Cajanus</i>	<i>Dioscorea</i>	<i>Cucurbitaceae</i> <i>Amaranthus</i> <i>Abelmoschus</i>

TABLE 1 (contd)

Country	Fruit and nuts	Industrial and plantation crops	Forages	Others
Benin	—	cocoa coffee tobacco oil palm	—	—
Burundi	—	—	—	—
Chad	—	—	<i>Panicum</i> <i>Chloris</i> <i>Brachiaria</i> <i>Cenchrus</i> <i>Clitoria</i> <i>Macroptilus</i> <i>Dolichos</i> <i>Stylosanthes</i> <i>Desmantus</i>	—
Côte d'Ivoire	—	cotton sugarcane	grasses, etc.	—
Egypt	—	oil crops flax	forage crops <i>Lupinus</i>	—
Ethiopia	—	<i>Coffea arabica</i> <i>Ricinus</i> <i>Guizotia</i> <i>Linum</i>	—	<i>Sesamum</i> <i>Casthamus</i>
Ghana	fruit crops	—	—	—
Guinea	coffee cola	—	—	—
Kenya	—	groundnuts <i>Mangifera</i> <i>Vitis</i> <i>Citrus</i> <i>Musa</i> <i>Persea</i>	<i>Coffea</i> <i>Saccharum</i> <i>Camellia</i> <i>Ricinus</i> <i>Helianthus</i> <i>Chrysanthemum</i> <i>Agave</i> <i>Gossypium</i>	forage and pasture crops
Liberia	—	—	—	—
Madagascar	coffee cocoa	mango cashew vanilla	<i>Brachiaria</i> pearl millet	forestry species and others
Mauritania	—	—	—	—
Mauritius	—	sugarcane	—	—
Morocco	—	—	alfalfa alfalfa <i>Rhizobium</i> strains wild legumes and forbs wild grasses	—
Niger	—	—	—	<i>Acacia</i>

TABLE 1 (contd)

Country	Fruit and nuts	Industrial and plantation crops	Forages	Others
Nigeria	<i>Ananas</i> <i>Annona</i> <i>Artocarpus</i> <i>Blighia</i> <i>Carica</i> <i>Chrysophyllum</i> <i>Citrus</i> <i>Dacryodes</i> <i>Irvingia</i> <i>Mangifera</i> <i>Musa</i> <i>Persea</i> <i>Phoenix</i> <i>Poncirus</i> <i>Psidium</i> <i>Syzygium</i> <i>Terminalia</i> <i>Trecucia</i> <i>Vitis</i>	<i>Agave</i> <i>Luffa</i> <i>Hildegardia</i> <i>Parkia</i> <i>Triumfetta</i> <i>Anacardium</i> <i>Cocos</i> <i>Coffea</i> <i>Cola</i> <i>Havea</i> <i>Theobroma</i> <i>Sanseveria</i> <i>Helianthus</i> <i>Beta</i> <i>Sacchrum</i>	<i>Lupinus</i> <i>Tamarindus</i>	abras <i>Cassia</i> <i>Cnestis</i> <i>Curaima</i> <i>Glypphoea</i> <i>Jatropha</i> <i>Lawsonia</i> <i>Ocinum</i> <i>Piper</i> <i>Zingiber</i> <i>Tetrapleura</i>
Rwanda	coffee tea pyrethrum tobacco	banana avocado pineapple	Various nonspecified introductions	eucalyptus pine others
Sao Tomé and Príncipe	cocoa	—	—	—
Senegal	cotton	—	—	—
Sudan	—	—	—	—
Tanzania	groundnuts	jute pyrethrum	—	—
Tunisia	—	—	—	medicago
Zaïre	cotton coffee cocoa oil palm	banana sugarcane	—	—
Zambia	<i>Arachis</i>	<i>Hibiscus</i> <i>Ricinus</i> <i>Helianthus</i>	—	trees forage fruits

CONCLUSION

The picture which has emerged is that although Africa is a continent endowed with great genetic diversity, this wealth has not been adequately taken care of in terms of conservation and utilization. Fortunately, there is now a greater awareness of the need to salvage the landraces, primitive cultivars and wild relatives of cultivated crops, so that the rich genepool can be sustained for as long as possible and be available to future breeders.

In order to effectively execute the conservation and utilization of genetic diversity, there are certain problems that should be reduced as much as possible, if not eradicated completely:

- every country should endeavor to train scientists and technicians in relevant disciplines of genetic resources activities;
- there should be concerted efforts to establish plant genetic resources units that are well equipped to handle medium-term and long-term storage of orthodox seeds;
- a pragmatic approach toward genetic resources activities should be adopted so that there is a balance between the development of agriculture through the use of improved varieties and one that relies on the landraces.
- several methods of conservation of plant germplasm should be employed, depending on the type of species in question;
- evaluation and utilization of species should be enhanced in order to reap the full benefits from every species in the genepool;
- sufficient funds are needed from national governments and the international community to carry out the above activities;
- collaboration between all those who have the resources, those who handle them and those who benefit from them is essential.

If the above points are taken seriously, then Africa may not only conserve its national heritage of plant genetic resources, but may also contribute tremendously to the improvement of agriculture, forestry, health and the environment. To achieve this goal, the work by the international bodies is commendable but still needs to be stepped up to ensure that the activities discussed above are promoted fully on the continent of Africa.

6.2

The African Ministerial Conference on the Environment (AMCEN) and a Continental Network for the Conservation and Management of Genetic Resources

H. ZEDAN

As we all know, Africa is a continent in crisis. The current rate of degradation of natural resources in Africa, with its wealth of genetic resources, and the need for urgent action to halt and reverse this degradation in order to satisfy the needs of the peoples of the continent, particularly in food and energy, led to the adoption by the African Ministerial Conference on the Environment (AMCEN) in Cairo in 1985 of the Cairo Program for African Cooperation.

This program aims at strengthening cooperation between African states in economic, technical and scientific activities. To help achieve these objectives, the Conference, which normally meets every two years, decided at its first session to establish, *inter alia*, eight technical cooperation networks to implement the program, as well as four committees. Each network has been allocated responsibility for one of the following: environmental monitoring; climatology; soils and fertilizers; water resources; genetic resources; science and technology; and environmental education and training. Each committee has been allocated responsibility for one of the following: deserts and arid lands; forests and woodlands; rivers and lake basins; and seas. The main objective of the networks is to promote inter-country cooperation for the conservation and management of African genetic resources and to help make material and related information and technology readily accessible for utilization in the improvement of agriculture, forestry, industry, health and the environment.

The conference decided:

- that cooperation between the technical and research institutions of African countries should be strengthened and developed through the exchange of information and the conduct of the basic studies and scientific research necessary for the environmentally sound utilization of African resources;

- to strengthen and develop technical cooperation among African countries through the development of horizontal scientific and technical links between national departments in specific areas;
- to establish or strengthen eight specialized regional networks, in the fields that are listed above.

THE REGIONAL NETWORKS

The terms of reference for the regional networks cover:

- making available infrastructural facilities such as existing institutions (for example, subregional environment groups, economic communities and development organizations);
- ensuring proper geographical distribution of the coordination units of the networks;
- strengthening horizontal cooperation between national technical departments and scientific institutions, thus pooling the experience acquired continent-wide and ensuring the utilization of available national skills, capabilities and expertise on a regional basis;
- seeking solutions to environmental problems that transcend national boundaries;
- using scientific and technical tools to support development projects through the mobilization of regional efforts (human, institutional, technical and financial);
- collecting, processing, storing and disseminating (as appropriate) basic data provided by national technical departments;
- providing scientific and technical assistance to African countries (as requested) in the analysis, collation and correlation of data.

Network requirements

A number of requirements must be met if the networks are to play their role effectively:

- *at the national level* they should designate relevant national institutions to form a national network around a focal point; designate a qualified institution to serve as the national focal point for each network; provide back-up services; and have access to information that enables them to mobilize national skills;
- *at the regional level* there must be commitment by countries to provide the regional network with available information necessary for their functioning;
- *at the international level* there must be support for national and/or subregional activities.

Selection of member institutions

In selecting national institutions as members of a regional network, it is recommended that governments should apply the following criteria:

- their relevance to specific areas of concern and concentration;
- their potential for providing expertise and information;
- their willingness and ability to provide a contribution in kind to the network.

Selection of regional coordination units

In selecting a regional coordination unit for a network, an institution should satisfy not only the above requirements but also have:

- adequate human resources and managerial capacity;
- good equipment and infrastructure;
- an ongoing research and development program;
- training facilities in the area concerned.

Mechanisms for operating a network

The principal components for operating a network are as follows:

- a focal unit (hosted by one member of the network or a competent regional institution that already exists) to provide the technical and administrative secretariat for the network and build up an information or data facility;
- a planning and management group composed of the directors of national members that will meet (usually) once a year under the rotating chairmanship of its members to discuss an agenda comprising: reports from national members; actions (and projects) for support of members; network program for the following term (year) identifying the share of each member in implementing this program; requests from national governments for special studies, training, research, etc.; and report on financing network activities (needs and resources).

OBJECTIVE, COMPOSITION AND LOCATION OF REGIONAL NETWORKS

Objective

The objective of each regional network is to assist the continent of Africa to integrate conservation with environmentally sound management and sustainable resources utilization

with a view to conserving its plant, animal and microbial genetic resources. To this end, the network should:

- promote inter-country cooperation within the region for the conservation of genetic resources;
- encourage and promote national and subregional *in situ* conservation of plant and animal genetic resources and their wild relatives within existing nature reserves and protected areas;
- promote the establishment of genebanks for long-term *ex situ* conservation of plant, animal and microbial germplasm;
- encourage and support the referral collections;
- support the establishment of data banks for plant, animal and microbial genetic resources;
- collect, analyze and disseminate material and information on African genetic resources for the countries of the region;
- encourage, at the regional level, field applications of genetic resources and appropriate biotechnologies with a view to improving agriculture, forestry, animal husbandry, industry, etc.;
- facilitate and promote access among African countries to the genetic resources of the region and to all relevant information;
- assist, at the national, subregional and regional levels, in providing training in the fields of genetic resources, genetic engineering and biotechnology.

Criteria for national membership

A national member of this network would be ideally a central institution with access to one or more of the nature reserves, biosphere reserves, germplasm banks or biological referral collections. This may not be easy at the initial stage because, for example, nature reserves may belong to different government departments, germplasm banks often belong to ministries of agriculture, and referral collections may belong to various natural history museums.

Thus, a preparatory phase may need to precede the full establishment of a network. In this phase, countries would be encouraged to establish national commissions or central government bodies for the conservation of genetic resources. Such commissions or central bodies would be ideal members of this network.

Location of regional network coordination units

A regional network coordination unit should be located in an institution that is recognized as being experienced and active in this field. In addition to meeting the requirements for

membership in the network, the unit should have computer facilities and staff who are competent in biotechnology and genetic engineering.

CONCLUSION

Most of you who are present at this workshop are concerned only with plant genetic resources and are attending the workshop as a representative of an institution concerned with conservation of plant genetic resources. However, you are also representing the various African countries in which the United Nations Environment Programme (UNEP), the International Board for Plant Genetic Resources (IBPGR), the Food and Agriculture Organization of the United Nations (FAO) and many other governmental and nongovernmental organizations are working. As such, your advice and comment on the content of this paper will be highly valued.

6.3

La conservation des ressources phytogénétiques des pays des grands lacs (CEPGL: Burundi, Rwanda et Zaïre)

N. NE NSAKU

La disparition progressive des ressources phytogénétiques de la CEPGL en Afrique centrale a obligé l'IRAZ de créer un programme de collecte et de conservation du patrimoine végétal de la région, qui a pour objectif la collecte, la caractérisation, l'évaluation, la documentation, la conservation et l'utilisation des ressources phytogénétiques de la CEPGL.

Ce programme initié par l'IRAZ en 1983 fonctionne depuis mars 1985 en collaboration avec le Conseil international des ressources phytogénétiques (CIRPG). Le programme de la CEPGL comprend sept centres:

- le centre régional de l'IRAZ à Gitega en République du Burundi;
- le centre de l'ISABU/Imbo-centre (en République du Burundi);
- le centre de l'ISAR/Rubona (en République Rwandaise);
- le centre de l'INERA/Mulungu (à l'Est du Zaïre);
- le centre de l'INERA/M'vuazi à l'ouest du Zaïre qui détient le matériel végétal des Régions du Bas-Zaïre et du Bandundu.

Ces centres sont opérationnels et 2 autres centres sont prévus pour couvrir le reste du Zaïre il s'agit:

- du centre de l'INERA/Yangambi qui abritera le matériel végétal des Régions du Haut-Zaïre et de l'Equateur;
- du centre de l'INERA/Gandajika choisi pour couvrir et conserver les ressources phytogénétiques des Régions du Shaba et de Kasa-Oriental et Occidental.

REALISATION DU PROGRAMME DE COLLECTE ET DE CONSERVATION DES RESSOURCES PHYTOGENETIQUES DES REGIONS DU SHABA ET DE KASA-ORIENTAL ET OCCIDENTAL

Collecte

Plusieurs missions de collecte ont été organisées en 1985/86 pour rassembler les principales cultures de la région (haricots, sorgho, petit pois, éleusine, bananier, manioc, etc.) et des plantes fourragères du Burundi, du Rwanda et de l'est du Zaïre (Région de Kivu) qui a les mêmes caractéristiques (climat, relief, végétation, etc.) que les premiers pays.

Une autre mission de collecte de germoplasme des principales cultures de l'ouest du Zaïre (Bas-Zaïre et Bandundu) a été réalisée en 1987.

Les résultats de ces missions de collecte sont présentés au tableau 1.

TABEAU 1 Nombre d'accessions par groupe de cultures collectées en 1985, 1986 et 1987 au sein de la CEPGL

Groupes	Pays			Total	Modes de conservation
	Burundi	Rwanda	Zaïre		
1. Céréales cultivées	59	117	89	265	Graines (conditions de basse T° et basse humidité)
2. Légumineuses	105	14	167	286	Graines (conditions de basse T° et basse humidité)
3. Racines/tubercules	51	-	154	205	<i>in vivo</i>
4. Bananes	44	81	47	172	<i>in vivo</i> and <i>in vitro</i>
5. Plantes fourragères					
Légumineuses	49	17	34	100	Graines
Graminées	30	11	27	68	
6. Divers	9	3	42	54	Graines (conditions de basse T° et basse humidité)
Total	347	243	560	1150	

Caractérisation

Caractérisation du haricot

Méthodologie

L'IRAZ fait un travail d'identification des variétés de haricot collectées en milieu rural dans les trois pays membres de la CEPGL. Ce travail a commencé sur un nombre de 158 variétés de haricot caractérisées entre 1986 et 1987. Le descripteur modèle CIRPG, CIAT et le livre de couleur *Methuen Handbook of Colour* a servi de guide.

Le semis se fait suivant les écartements de 60 cm x 20 cm pour faciliter la caractérisation avec une graine par poquet sur une ligne de $\pm$ 10 m. Le terrain fut enrichi de fumier à raison de 25 kg/ha. Les observations ont été faites sur 10 plantes choisie au hasard sur 30 plants que contenait chaque cultivar.

Résultats

Quatre types de couleurs ont été observés parmi les variétés caractérisées. Les résultats montrent également qu'il y a 4 types d'habitats ou de développement des plants: nain type 1, semi-volubile type 2, volubile type 3 et volubile type 4.

- parmi les 158 variétés, 27 cultivars sont nains (type 1);
- 49 cultivars semi-volubiles (type 2);
- 82 cultivars volubiles de type 3 et 4.

Sur 158 cultivars caractérisés, nous avons pu identifier 128 différents cultivars. Les cultivars qui se ressemblent sont conservés séparément. Le tableau 2 illustre les caractères semblables des variétés considérées comme identiques.

TABEAU 2 Les caractères semblables des variétés considérés comme identiques

Cultivars	Cycle végétatif (jours) 1 ¹	Type de plant 2	Couleur des fleurs 3	Couleur des gousses non mûres 4	Brillance des graines 6	Forme des graines 7	Dessins couvrant la graine 8	Poids de 1000 graines	Remarque
17/1	99	4	2 ² 1 ³	7	6	5	3	0	350 ⁴
16/2	99	4/3	2 1	7	6	5	4	0	450 ⁴
16/2	99	4/3	2 1	7	6	5	4	0	490
12/1	103	4/3	2 1	7	4	5	5	0	240
13/1	101	4/3	2 1	7	4	5	3	0	440
12/1	103	4/3	2 1	7	4	5	5	0	240
296 B	108	4	9 8	3	1	5	4	10	400
237 A	109	4	9 9	3	1	5	4	10	260
282 A	106	4	9 8	3	1	5	4	10	260
237 D	108	4/3	3 3	7	6	7	3	10	200
230 A	107	4	3 3	7	6	7	3	10	200

1 Les lettres A, B, C, D et les nombres 1, 2, 3 des échantillons 230 et 16 montrent que ces cultivars ont un même échantillon original.

2 Etendard (calice).

3 Corolle (ailes).

4 Haricots verts.

Les principaux ennemis et ravageurs observés de haricot:

Les maladies

- les maladies cryptogamiques (anthracnose causée par *Colletotrichum lindemuthianum*; (ascochytose causée par *Ascochyta phaseolorum*; la maladie des taches anguleuses causée par *Isariopsis griseola*; la rouille causée par *Uromyces appendiculatus*)
- les maladies bactériennes
- les maladies virales

Les insectes

- la mouche du haricot (*Ophioma phaseoli*)
- le grillon (*Brachytrypes membranaceus*)
- les thrips (*Taeniothrips sjostedti*)
- les pucerons noirs (*Aphis fabae*)
- les chenilles foreuses des gousses (*Maruca testulalis*)

Une étude plus appropriée est programmée pour identifier les variétés résistantes ou tolérantes à ces ennemis du haricot.

Ce travail continue en vue de confirmer les résultats du premier essai d'identification.

Caractérisation du sorgho

Méthodologie

La caractérisation du sorgho a commencé en 1987 sur des cultivars provenant du Rwanda et du Zaïre à la station de l'ISABU/Imbo-centre (800 - 830 m d'altitude et $\pm 25^{\circ}\text{C}$ de moyenne). Le semis se fait en decembre avec 3 à 5 graines par poquet, suivi d'un démariage de 1 à 3 plants tandis que la récolte s'est échelonnée entre le mois de mai et de juin.

Le descripteur modèle CIRPG a servi de guide. Plus de 29 caractères ont été considérés, mais 18 seulement ont été retenus pour identifier les cultivars.

Résultats

Les résultats des observations montrent une certaine variabilité au sein des cultivars; il s'agit par exemple:

- du cycle végétatif (hâtif, tardif, etc.);
- de la hauteur du plant (1,5 à 3,0 m);
- la forme du panicule (compacité et forme de l'inflorescence);
- le recouvrement des graines (à 25 %, à 75 %) par les glumes;
- la couleur des glumes (brune, noire, jaune, etc.).

On a remarqué des variétés précoces (de 5 mois) et des variétés tardives (de 6 mois). Ce travail devra continuer pour arriver à identifier ces différents cultivars en races ou en principaux types: Guineas, Durras, Bicolor, Karif, Caudatum, etc.

Ennemis et ravageurs

Plusieurs ennemis (insectes et maladies) ont été également remarqués, les résultats de la caractérisation fait mention de ces attaques suivant les cultivars. Voici la liste de plusieurs maladies et insectes remarqués:

- la cercosporiose causée par *Cercospora sorghi* Ellis et Everhart
- l'helminthosporiose causée par *Helminthosporium turcicum* Pass
- le charbon nu causé par *Sphacelotheca cruenta*
- le mildiou causé par *Sphacelotheca sorghi*
- le charbon de la panicule causé par *Sphacelotheca reiliana*
- les chenilles foreuses des tiges (*Busseola fusca*, *Sesamia* spp.)
- les attaques de *Chilo partellus* Swinhoc
- les attaques des pucerons

Une étude appropriée est prévue pour identifier les cultivars résistants ou tolérants à ces ennemis du sorgho.

La multiplication

Les échantillons de certains cultivars récoltés en quantité insuffisante ont fait l'objet d'une multiplication de semences pour augmenter la quantité de semences et satisfaire les exigences de la conservation. Il s'agit notamment des cultures suivantes:

- patate douce, *Ipomoea batatas*, réalisée à Mashitsi (1,650 m d'altitude au Burundi);
- haricot commun, *Phaseolus vulgaris*, réalisée à Mashitsi et au Mosso (1,250 m d'altitude au Burundi);
- pois cajan, *Cajanus cajan*, réalisée à Citega (Service vétérinaire à $\pm$ 1,650 m d'altitude au Burundi);
- voandzou, *Vigna subterranea*, réalisée à l'Imbo (800 m d'altitude au Burundi);
- millet, *Pennisetum typhoides*, réalisée à l'Imbo;
- niébé, *Vigna unguiculata*, réalisée à l'Imbo;
- sésbame, *Sesamum indicum*, réalisée à l'Imbo.

Documentation

L'IRAZ dispose d'un système manuel de documentation pour enregistrer toutes les informations de collecte, de caractérisation, de conservation, etc. Toutes ces informations sont notées dans deux registres:

- le registre de données de passeport (collecte, etc.);
- le registre de la gestion des informations (caractérisation, distribution, conservation, etc.).

La documentation des ressources phytogénétiques de la CEPGL comprend un centre régional situé à Gitega et des centres nationaux localisés au niveau des instituts nationaux de recherche (ISABU, ISAR et INERA).

Distribution du germoplasme

Les duplicata du matériel végétal conservé à l'IRAZ ont été distribués d'une part aux instituts nationaux respectifs (ISABU, ISAR et INERA) et d'autres au réseau mondial de ressources phytogénétiques (CIRPG, ICRISAT, CIAT) via Kew (Angleterre) pour une éventuelle évaluation et/ou une collection de base.

La conservation du germoplasme

La conservation de semences de cultures à graines orthodoxes et des plantes fourragères se fait dans les congélateurs après le test de germination et d'humidité tant au niveau de l'IRAZ que celui des instituts nationaux, tandis que les plantes à racines et tubercules sont maintenues sous forme de collections vivantes ou sous forme de cultures de tissus (cas du bananier, du manioc et de la patate douce).

RECOMMANDATIONS

L'IRAZ souhaite que les travaux d'identification des variétés du matériel collecté continuent en vue de bien connaître les variétés en conservation et recommande à au CIRPG et à tous les organismes qui jouent le même rôle dans le monde de bien vouloir continuer leur action pour stimuler la conservation du matériel végétal tant au niveau national, régional qu'international, de continuer à former le personnel qui devra s'occuper de la gestion de ces ressources phytogénétiques et de chercher les voies et moyens pour renforcer les structures nationales de conservation pour une meilleure conservation du patrimoine végétal au niveau de tous les pays du monde.

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6.4

Conservation and Utilization of Genetic Resources in the SADCC Region: A Collaborative Approach

M. L. KYOMO

The Southern African Development Coordination Conference (SADCC), comprising nine member states (Angola, Botswana, Lesotho, Malawi, Mozambique, Swaziland, Tanzania, Zambia and Zimbabwe), decided in 1986 to establish a regional Crops and Forest Seeds Genebank. This decision was based on a recommendation from a Consultation on Plant Genetic Resources in SADCC Countries, organized jointly by the Southern African Centre for Cooperation in Agricultural Research (SACCAR), the Nordic Genebank and the International Board for Plant Genetic Resources (IBPGR).

The Consultation noted that plant breeders often fall back on wild plant species, landraces and varieties when looking for genes to confer resistance to diseases, pests and environmental stresses and to provide a quantum leap when a plateau in yield has been reached. It also noted that most base collections of crop and forest seeds were kept outside the SADCC region, and that the working collections kept by plant breeders all over the world were more readily shared than the base collections.

In the light of these and other findings, it was decided to recommend to SADCC's policy-makers that a regional genebank for base collections and national centres for working collections be established. The former would be guided by policies formulated by a Board comprising the chairpersons of national plant genetic resources committees which, in turn, would be comprised of botanists, plant breeders, managers of botanical gardens, taxonomists, pasture agronomists, herbarium managers, foresters, range ecologists and others.

THE SADCC ENVIRONMENT

The SADCC region stretches from about 2°S to 30°S, and from 12°E to 40°E. The altitude varies from sea level to areas with permanently snow-capped mountains. The terrain varies

from hilly and mountainous in the case of Lesotho, parts of Angola, Malawi, Mozambique, Swaziland, Tanzania, Zambia and Zimbabwe to almost flat plateau in the case of Botswana. The annual rainfall varies from 0-200 mm per annum in the Namibian Desert, which extends to part of Angola, to over 1400 mm in parts of Angola, Malawi, Mozambique, Swaziland, Tanzania and Zambia.

With such varied physical features and climatic factors, the region supports a wide diversity plant species which are used for food and forestry purposes. The diversity of species in natural habitat has long fascinated ecologists. They have tried to link diversity with stability in agriculture, but this link does not seem to apply in cases such as the tropical rainforests, which are rich in plant species diversity but have among the most fragile soils. This fragility was not obvious in the 19th century when pressure on natural resources was low. However, during the present century, as human populations have increased, the common strategy adopted to meet demand has been to expand the cultivated land area. This has led to indiscriminate reduction of forest areas and consequently to exposure of soils to heavy tropical rains and intense insolation.

When these factors are coupled with poor management conservation of soils and water, serious soil erosion occurs. The loss of top soil also occurs if there is indiscriminate burning of the plant species in the rangelands, which exposes the top soil to pounding by heavy tropical storms. Indiscriminate burning of the rangelands and forests and expansion of the cultivated area are probably the two main factors which reduce the diversity of cultivated plants and their wild relatives. Other factors which reduce plant diversity include pests such as locusts, quelea birds and army worms, and some which are specific to particular crops, such as the cassava spider mite and the cassava mealybug.

THE REGIONAL GENE BANK PROJECT

SADCC's stated development objectives include sustainable development of agriculture and forestry. The regional genebank project aims at building up competence in germplasm collection, characterization, evaluation, documentation, storage and utilization. Member states are aware that plant genetic material required for the long-term development of new improved crop varieties can ensure a stable and sufficient supply of food, feed, fiber and forest products possessing desirable qualities. The availability of improved crop varieties (food and industrial crops, horticultural crops, and pasture and forestry species) is considered an essential part of the agricultural development process.

It is essential, therefore, that a plant genetic resources conservation program be put in place to ensure that there is minimal loss of old landraces, utilized wild plants and other plant genetic resources. SADCC's agricultural development strategy is to concentrate mainly on smallholder farmers who are likely to have kept their own seed supply and not to have used commercial seed. Any plant material lost is unlikely to be regained.

Considering the economic situation of the region, the scarcity of technical competence and the consequent training and education needs, as well as the fundamental role of a plant genetic resources program for the development of agriculture in the region, the project needs to be substantial and long term. Since the countries also have broad climatic and ecological zones in common, a SADCC Regional Genebank (SRGB) with national support on a cost-sharing basis has been considered the most efficient solution because:

- coordination of work within the region can greatly reduce recurrent costs and increase efficiency;
- training is costly and time-consuming, and the few available highly qualified experts can serve a greater community if used in a regional context;
- a computerized regional documentation and information center can greatly increase utilization of material and thereby become much more cost-effective;
- plant quarantine in plant introduction could be more efficiently handled by one central institution.

The project will contribute to agricultural development in the region:

- by preventing, through the collection and proper preservation of irreplaceable materials, the erosion and loss of the countries' crop genetic resources;
- by characterizing, evaluating, multiplying and rejuvenating collected germplasm material;
- by documenting the plant genetic resources material of the region;
- by providing means for efficient utilization of the plant genetic resources throughout the region;
- by making available the genetic resources of endemic or indigenous plants for plant breeding and research;
- by ensuring, through exchange with other genebanks and sources, the continued availability of exotic (introduced) plants for plant breeding and research;
- by providing a forum for the exchange of knowledge and experience, scientific as well as cultural.

At the same time, National Plant Genetic Resources Centers (NPGRC) will be established and/or strengthened in each country, to function as counterparts to the SRGB and to handle collection trips, *in situ* conservation and germplasm utilization on the national level. The establishment/strengthening of the NPGRCs is to be considered an 'input in kind' to this project, and will be funded mainly by the governments of the SADCC member states alone or in conjunction with donor agencies.

According to the recommendations in the report of the Agricultural Research Resource Assessment (ARRA) of SADCC, the project and, in particular, the NPGRCs could make considerable contributions to specific areas of agricultural development. The ARRA report placed particular emphasis on improving the situation for smallholders, since these people at present represent the majority of farmers, in number and acreage. The NPGRCs can here make a short-term input at the same time as securing plant genetic resources material.

In order to make the smallholder interested in new cultivars without risking dramatic setbacks, work on improving the strains already being used might be a suitable beginning. This process could be initiated by collection by the NPGRCs and characterization and

evaluation in cooperation with breeders, who would do a straight selection for the best available types to return to the smallholder within 5-10 years. By bringing in a large amount of material from the smallholders to characterize and evaluate and making it easily available, the genebank may be instrumental in bringing about a worthwhile research focus on smallholder problems.

Program 13 of ARRA (Sorghum/Millet Improvement) is already partly under way, and other programs are to be designed. It is now urgent to also get a plant genetic resources program under way. Collections of older material must be well advanced before new varieties appear. More importantly, knowledge of the existing variation in crops brought about by the genebank activities may well be a prerequisite for the success of various planned regional projects.

The ARRA report also describes ways in which plant genetic resources activities could be of some importance. The descriptions of some of the cultural traditions of the region and the role of cattle in some of the countries suggest that forage plant species deserve particular attention. Efficient forage production could free land for food production without, for instance, challenging smallholders' cultural traditions concerning the size of cattle herds. Furthermore, much of the arable land receives less than 600 mm of rain per year, and thus much of it is suitable only for grazing.

In a large part of the region, rainfall is irregular and droughts are frequent. The identification of genetic sources for short maturity period and drought resistance is thus an important target for plant genetic resources programs. The use of mixed crops by smallholders will require particular consideration by the genebank and particular breeding methods in plant breeding programs. The problem of deforestation and erosion may necessitate prioritizing forest issues in the genebank; an evaluation could be carried out in cooperation with the forestry workers to promote fast-growing provenances on a short-term basis, while concurrently promoting more enduring provenances for long-term use.

Deforestation and erosion pose a considerable threat to a large number of wild plant species, many of which are close to extinction. A regional genetic resources program, which includes such activities as documentation and *in situ* preservation, will be a center of knowledge and a source of information for efforts aimed at preventing the loss of wild plant genetic resources.

PROJECT STRUCTURE AND OBJECTIVES

The SRGB will be established in one of the SADCC member states and will coordinate and serve the NPGRCs which, in their turn, will serve the national breeders and researchers. The SRGB will be an independent institution governed by a Board which will provide policy guidelines. This Board will be composed of the chairpersons of the member states' national plant genetic resources committees (PGRs). The SRGB will help the NPGRCs develop a network of collaborating national plant research and breeding institutes for the collection, characterization, evaluation and utilization of plant genetic resources.

An NPGRC will be established in each SADCC member state by the respective governments with assistance from IBPGR, the SRGB and other sources. The strengthening of national programs, where necessary and desired, could precede formal acceptance of the project. This is particularly urgent where large collections are currently maintained under poor storage conditions.

A Technical Advisory Committee (TAC) to advise the SRGB will be established. It will comprise one member from the Board of SACCAR, one representative of the Board of the Nordic Genebank, one IBPGR representative and an additional member or members from one or more of the other international agricultural research centers on a rotational basis. The TAC will meet at regular intervals in one of the SADCC member states.

A recent survey shows that about 44,000 accessions (mainly seeds) have been collected over the past decade in the SADCC region (*see* Table 1). However, because of poor storage conditions, many of these may no longer be viable. On the basis that the number of collections will diminish with time, the regional *ex situ* seed collection is estimated to reach 100,000 accessions over the first two 5-year periods and to increase by an average of 1,000 accessions annually for the following 10 years. A Plant Genetic Resources Inventory (PGRI) is to be established soon, so that the estimate of accumulated accessions can be accurately updated.

TABLE 1 Plant species that have been collected in SADCC through IBPGR initiatives

Country	Plants	Characteristics
Botswana	Sorghum and millets Durra-Kafir races Some Durra and Guinea races Further collections sorghums and millets, wild rice, forage grasses and legumes	Resistant to downy mildew Have a day-neutral photoperiod Agronomic superiority and adaptability to low moisture and poor soil conditions
Lesotho	Sorghums Future collections of maize, food crops and pasture plant species are necessary	
Malawi	Sorghum, pearl millet, finger millet, groundnuts, pigeonpea, cowpea and others; other collections have been made of beans, cassava, okra, bambara nuts and finger millet	
Mozambique	Sorghum, millet, groundnuts, bambara nuts, legumes, cotton, rice, maize, sweet potatoes, horticultural crops, forage grasses and legumes, cashew nuts, coffee and coconuts	

For each major crop species or group of minor species, Crop Working Groups are to be formed, the members (experts on the crop species or species groups) being appointed by the SRGB Board. Although technical expertise is to be the first criterion, a fair representation of SADCC member states in the working groups as a whole is considered desirable.

Initial funding of US\$ 11 million has been secured, and SADCC member states have pledged to contribute US\$11.6 million in future. Plans are under way to identify an executing agency for the project. It is expected that the project will start in 1989.

Objectives of the SADCC Regional Genebank

In line with the Consultation recommendations, the objectives of the SRGB are:

- to hold the base collection of the SADCC member states;
- to maintain and manage the long-term base collection;

- to maintain and manage medium- to long-term storage facilities for active collections of the SADCC member states;
- to arrange and provide for the collections to be duplicated in designated crop-specific base collections in the IBPGR network and in the duplicate store of the Nordic Genebank in Svalbard; the SRGB should be provided with its own container in this store;
- to develop, maintain and manage the Regional Central Inventory Database for the indigenous plant genetic resources of the SADCC member states stored *ex situ* and *in situ*;
- to coordinate the collection, characterization, evaluation, documentation, rejuvenation and multiplication of indigenous genetic resources material of the SADCC member states;
- to coordinate the introduction, evaluation and documentation of introduced plant genetic resources material in the SADCC member states;
- to maintain and manage a medium- and long-term store for introduced plant genetic resources materials which are of common interest to the SADCC countries;
- to keep records of plant introductions in the Regional Central Inventory Database ;
- to publish a *SADCC Plant Genetic Resources Newsletter* which pays particular attention to urgent problems in plant breeding and in seed and crop production;
- to issue catalogs of plant genetic resources available from or obtainable through the regional genebank;
- to organize such meetings and training activities as decided by the Board.

The Consultation recommended that the SRGB be located at Mount Makulu Research Station, near Lusaka, Zambia.

Objectives of the National Plant Genetic Resources Centers

In line with the recommendations of the Consultation, the objectives of the NPGRCs are:

- to gather, through exploration and collecting expeditions in the different ecological zones of the countries, information and genetic resources of all endemic and indigenous plants which are cultivated or used in the country or have the potential for cultivation or use, together with wild relatives of such species;
- to characterize, evaluate, rejuvenate, multiply and document indigenous and exotic plant genetic resources material under the coordination of and in agreement with the SRGB;
- to hold short-term working collections of indigenous or adapted plant genetic resources material under the coordination of and in agreement with the SRGB;

- to handle *in situ* conservation in collaboration with the SRGB;
- to serve directly national plant breeding and research efforts on indigenous or adapted plant genetic resources material in the national working collection and from the SRGB;
- to work in close collaboration with national plant breeding institutions for effective utilization of plant genetic resources.

The location of the NPGRCs are to be decided by each country. The following locations have been suggested:

Angola:	Agronomy Research Institute, Huambo
Botswana:	Sebele Research Center
Lesotho:	Department of Agricultural Research, Maseru
Malawi:	Chitedze Agricultural Research Center, near Lilongwe
Mozambique:	Instituto Nacional de Investigacao Agronomica, Maputo
Swaziland:	Malkerns Experimental Station
Tanzania:	Kibaha Research Station
Zambia:	Mount Makulu, Lusaka
Zimbabwe:	Crop Breeding Institute, Harare

Because of the large size of many of the SADCC member states and consequent communication problems, a system of sub-centers may be considered. One possibility is to designate a staff member of each of the major research stations in the country as a plant genetic resources officer, with the responsibility to liaise with the NPGRC and carry out a certain amount of exploration and collecting in his or her area.

A considerable number of germplasm accessions have been collected and are maintained in the SADCC member states (*see Table 2 overleaf*). However, the condition of many of these samples is uncertain or precarious because of poor storage facilities, and the actual quality and number of the accessions have therefore to be checked. The rapid establishment of proper storage facilities in the SRGB is one of the overriding objectives of the project. To help solve particularly urgent problems, a certain amount of money can be made available from the project's Contingency Fund. The Consultation recommended the establishment of highly reliable, durable and low-cost stores and the implementation of a thorough study of the potential of sun-drying for the storage of seeds for longer terms.

Education and training

The Consultation noted that the limited availability of trained personnel is a serious initial constraint which has to be overcome. The project must therefore include a strategy which responds to the need for long-term education as well as short-term training. In devising a strategy to be funded by the project, the following has been agreed:

- IBPGR will provide fellowships for the University of Birmingham MSc course to one trainee from each SADCC country;
- IBPGR will allocate fellowships on its short courses for trainees from SADCC member states;

TABLE 2 Germplasm accessions maintained in the SADC region

Species	Number of accessions									
	Angola	Botswana	Lesotho	Malawi	Mozambique	Swaziland	Tanzania	Zambia	Zimbabwe	Total
<i>Abebrusculus exculentus</i>	-	-	-	30	-	-	29	108	69	236
<i>Amaranthus</i> spp.	-	-	-	-	-	-	-	74	16	90
<i>Arachis hypogaea</i>	-	9	-	349	754	-	290	495	183	2,080
<i>Brassica</i> spp.	-	-	-	-	-	-	-	-	48	48
<i>Cajanus cajan</i>	-	-	-	25	53	-	284	45	2	409
<i>Corchorus</i> spp.	-	-	-	-	-	-	-	26	8	34
<i>Cucurbits</i>	-	-	-	-	-	-	-	531	446	977
<i>Eleusine</i> spp.	-	6	-	257	4	-	40	273	292	872
<i>Glycine max</i>	-	-	-	-	-	-	-	441	556	997
<i>Hibiscus</i> spp.	-	-	-	-	-	-	-	127	4	131
<i>Oryza</i> spp.	-	-	-	142	32	-	348	336	80	938
<i>Phaseolus</i> spp.	540	-	-	6,000	30	-	1,744	272	8	8,594
<i>Ricinus communis</i>	-	-	-	-	-	-	-	55	-	55
<i>Sesamum</i> spp.	-	-	-	-	-	-	-	62	4	66
<i>Solanum</i> spp.	-	-	-	-	-	-	-	49	22	71
<i>Sorghum</i> spp.	-	7,236	130	495	61	99	236	561	302	9,120
<i>Vigna</i> spp.	-	800	-	222	234	-	427	264	208	2,155
<i>Voandzeia subterranea</i>	-	14	-	63	13	-	1,615	264	150	2,119
<i>Zea mays</i>	330	-	-	83	45	-	103	307	36	904

TABLE 2 (contd)

Species	Number of accessions									Total
	Angola	Botswana	Lesotho	Malawi	Mozambique	Swaziland	Tanzania	Zambia	Zimbabwe	
<i>Helianthus annuus</i>	-	-	-	-	-	-	-	30	5,550	5,580
<i>Coffea</i> spp.	-	-	-	-	-	-	500	20	-	520
<i>Panicum</i> spp.	-	-	-	6	-	-	-	67	-	73
<i>Triticum</i> spp.	-	-	-	-	-	-	-	640	550	1,190
<i>Pennisetum</i> spp.	-	65	-	229	29	-	177	161	129	860
<i>Manihot</i> spp.	-	-	-	148	29	-	246	36	-	459
<i>Nicotiana tabacum</i>	-	-	-	-	-	-	-	-	462	462
<i>Gossypium</i> spp.	-	-	-	1,375	-	-	-	-	838	2,213
<i>Lablab purpureus</i>	-	-	-	-	15	-	14	-	-	29
<i>Ipomoea batatas</i>	-	-	-	-	20	-	77	-	-	97
<i>Pisum sativum</i>	-	-	-	-	-	-	15	-	-	15
Sugarcane	-	-	-	-	-	-	455	-	430	885
Temperate fruits	-	-	-	-	-	-	206	-	-	206
Citrus fruits	-	-	-	-	-	-	50	-	-	50
Other tropical fruits	-	-	-	-	-	-	55	-	-	55
<i>Musa</i> spp.	-	-	-	-	-	-	317	-	-	317
Forage legumes	-	-	-	-	-	-	152	-	48	200
Forage grasses	-	-	-	-	-	-	162	-	340	502
Total	840	8,130	130	9,494	1,319	99	7,542	5,244	10,781	43,609

- the international agricultural research centers will continue to provide fellowships, especially in the area of germplasm utilization;
- training in the region (mainly by and at the SRGB) will be implemented after the first 5 years;
- on-the-job training at the SRGB and the NPGRCs will be funded by the project.

Efforts should be made by the project to strengthen one university in the SADCC region so that it would be able to provide postgraduate courses in genebank management and related fields.

CONCLUSION

The decision by the nine member states of the SADCC region to establish a regional genebank, to be supported by a network of national genetic resources centers, is in response to the realization that:

- the SADCC region possesses a wide assortment of domesticated and wild plants with characteristics of potential use in breeding programs;
- a very real risk exists of losing valuable germplasm through attack by pests, diseases, weather extremes and human activities;
- some of the region's crop and forest seed has already been removed to storage in foreign genebanks to which plant breeders have little or no access.

The project integrates action at national and regional level to characterize, evaluate and conserve germplasm within the overall objective of crop and forestry species improvement and it embodies the important SADCC principle that action should be initiated at and emerge from the national level. It has been established to achieve the degree of collaboration and exchange of information at regional level that is required in order to ensure the conservation and effective utilization of the plant genetic resources of the SADCC region.

6.5

The Role and Activities of the Genebank of Kenya

E. N. SEME

The past few decades have seen a rapid loss of plant genetic resources in Kenya. This has been triggered off by number of factors, including the acute population and socioeconomic pressures that have led to increased land use and adoption of modern agricultural practices. In recognition of this threat to its genetic heritage, the Government of Kenya has established a crop plant genetic resources center, the Genebank of Kenya, at Muguga. This was made possible with the financial and technical assistance of the Federal Republic of Germany.

The decision to establish the genebank was made in the early 1980s and the genebank was fully operational by mid-1988 as a service institution within the framework of the Kenya Agricultural Research Institute (KARI).

The genebank is responsible for the following tasks:

- organization of germplasm exploration and collection missions at the national level;
- introduction of new genetic resources in consultation with other research institutions and the National Plant Quarantine Station;
- international exchange of germplasm and relevant information;
- germplasm multiplication, rejuvenation, characterization and preliminary evaluation work for specific genebank purposes;
- coordination of all crop plant genetic resources activities in Kenya;
- long-term conservation of germplasm;
- organization of technical meetings and workshops, and staff training.

In addition to the central genebank, which will be for base collections, 10 KARI centers have been provided with medium-term cold-storage facilities for active collections.

The Genebank of Kenya bases its priorities for crop collection on the economic and social importance of any given crop, its genetic state of development and the degree of genetic erosion. Special attention will be paid to those crops with unique diversity, mainly the landraces of indigenous crops such as sorghum, millet, pigeonpea and forage species.

To provide a database on previous crop-collection activities, the staff of the genebank are collecting and evaluating information gathered in the past on germplasm from breeding stations and other research institutions. This exercise is deemed necessary to ascertain where and in what state the collected accessions are stored before they are transferred to the genebank for long-term storage as base collections, or before countrywide collecting missions are undertaken.

In the past, no systematic countrywide collecting missions were undertaken. Most missions were initiated by foreign sources and focused on just a few crops. Because of the poor storage conditions, most duplicate samples of the collected materials left behind lost their viability. Thus, collections from the original site will have to be undertaken again or duplicate samples from abroad will have to be retrieved. Systematic countrywide exploration and collection missions are being organized by the genebank staff, with financial assistance from the International Board for Plant Genetic Resources (IBPGR). All future missions will involve the genebank and research institutions dealing with crops to be collected. With funds provided by IBPGR, India's National Bureau of Plant Genetic Resources (NBPGR) assisted the genebank in collecting wild and cultivated forage sorghum in Kenya in 1987.

The major activities of the seed technology and phytopathology section focus on seed processing, seed drying, seed testing, seed health, seed storage and the field genebank. Seed processing activities include germplasm cleaning, counting, germination testing and data recording. Samples with the minimum number of seeds, as recommended by IBPGR, are processed further. ISTA rules are followed in germination testing. However, 200 seeds in four replicates are used in each sample and minimum viability is set at 85%. The unit is equipped with an incubator/germinator, Jacobsen germinator, and a germination room set at normal room temperature with a humidifier. After processing, the seed is dried at 25°C and 15% RH to ensure a moisture content reduction to 4-6%. Accessions are divided into sub-samples depending on their heterogeneity and seed size. Finally, the seed is weighed and packed in aluminum foil packets which are then hermetically sealed.

The seed drying unit will in future also work on viability monitoring of stored accessions. Research into seed testing, especially dormancy breaking tests, will constitute an important program in the unit.

There are plans to set up a laboratory with facilities for detecting and preventing the transfer of seedborne pathogens into or out of the genebank along with germplasm. These procedures will be closely integrated with other routine laboratory tests. The Plant Quarantine Station, located next to the genebank, will work closely with the genebank on these matters.

The genebank has two long-term cold stores, each 75m³, for base collections to be maintained at -20°C. Active collections are maintained at research stations at +5°C. Plans are under way to transfer some germplasm from national research stations for storage at the central genebank.

A field genebank for low-altitude crops (coconut, mango, citrus, avocado, cassava, cashew nut and banana) has been established at the Matuga Agricultural Research Center in the Coast Province. Other field genebanks are planned for Thika and Molo for high-altitude crops. In addition to these, field collections of coffee and tea are maintained at the Coffee Research Foundation and Tea Research Foundation Centers, respectively.

Having identified priority crop germplasm for characterization and evaluation, the genebank staff developed descriptor lists in consultation with plant breeders, based on the recommendations of IBPGR. This ensures a standardized description of the various accessions identified.

Between May and August 1988, about 4,000 accessions of sorghum, finger millet, durum wheat and groundnuts were characterized and evaluated. This was the beginning of the long-term evaluation work on local landraces, which had previously been ignored. Multiplication and rejuvenation of base collections will be undertaken in environments suitable to the crops' ecological adaptation. Where possible, these activities will be combined with characterization and evaluation to avoid having many crop cycles in the field and to save on costs. Multiplication and rejuvenation of active collections will be undertaken by those stations holding them.

A central computerized documentation system is being established at the genebank. This will list all information on germplasm available in the country and held by research stations and the genebank. This information will be readily available to users through the germplasm information unit.

The Genebank of Kenya collaborates with several institutions, especially in the areas of training, collection, characterization, evaluation and conservation. These are IBPGR, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Center for Agricultural Research in the Dry Areas (ICARDA), the Plant Genetic Resources Center/Ethiopia (PGRC/E) and the NBPGR in India.

Closing Statement

HON. J. J. M. NYAGAH

Minister for Environment and Natural Resources, Kenya

I feel greatly honored to be invited here to formally close this International Workshop on Plant Genetic Resources in Africa. I regard this workshop as a timely follow-up to the First African Ministerial Conference on the Environment which was held in Cairo in 1985 and which I attended. At the Cairo Conference, African countries resolved to strengthen and promote inter-country cooperation in this important field of genetic resources and, as a result of this decision, a network for the African region was established.

It is my understanding that the purpose of this workshop was to act as a forum for exchanging information on the status of plant genetic resources conservation in our continent and the achievements and needs in this area, as well as to foster continental and national links and to formulate aims which were compatible with development objectives.

May I take this opportunity to thank the United Nations Environment Programme (UNEP), the International Board for Plant Genetic Resources (IBPGR) and the International Institute of Tropical Agriculture (IITA) for organizing this very important workshop and to thank the participants who traveled from so many different places to attend the workshop and make it a success. The efforts each of you have put into the deliberations of this workshop are appreciated by the Kenya Government.

Ladies and gentlemen, allow me to remind you that plants are crucial to the welfare of mankind as sources of food, fiber, energy, drugs, chemicals and a host of other materials. They also have ethical, cultural, psychological and recreational values, and as such their importance cannot be overemphasized. Notwithstanding this, countless species of plants are still undiscovered or undescribed. Yet these species are disappearing at an unprecedented rate, essentially as a result of human activity and particularly through irreversible habitat destruction. It is very probable that at this rate some species will disappear even before we know of their existence — before science is given a chance to assess their potential value to mankind. Wetlands and natural woodlands are particularly at risk.

Not only are species of plants being lost, but also varieties and races within plant species, and thus a reduction in intraspecific diversity is also occurring. You are all aware that all cultivated plants originate from wild relatives and it is imperative that we conserve representative samples of these wild relatives to serve as the basis for continuing genetic selection and improvement in agriculture and forestry. Approximately 256,000 plant species are at risk of extinction globally during our lifetime through habitat destruction. About 6,000 plants are known to be used in agriculture, forestry and medicine, whereas only 150 are used for intensive cultivation. Of the number of plants used for cultivation, only some 20 species

produce about 90% of the world's food. The extinction of wild species of plants therefore deprives agriculture, forestry, medicine and industry of the genetic diversity on which they depend.

Without belaboring the point, may I say that current emphasis on intensive production based on specifically bred high-yielding strains of plants with narrow uniform genetic bases makes it all the more necessary to further the conservation of genetic diversity in crop plants and their wild relatives. As prospects of food shortage become more acute, we must depend increasingly on plants rather than animals for protein in our diet. However, reliance on a small number of plants carries a great risk — monocultures are extremely vulnerable to catastrophes caused by diseases and climatic variation. Therefore, raising food production and providing food security in the African region will require the availability of a broad-based gene pool which is the ultimate requirement for human survival.

To be blunt, it is disturbing to note that poor people's crops, especially indigenous fruits and vegetables, with low international commercial value, have been neglected in the past in breeding programs. Yet these indigenous crops form basic food materials that improve nutritional qualities of rural diets. I appeal to the scientists and policy-makers gathered here today to pay more attention to the conservation and improvement of traditional African plants. It is encouraging, on the other hand, to note that conservation and improvement of indigenous trees is under way in many countries of Africa through the promotion of seedbanks, specialized research and increased community participation.

It is my belief that, in the long run, mankind's great hope lies with *in situ* conservation of plant germplasm in protected areas. *Ex situ* conservation based on the genebank concept complements but does not substitute for *in situ* conservation. Both approaches need to be strengthened and coordinated in the African region.

The establishment of protected areas, the application of conservation principles outlined in the World Conservation Strategy (WCS), the World Charter for Nature and the Plan of Action for Biosphere Reserves and the formulation and implementation of national and regional conservation strategies are among the measures aimed at conserving plant germplasm. I appeal to everyone to give support to such measures in their individual capacities. Likewise, I appeal to everyone here to facilitate the signing and implementation, in their individual countries, of the three instruments concerned with conservation of plant germplasm: the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on the Protection of the World Cultural and Natural Heritage and the Convention on Wetlands (Pamsar Convention).

We note with appreciation the work being done by United Nations agencies, international organizations and the donor community in relation to plant genetic resources conservation and improvement. This work has included collection, evaluation and storage of germplasm; *in situ* conservation in protected areas; and the establishment of genebanks and microbiological resources centers. I would like to express my gratitude in particular to UNEP, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Industrial Development Organization (UNIDO), IBPGR, the International Livestock Center for Africa (ILCA), the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), the International Council for Research in Agroforestry (ICRAF), the Plant Genetic Resources Center (PGRC), the International Union for Conservation of Nature and Natural Resources (IUCN) and the World Wide Fund for Nature (WWF). It is my hope that their efforts in this field will be even more concerted in future.

It is gratifying to note that the Workshop on African Genetic Resources held in Addis Ababa, Ethiopia, last year laid down the foundations for cooperation in genetic resources conservation and improvement in Africa and can serve as a basis for networking as recommended by the African Ministerial Conference on the Environment. That workshop also recommended the formation of an African Genetic Resources Commission to coordinate issues concerning genetic resources and to formulate strategies, and emphasized the need for exchange of plant germplasm, information and experiences on current plant genetic resources activities among African countries. To give effect to this proposal I would urge that work be intensified with a view to developing such a commission. In the East African region, a Permanent Steering Committee of Directors of National Agricultural Research Programs has been recommended under the auspices of the Intergovernmental Authority on Drought and Development (IGADD) to coordinate plant genetic resources research.

My statement would be far from complete without saying something about nongovernmental organizations (NGOs). They have in the past done a commendable job in the field of plant genetic resources and their involvement has been at a level that has ensured close contact with groups such as herders, woodgatherers, gardeners, medicine men and wood carvers, all of whom use plant resources. However, NGOs must also endeavor to maintain contact with the scientists and institutions that may provide technical assistance to help communities manage their resources in a sustainable manner.

I am quite sure that you were all briefed about Kenya's programs on crop plant germplasm conservation and improvement at the beginning of the workshop and will be aware of our commitment in this field. We are in the process of formulating a National Conservation Strategy which will address genetic resources management, among other issues, and have set up a National Germplasm Committee. We also maintain a tree seedbank and a clonal treebank and have designated four biosphere reserves. We have been greatly encouraged by the possibilities which have arisen from the use of micro-organisms in biological nitrogen fixation by legumes in agriculture. We have witnessed the establishment of a network of field stations through microbiological resources centers (MIRCENS) to demonstrate biological nitrogen fixation to farmers and the local production of biological nitrogen fixation fertilizer.

In the past, Kenya has organized two national workshops on plant communities and one national seminar on germplasm conservation and seed technology. Another seminar on germplasm conservation is planned for the near future. An attempt has been made in Kenya to identify endangered, rare and threatened species of plants. This effort has been part of the ongoing task of assessing the status of plant communities countrywide.

In conclusion, I wish to say that I hope that your four days of deliberation have borne fruit in which all of us can take considerable pride. I thank you for the opportunity to address you at the end of this long session and wish you a pleasant stay during the remainder of your time in Kenya. It is my pleasure now to declare this workshop officially closed.

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