CONSERVATION OF THE GENETIC RESOURCES OF THE GENUS *COFFEA*

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Any research center specialized in improving coffee production maintains collections of cultivated coffee trees under the breeder's responsability. These collections have been of minor importance compared to the breeding and agronomic programs. These "working collections" of breeders are to be distinguished from the rare major collections which ensure the conservation of genetic resources. The latter are distinguished by their specific wealth and their origin diversity resulting from prospections of wild coffees.

One knows that coffee genetic resources are not limited to the two cultivated species alone ; the whole genus *Coffea* (with more than 70 sp.), even the close genus *Paracoffea* and *Psilanthus*, belong to the same gene pool (Charrier, 1978). An organisation and methods adapted to genetic resources centers are required for the safeguard and the rational use of the major coffee collections. Based on our experience in Ivory Coast and Madagascar in this field, we will suggest the general orientations to ensure conservation, evaluation and distribution of the coffee germplasm by autonomous organisations in charge of the major coffee collections.

I. WORKING COLLECTIONS FOR COFFEE RESEARCH CENTERS

Their first objectives are the improvement of the two cultivated species, *C. arabica* and *C. canephora*. Such collections are often established and completed by successives introductions of strains more or less selected from other coffee stations, botanical gardens or local plantations. The other species are rarely represented.

A world wide survey conducted in 1978-79 on the existing coffee collections under the auspices of FAO provides an up-to-date document. Let us summarize the common gaps in the working collections :

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(i) some cultivars are replicated in most stations ; these redondances are common for *C. arabica* mutants,

(ii) on the contrary, some species and strains are represented in unique collection and should be distributed in order to reduce the risks of genetic erosion. That is the case of *Mascarocoffea* species in Madagascar, *C. congensis*, *C. eugenioides*, *C. zanguebariae* in Ivory Coast.

(iii) the species and variety names of the genus *Coffea* are confusing ; a more modern taxonomy would by necessary to replace that of Chevalier (1947),

(iv) the establishment of coffee collections through exchange of open-pollinated seeds does not preserve their genetic structure. This method may be acceptable for the autogamous species *C. arabica*, but in allogamous species, we only know the maternal filiation. In the case of the multiplication of a specific genotype, vegetative propagation could be used,

(v) the pedigree and sampling technique of the coffee trees in collection are not always well defined,

(vi) the museum collections are established without experimental design and isolation. Cross pollination between and within species are therefore likely to occur.

Now let us have a look at some possibilities of increasing genetic diversity of cultivated and wild coffee species in the major collections.

II. ENRICHING THE COLLECTIONS WITH PRIMITIVES STRAINS OF *COFFEA*

It is known that wide expansion of coffee culture in the world has been done with few genetic origins, especially for *C. arabica* (Wellman, 1961). Consciousness of the lack of variability in the coffee collections has led FAO and French organisations (ORSTOM, IFCC, Museum) to intensify collecting missions in the last twenty years. These collecting missions are summarized in table 1 where one can see the countries covered, species collected and the countries where the coffee germplasm is stored (FAO 1968 ; Charrier 1976 et 1978 ; Porteres 1962 ; Berthaud et *al*. 1977 ; Leroy 1962). This increase of the coffee germplasm concerned particularly *C. arabica*, because of its economic importance. A number of uncultivated species were also collected like *Mascarocoffea* (coffeine free), *C. congensis* (genitor for *congusta* hybrids), *Pachycoffea*, *C. eugenioides* (presumed ancestor of *C. arabica*) and the close genus *Psilanthus* and *Paracoffea*.

In intertropical Africa, one can still find, at least for a short time, wild coffee in undisturbed forests and semi-cultivated coffee in traditionnal agricultural areas. It is therefore urgent to proceed with the coffee germplasm collecting missions in the following areas (figure 1):

Years	Collections countries	Organisations	Species	Germplasm maintenance countries
1964	Ethiopia	FAO	*Arabica*	Ethiopia, India, Tanzania, America
1966	Ethiopia	ORSTOM	*Arabica*	Ethiopia, Madagascar, Cameroon, Ivory Coast
1960-1974	Malagasy region	Museum/ IFCC/ORSTOM	*Mascarocoffea*	Madagascar
1975	Central Africa	ORSTOM/IFCC	*Congensis, liberica, canephora,* caféier Nana	Ivory Coast, Central Africa
1975-1980	Ivory Coast	ORSTOM	*Liberica, canephora, Humilis, stenophylla, Paracoffea, Psilanthus*	Ivory Coast
1977	Kenya	ORSTOM/IFCC	*Arabica, eugenioides, zanguebariae, C.* sp.	Ivory Coast, Kenya

Table 1 : Summary of major Germplasm *Coffee* missions since 1960

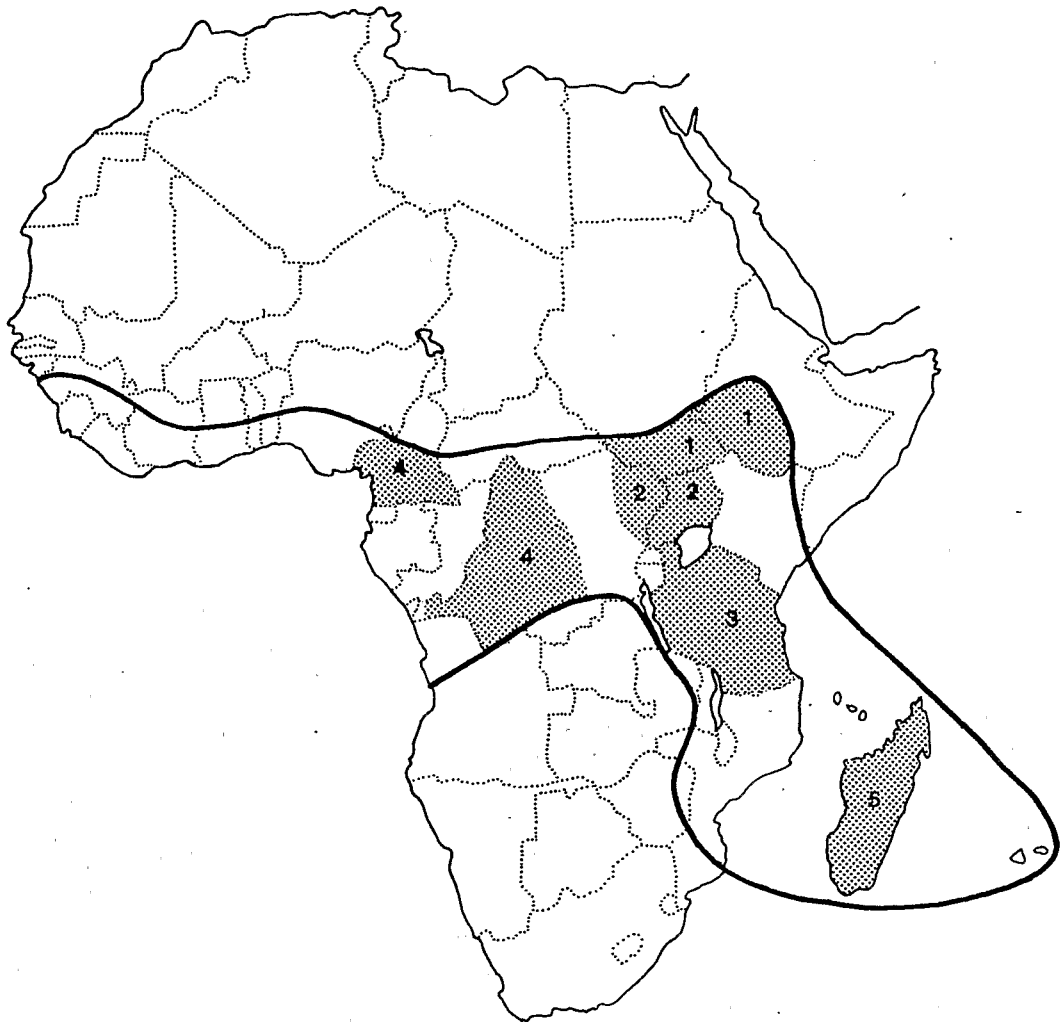

Fig. 1 : COFFEE GERMPLASM AREAS TO BE EXPLORED

(i) Southwestern Ethiopia and southeastern Sudan which are centers of diversification of *C. arabica*. The new expeditions should be directed towards areas not covered by the preceding missions and the collection of strains tolerant to coffee berry disease (CBD).

(ii) Uganda and eastern Zaïre.

In this zone where the distribution areas of the major diploid species overlap, emphasis will be put on the biogeographical relationships with *C. arabica* of south Sudan and the origin of this allotetraploid species.

(iii) Tanzania will complete the exploration of Kenya in order to increase representation of the *Mozambicoffea* section.

(iv) Central Africa : A coffee exploration in Cameroon, Gabon, Congo, Zaïre would increase the representation of *C. canephora*, *C. congensis*, *C. liberica*, *C. brevipes* which are very important species in breeding programs.

(v) Malagasy region : the diversity and the originality of *Marcaro-coffea* alone justify further prospections.

One can see that sending germplasm collecting missions from abroad for a short time, have been effective in collecting large amount of seeds and cuttings to be sent to the conservation centers. This approach should be completed with a germplasm collection on a permanent basis, at a local level.

III. CONSERVATION SYSTEMS OF THE COFFEE GENETIC RESOURCES

It is possible to protect that gene pool either through natural forest reserves or through living plant collections.

(i) Strict natural reserves

It is the best conservation system because it maintains the evolutionnary potential of natural populations. They follow the dynamic transformations of the biotype and particulary the evolution of pests and diseases. In this respect, the *C. arabica* exemple is very instructive. A number of genotypes collected from Ethiopia show a good tolerance for rust ; a host-parasite equilibrium has taken place in the variability center. On the other hand, the recent spread of the CBD from East Africa is a serious threat to the world production of arabica coffee. The cultivated varieties are succeptible and tolerant genitors are scarce among the plant material from Ethiopia and Sudan (Van der Vossen, 1978). Is the selective pressure of *Colletotrichum coffeanum* too recent for the natural populations of *C. arabica* to develop an adaptive response ?

Undisturbed forests containing wild coffee trees are becoming rare and should be reserved. Could we have the facilities to create such strict natural reserves in Ethiopia, Madagascar, Tanzania, Zaïre, Cameroon, Ivory Coast or Guinea ? Such system will require experimental studies on the genetic structure of the local populations.

(ii) Living collections of coffee trees

They are established from seeds and unrooted cuttings obtained from the existing collections or during the explorations. This genetic variability that has been accumulated is strongly influenced by the initial sampling, the propagation means, the structure of the original populations and the reproductive system. With this conservation technique the genotypes introduced in living collections are maintained vegetatively but are static.

Coffee tree plantations require a large area because of the size of the trees : around 5 ha with 1000 to 2000 trees per ha. The long life span of coffee trees (20 to 50 years) is an advantage for maintaining the genetic integrity for a long time which can be extended through a vegetative propagation. The risk of genetic erosion depends therefore upon the adaptation of the different origins to the same new biotope and the care and treatment of the plant material.

As an exemple, let summarize what has been done in that respect in Ivory Coast :

- plantation in two favorable locations, one at high altitude (Mt Tonkoui 1100 m) and the other at low altitude (Divo 200 m),
- plantation under natural or artificial shade in order to recreate the original environment of the wild coffee trees,
- grafting of the less vigorous species (*C. congensis*, *C. humilis*, *C. eugenioides*) on the *C. canephora* adapted to local conditions,
- spraying with pesticides and fungicides, watering the young coffee trees, and grafting the dying plants.

These precautions do not protect against exceptional climatic aleas such as tornadoes, cyclons, drought, epidemics and pests. Only can the duplication of the living collections increase the security of the conservation.

In view of the high coast of these operations, it seems appropriate to study the possibility of making living collections of small plants through tissue culture.

IV. ORGANISATION OF GENETIC RESOURCES CENTERS (GRC's)

We will go through the different functions of GRC's as shown in Figure 2.

(i) To increase the genetic pool

This can be achieved through germplasm collecting missions and introductions. The risk of transferring diseases and pests will be strickly controlled by the use of healthy plant material, their treatment with fungicides or pesticides, and their isolation in quarantine outside the coffee culture areas (USDA Station at Gleen Dale in USA ; GERDAT at Montpellier in France).

(ii) To ensure the conservation of the plant material

Living collections are grown in a research station having agricultural and horticultural facilities (nurseries, greenhouses). Other means of conservation of genetic resources such as a long term conservation of seeds, or pollen storage or small plants through tissue culture need to be more studied before they can be applied to coffee collections.

For example, the seed viability of *C. arabica* could be maintained above 80% only for 2 or 3 years through storage of hydrated seeds containing 40% water, at a temperature between 15 and 19°C (Van der Vossen 1978, Couturon 1980). This conservation time is still too short to be applied to coffee collections although the method is commonly used for other plant species.

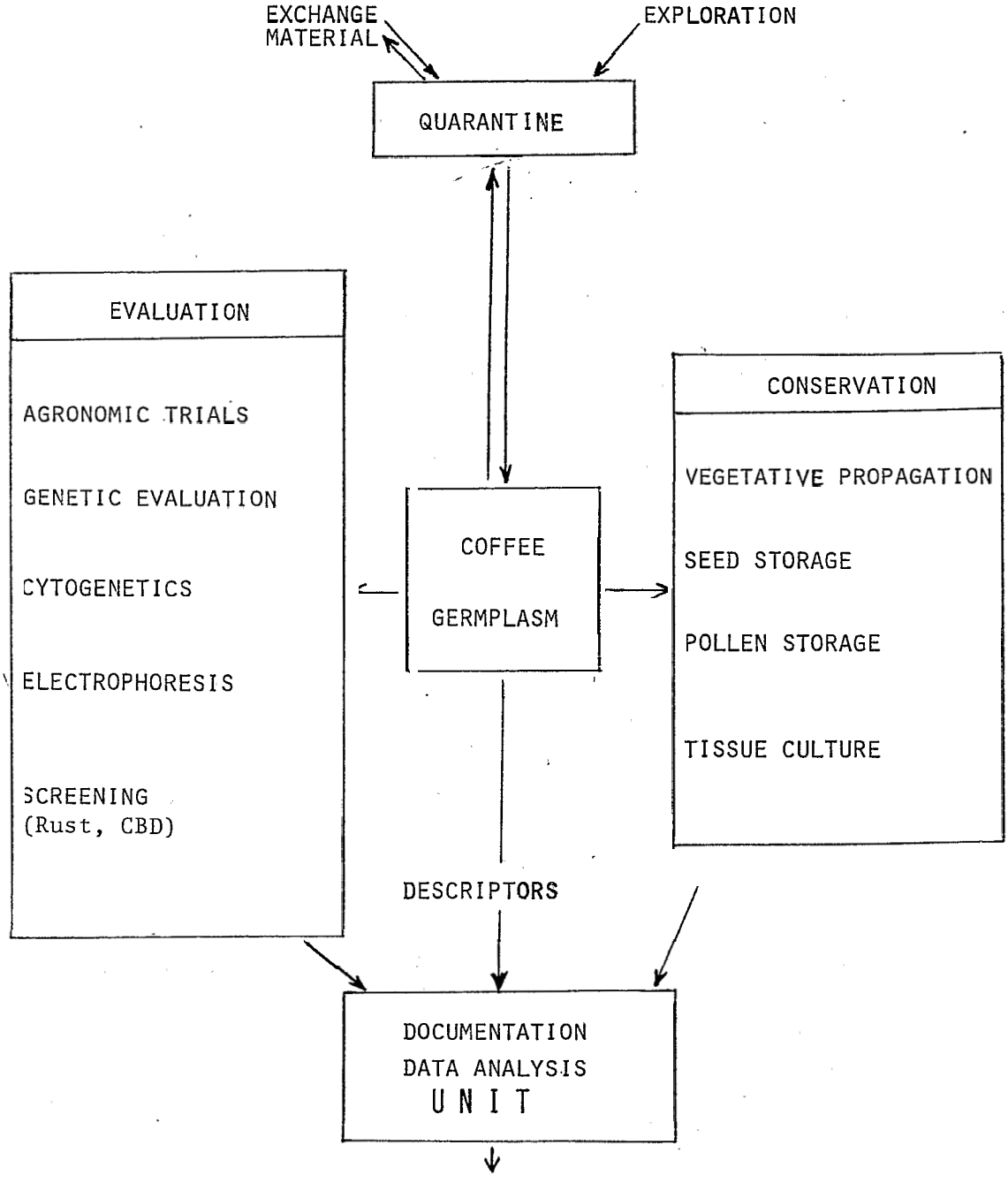

Fig. 2 : Organization of the Genetic Resources Centers

The pollen storage of coffee trees is commonly used in plant breeding. The dehydrated pollen of *C. arabica* stored under vacuum at minus 18°C has 60% of germination after 26 months of conservation (Walyaro, Van der Vossen 1977). This technique can only be used to distribute pollen for different genetic and breeding research programs in order to gain several years over the transfer of whole plants.

The different systems of tissue culture of coffee will be discussed during this congress = bud culture (Custers 1980), regeneration of tissue (Staritsky 1970 ; Dublin 1980), single cells or protoplasms (Söndahl 1979), male and female gametophyte (Lanaud 1980). As far as the genetic resources are concerned, it is important to be able to apply the tissue culture technique to various genotypes and also to obtain an exact copy of the mother plant i.e. exactly the same genetic and chromosomic make up and the same morphogenesis as the mother plant. Usually microcutting and apex culture are the most appropriate and provide an exceptionnal phytosanitary protection during international transfers of plant material.

(iii) To evaluate the plant material

Plant breeders are directly interested in the agronomic evaluation of coffee germplasm. This evaluation is useful only under the same climatic and parasitic conditions as the collection. A more general agronomic evaluation requires a network of trials at several locations and the evaluation of resistance to different races of parasites under artificial conditions as it is done at the "Centro de Investigação des Ferrugens do Caffeeiro" at Oeiras in Portugal. Now it would be necessary to have a research center outside the coffee culture areas to screen material for resistance to *Colletotrichum coffeanum* using the method developed in Kenya by Van der Vossen (1976).

The use of desirable agronomic traits requires information on the reproductive barriers and the genetic relationship within the coffee gene pool. This information could be obtained through intra and interspecific hybridization, cytogenetic studies, quantitative genetic analysis and enzymatic variability by electrophoresis. The team ORSTOM is conducting both genetic and agronomic evaluations of the coffee germplasm maintained in Ivory Coast.

The use of carefully choosen descriptors is absolutely necessary for a standard approach to germplasm collections and should facilitate international exchange of information.

(iv) To create a documentation and data analysis unit

The classification and statistical analysis require computing and data storage facilities. Different management units are available. Recently the American Institut of Boulder in Colorado (USA) has developed a new type of germplasm data management (GDM) adapted to minicomputers which can be connected to more powerful computers.

(v) To dispatch the plant material and the information

A GRC ensures a regional and world wide dispatch of germplasm material and information in cooperation with other GRC's and coffee breeding stations. Some international regulations are necessary to facilitate the exchanges.

(vi) To train and to inform

Besides maintaining the genetic resources, one should inform politicians and scientists on the usefulness of germplasm conservation, use the media to educate the public on the interest of the biological heritage, and also train scientists from developed and developing countries in the subject.

The staff members of a GRC have different education levels and are specialized in different subjects : botany, population and quantitative genetics, plant pathology, statistics and computer sciences, agronomy and horticulture, biochemistry, physiology...

In fact, the organisation of GRC's requires a multidisciplinary approach and laboratories specialized in different fields.

V. CONCLUSION

The difference made between the breeders' working collections and the major collections of GRC's is very important as far as the responsability sharing and the working facilities are concerned. So the management of GRC's in poor countries cannot be efficient without foreign financial aid.

Depending upon the world distribution of coffee culture and major collections, it would be advisable to establish an international network of about 10 regional GRC's in the following countries : Ethiopia, Tanzania, Malagasy, Cameroon, Zaïre, Ivory Coast, America, Indonesia, Portugal (rust center of Oeiras) and a Center for CBD. We should also mention the "Centro agronomico tropical de Investigacion y Ensênanza" at Turrialba (Costa Rica) wich is in charge of conserving and distributing *C. arabica* germplasm throughout Colombia and Brazil.

This genetic resources conservation scheme should be accompanied by international harmonisation. The IBPGR (FAO) which organizes and promotes the conservation of genetic resources has been interested in the genus *Coffea* since 1978 : as a result a working group on coffee germplasm met in Rome in December 1979 to define priorities and make recommandations.

Acknowledgments

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Les auteurs ont eu pour objectif d'essayer de dégager les bases palynologiques applicables à la systématique de l'ensemble des caféiers. Ils ont également tenté de progresser dans la compréhension de la parenté de l'espèce C. arabica.

LOBREAU-CALLEN (D.), LEROY (J.-F.).- Some palynological data on the genus Coffea and other genera of the coffee tree range. IX^{e} Colloque Scientifique International sur le Café, Londres, 16-20 juin 1980. ASIC (Paris), 1981, 14 p., 4 schémas, 2 réf., 8 pl. h.t.

The authors' aim was to try to establish the palynological basis applicable to the systematic of the whole of the coffee trees. They have also tried to progress in the understanding of the relationship of the species C. arabica.

CHARRIER (A.).- La conservation des ressources génétiques du genre Coffea. IX^{e} Colloque Scientifique International sur le Café, Londres, 16-20 juin 1980. ASIC (Paris), 1981, 10 p., 2 fig., 1 tabl., 20 réf.

Les collections de travail des sélectionneurs sont presque exclusivement composées de représentants des espèces cultivées C. arabica et C. canephora. Elles ont été utilement complétées, au cours des vingt dernières années, par les prospections réalisées en Afrique et dans la région malgache. Celles-ci ont permis de rassembler de nombreuses espèces du genre Coffea dans un nombre limité de collections de base qu'il serait aisé d'enrichir par quelques prospections complémentaires.

L'utilisation rationnelle de ce patrimoine génétique à l'échelle mondiale requiert maintenant une organisation régionalisée et des méthodes appropriées.

Ces centres de ressources caféières doivent assurer la pérennité des collections de base, réaliser l'évaluation génétique du matériel végétal, assurer sa distribution vers les collections de travail et la diffusion de toutes les informations recueillies. L'expérience acquise en ce domaine à Madagascar et en Côte d'Ivoire, dans le cadre d'une opération conjointe ORSTOM-IFCC, servira de référence à nos suggestions.

CHARRIER (A.).- Conservation of the genetic resources of the genus Coffea. IX^{e} Colloque Scientifique International sur le Café, Londres, 16-20 juin 1980. ASIC (Paris), 1981, 10 p., 2 fig., 1 tabl., 20 réf.

The working collections of breeders almost exclusively consist of representatives of the cultivated species C. arabica and C. canephora. They have been advantageously supplemented in the course of the last twenty years by expeditions in Africa and the Malagasy region. These have enabled many species of the genus Coffea to be included in a limited number of basic collections, which it would be easy to enrich by a few additional expeditions.

The rational utilisation of this genetic inheritance on a world scale now requires a regionalized organisation and suitable methods.

These centres of coffee resources must ensure the perenniality of the basic collections, make genetic evaluations of the plant material, distribute it to the working collections, and disseminate all the information that has been collected. The experience acquired in this field in Madagascar and Ivory Coast in the joint ORSTOM-IFCC operation will provide support for our suggestions.

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