

Coffee Improvement Project IV

Some Views about the Coffee Landraces Selection Programme

Developed at JARC/EARI

in Relation with the CIP IV Research Component

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1 December 2005

1. Introduction

Ethiopia, the centre of origin of *C. arabica*, holds a unique position in the world for that species. Wild forms of coffee trees are still confined to some moist montane forests, but the largest proportion of coffee germplasm is exploited by picking in more or less managed forests, or grown in highly diversified farming systems in plantations spread over different types of land areas that can be called *terroirs*. Each of these *terroirs* is characterized by a physical environment, cultural practices, harvesting and processing methods that add to the originality of its production and give a unique character to the coffee. This agrobiodiversity, which results from interactions between the environment, the genetic make-up of the coffee trees and the cropping systems developed by Ethiopian farmers, is a major asset that needs to be taken into account in the coffee breeding strategy.

One of the main components of this agrobiodiversity is the coffee landrace. A landrace is an early, cultivated form of a crop species, evolved from a wild population, adapted to local environments and uses, and generally composed of a heterogeneous mixture of genotypes. Through its heterogeneous genetic structure, the landrace has the ability to adapt to changes in its environment, but such adaptation usually takes long time. Farmers play a major role in this process by selecting and multiplying the genotypes that they consider to be the most adapted to their local growing environment.

The advent around the early 1970s and dramatic spread of Coffee Berry Disease (*Colletotrichum kahawae*), a parasite that had been unknown until then in Ethiopia, caused a significant drop in production from 1974 onwards, threatening the livelihood of many subsistence small farmers who were economically very vulnerable in any case, and who earned a major share of their cash income from coffee growing.

2. Selection programme for CBD resistance at JARC

In the early years of the epidemic, observations carried out in Ethiopian plantations revealed the existence of different levels of resistance to attacks by the parasite on individual trees. Following these observations, it was decided to take advantage of the genetic diversity which is specific to the birthplace of the species. A programme for the selection of resistant genotypes was proposed by R.A. Robinson (FAO) and launched in 1972. The search for resistant individual trees among coffee tree populations was mainly conducted in the former administrative divisions of Kefa and Illubabor.

Results were obtained very quickly and around twenty coffee pure lines displaying good tolerance of CBD under conditions of strong parasite pressure were selected and distributed to farmers from 1978 onwards throughout the coffee producing areas in the country.

Since then, this strategy has revealed its limitations. Significant Genotype x Environment interaction has been detected for growth and yield traits, and many CBD-tolerant lines turned out to be poorly adapted to the growing conditions and environment encountered when grown outside their area of origin (especially in Harerge). Under these conditions, they are poorly received by farmers and they have also been blamed for contributing to dilution of the sensory characteristics specific to each *terroir*.

A hybridization programme was also launched in 1978. To date, three hybrid cultivars with high yield and moderate resistance to CBD have been selected. Massive dissemination of the F1 hybrids has so far come up against the problem of their propagation. If their propagation were to be possible one day at a reasonable cost for producers, it can be assumed that the homeostasis linked to hybrid vigour will make them good candidate varieties for all regions of the country. On the other hand, massive use of them might contribute to the phasing out of characteristics specific to each *terroir*.

Following these findings, a new strategy based on the selection of landrace varieties was proposed at the beginning of the 1990s. It consists in collecting, conserving, assessing and distributing coffee germplasm inside each production zone. The hypothesis being that the selected lines will display good adaptation to the growing conditions and environment, and that the sensory characteristics specific to each *terroir* will be preserved. In terms of CBD resistance, the level sought for a given line would depend on the parasite pressure conditions in the place it is intended for distribution.

This strategy is being implemented by JARC in two ways: a “crash programme” and a long-term programme.

- The “crash programme” is based on observing apparently CBD-resistant mother-trees in the field, and evaluating those mother-trees and their progenies over a short period.

Year	Activities	
	Mother-tree	Progeny
1	Observation, selection, evaluation for CBD (visual, ABT attached berry test, ST seedling test) and yield estimation	Seed sowing
2	Evaluation for CBD-visual, ABT, ST Yield estimation	Seedling planting
3		Maintenance
4		First crop, CBD evaluation
5		Second crop, CBD evaluation, growth. Data summarization & release

The current methodology implemented by JARC for this “crash programme” is different (and in fact has a better scientific base) from the methodology as defined in the CIP IV Formulation Report (Annexe 4-P3) which consists in observing the CBD resistant mother trees and spraying young seedlings in the nurseries with CBD spores in water suspension to assess the resistance of the progenies before distribution to farmers.

- The long-term programme consists in exploiting data from the collections and old trials, and using them to pre-select the best lines originating from a given production zone. These lines are then planted in verification trials to check that they adapt well, and to confirm their production, disease resistance and quality traits. These trials could also be used for small-scale seed production if their distribution is approved.

Year	Original plot	Verification plot
1	Planting	-
2	Maintenance	-
3	Recording (year 1)	-
4	Recording (year 2)	-
5	Recording and selection (year 3)	Planting
6	Recording (year 4)	Maintenance
7	Recording (year 5)	Recording (year 1)
8	Recording (year 6)	Recording (year 2)

Based on results from the coffee landrace selection programme, through which lines adapted to each *terroir* will have been identified, there are medium-term plans to continue improvement by crossing the best lines to obtain landrace F1 hybrids. However, that prospect is still far off from

realisation and in the rest of this document we shall merely analyse the strengths and weaknesses, opportunities and risks of the coffee landraces selection programme.

3. Strengths of the landraces selection programme

- *3.1. An approach well suited to Ethiopian conditions*

The current programme is well suited to Ethiopia and takes into account the agrobiodiversity found in the country. It is a very significant improvement on the initial CBD resistance selection programme. It also provides both short-term (“crash programme”) and medium-term results.

- *3.2. A well-developed network of research stations*

The new approach was only really possible to set in place with the creation of two research sub-centres, Awada in Sidamo (founded in 1997 through Swiss cooperation) and Haru in Wellega (1998, European Union). JARC now has a well-distributed network of stations and verification sites in the main production zones (except maybe Bale) enabling it to collect, conserve and evaluate landrace varieties. The Mechara Centre (even though some doubt still remains about the resources that could be provided by the Oromiya Region for its operation) is usable as of this year for the conservation and evaluation of the Harerge landrace varieties. This is major progress for the conservation of coffee diversity in that region, where genetic erosion is very severe.

- *3.3. Important germplasm conserved ex situ*

Over 40 years IAR/JARC has built up a major collection of around 4800 accessions of various origins, which form a work basis of great value.

- *3.4. A robust experimental design*

On the whole, collections and trials are managed in robust statistical designs (randomized complete blocks, single lattices, 6 to 10 trees/plot). They are usually well maintained and observed.

- *3.5. Significant results have been rapidly obtained*

Significant results have been obtained in a short time, despite the difficulties in implementing phase IV of the CIP project. Worth mentioning are:

- Crash programme: 208 selected mother-trees for Limu (2001-2005)
62 + 35 selected mother-trees for Harerge (2004 + 2005)

- Long-term programme :

Origin	Collected accessions	Evaluated accessions	Promising varieties	Selected for verification trials
Harerge	1013	225	50	14
Sidamo		349	91	12
Wellega	591	359	80	14

Five landrace varieties (4 for Limu, 1 for Sidamo) have just been submitted to the Variety Release Committee for approval. Other varieties ought to follow in the next few years.

4. **Weaknesses of the current programme**

- *4.1. Need to improve knowledge of the available genetic variability*

Genetic diversity can be evaluated by analysing agro-morphological traits, but using molecular markers (RFLP, microsatellites) would make it possible to overcome the environmental effect.

This would make it possible to:

- know the structure of the germplasm in the collection better
- rationalize field genebank duplication or renewal operations
- guide hybridization programmes by searching for heterotic groups
- search for genes linked to resistant traits

Implementing such a genotyping programme on all the accessions in JARC collections may seem difficult to envisage due to the costs involved and the labour required, but such a project can be carried out on a part of the collections. Its implementation would no doubt mean developing collaboration with laboratories possessing appropriate facilities and technologies inside Ethiopia (University, etc) or abroad. The ICGN (International Coffee Genomic Network) could be a good forum for seeking collaboration and funding on this subject. Doctorate or post-doctorate training for an Ethiopian researcher in Montpellier with CIRAD/IRD may also make it possible to launch an in-depth study.

On the other hand, phenotyping the entire collection by the NIRS (Near Infra Red Spectrometry) method can be envisaged. This tool will make it possible to:

- detect noteworthy plants (mutants)
- propose structuring based on biochemical diversity. Such phenotyping would be compared to the genotyping carried out on part of the collection, and with the available agro-morphological data.

- 4.2. *Difficulty of including CWD resistance in the selection process*

The spread of Coffee Wilt Disease (*Gibberella xylarioides*) incidence has been proved by recent surveys in Ethiopia under the CFC-CABI project. It is estimated that an average 27.9% of farms are infected (with particularly large proportions in certain areas such as Gedeo and Goma). According to 97% of farmers, this disease is spreading. This occurs through soil and air on bruised or damaged plants. Stumping, pruning, manual slashing and intercropping are known to contribute to the spread of the parasite when tools are not disinfected, which is usually the case. The only relatively effective control method is to pull up plants and burn them and not to use the wood of dead coffee trees for domestic purposes. The effectiveness of such control therefore relies on a massive awareness campaign among farmers, development staff and local administrations.

Using resistant varieties, as in the case of CBD, would be a particularly attractive alternative to this control method which farmers find difficult to accept.

The different nature of these two parasites needs to be taken into account in terms of epidemiology and symptomatology:

- CBD is a parasite whose transmission is easy and quick; CWD requires (at the current stage of our knowledge) a mean of access (wound of human origin, parasites, insects) and infestation is therefore "discrete" (in the statistical sense). The CBD incubation period is very short (2 to 3 weeks between infection and symptoms expression); little is known about that of CWD particularly in old trees. In any case, it is difficult to detect in the early stages of infection.
- CBD reduces production but does not kill the tree, CWD kills the tree.
- The search for varieties that are genetically resistant to CBD was based on visual observation in the field of substantial variability in the reaction of trees to the parasite and the existence of relatively or totally disease-free trees within severely affected populations. Although variability in resistance to CWD seems to be supported by field observations and

tests on seedlings, little is known about the symptoms that could reveal partial resistance (longer incubation time, remission symptoms?); an apparently healthy tree in the middle of affected trees is not necessarily "resistant" as it may not have been infected, or it might have been infected but is still in the incubation period.

- In the case of CBD, a test of resistance to the parasite, in good correlation with natural resistance, is the Attached Berry Test - artificial inoculation of fruits in the field, with a concentrated spores solution. In the case of CWD, intentional artificial inoculation (by wounding and applying a concentrated parasite solution) is difficult to implement on farms due to the lethal nature of the parasite, and a long and little known about incubation period in the case of old trees (when should symptoms be observed?).
- Lastly, there would seem to exist a wide variety of CWD isolates, with different degrees of virulence, indicating a great ability of the parasite to mutate.

Thus, as our knowledge stands at the moment, implementing such a selection programme appears to be much more difficult than for CBD. Therefore a wide range of research needs to be explored (early seedling screening well correlated to field observations, description of partial resistance, etc.) before drawing up an effective programme to search for genetically CWD resistant coffee trees. This will require a close cooperation of JARC breeding and plant protection divisions for all the activities (screening in the field, seedling tests, etc.).

- *4.3. Organization of data collection from trials and collections to be improved*

There is a lot of data (passport data, characterization data) about the collections, but it needs to be compiled in the form of an electronic database for easier use. This work is under way for passport data. This should provide an overview of the collection zones, making it possible to identify gaps and the future zones to be surveyed.

For the characterization and evaluation data (collections and trials) a centralized database ought to be set up for long-term preservation and to facilitate their analysis over several years at several sites.

- *4.4. The production capacity for improved landrace varieties is currently small*

The pure CBD-resistant lines developed at the end of the 1970s benefited from support from CIP (phases I to III) for their dissemination. They are currently being propagated in seed gardens under the regional administrations, on State farms and, to a lesser degree, on research stations.

These varieties are still distributed to all coffee producing zones apart from Harerge. But in the future the use of these first selections will be limited to Jimma and Illubabor zones.

For the more recent varieties (setting aside the Catimor and Geisha materials produced on State farms) and especially the landrace varieties developed recently and whose dissemination for 5 of them has just been proposed to the Variety Release Committee, the current production capacity is very modest and their large-scale distribution in the future remains problematic as the CIP project is in its closing phase. At the moment, the only seed sources are located at research centres or sub-centres, and also in off-station "verification trial" plots.

Much work therefore remains to be done to set up seed gardens in each producing region. This could be a priority activity to be funded by CIPIV during the last 2 years before project closure.

- *4.5. The accessions conserved ex situ are under threat of loss*

The rich germplasm conserved in JARC stations and substations is not totally secured. Most of the accessions are established in only one plot and fire could rapidly destroy a large number of them. CWD is also a threat especially in Gera and Awada. So there is a need to duplicate at least a part of the field genebanks. Better knowledge on the structure of the collections (see section 4.2) would no doubt make it possible to rationalize this duplication.

Cryopreservation (storage at -196°C in liquid nitrogen) is also an option that ought to be examined in the medium term. This method has been successfully applied, with CIRAD technical assistance and in compliance with IPGRI standards, for the CATIE coffee tree collection (Central America).

Faced with the high cost of such conservation (field or cryopreservation), it is essential to seek outside funding via IPGRI. The ICGN (International Coffee Genomic Network) could be a good forum for bringing up these problems and searching for the corresponding solutions.

5. Opportunities

- *5.1. Possibility of analyzing genotype x environment interaction*

Given the existence of multi-site trials comprising varieties of different origins, there is the possibility of carrying out an in-depth analysis of Genotype x Environment interaction for product quality and biochemical composition.

Several questions are asked of research:

- Does there exist biochemical diversity of genetic origin?
 - molecules involved
 - heritability
 - link with sensory quality
- Does there exist sensory diversity of genetic origin? The belief is yes but environment and post harvest systems are known to change the cup taste. But the question are: is there
 - typicity or basic flavours involved
 - heritability
 - link with biochemical characteristics

An initial approach to these problems could be launched with NIRS technology and then continued through in-depth biochemical and sensory analysis; a similar study conducted in Colombia has given some interesting results for the above questions. Such a study in Ethiopia, can be limited to three or four sites and carried out as part of doctorate or post-doctorate work.

Depending on the answers provided by this first study, consideration could be given to asking genetic questions based on the observation of segregating populations.

6. Risks

Three main risks can be cited that, since the beginning of what is known as the Green Revolution, based mainly on introducing high-yielding selected varieties combined with technical packages, have fuelled criticism of any genetically improved material. It is necessary to know those

risks and assess their importance, in order to contain/reduce them by taking the appropriate measures.

6.1. Risk 1 (certain risk): *Dissemination of a small number of improved landrace varieties to replace traditionally grown populations will unavoidably result in a reduction of the genetic diversity existing on farms¹.*

- *Action 6.1.1:* Increase the number of improved varieties disseminated

In a given environment, it is advisable to disseminate a sufficiently large number of selected landrace varieties, rather than limiting oneself to the "best" 2 or 3. A choice based on over-strict selection criteria applied by the Variety Release Committee is likely to result in a very small number of disseminated varieties. In that case, faced with a fixed genetic landscape, any biotic or abiotic change could have serious consequences. That risk already exists for CWD in the (very likely) hypothesis of an increase in the incidence of that disease, and in the case of climate change in the short term (drought year), or in the longer term (climate warming).

To partially counter that risk, it is advisable to distribute to farmers a bulk (a mixture of seeds) of at least 10 varieties-lines adapted to the region in question, chosen from the best in the current comparative trials, only ruling out those displaying clear defects, notably in terms of quality. Each of these varieties-lines is likely to be better than the average of unselected varieties (as they have undergone substantial selection pressure at the start of the breeding cycle). This multiline variety should display better adaptation to ever heterogeneous and changing environmental conditions. The rare inter-crosses might slowly modify its genetic structure. As new selections come out, this multiline variety could also be enriched, and the less good lines possibly replaced.

- *Action 6.1.2:* Continue with operations to conserve genetic diversity

Significant evidence exists indicating that many important locations of landrace varieties are under threat due to several processes (migration and settlement, population growth, fire,

¹ This risk is particularly great in the case of high-yielding pure lines that can easily be multiplied by farmers (which is not the case of hybrids whose dissemination can easily be controlled).

low coffee prices, competition with other crops, pests and diseases, replacement by improved varieties, etc.).

Ex situ conservation

Continuing collection operations with a view to *ex situ* conservation of part of the diversity existing in the landrace varieties maintained on farms is an essential corollary for the dissemination of improved varieties.

This aspect is not sufficiently highlighted in the CIP IV Formulation Report and only mention is made of collection from "forests" of CBD-free varieties (Annex 4- Page 9). In that report, the cost of collecting and conserving for the "crash programme" is also underestimated. In fact, in addition to transport and staff costs, the cost of the nursery activities and field establishment should be added. The problem of land availability for setting up living collections also needs to be mentioned, as this is a major constraint at several research centres/sub-centres.

In situ conservation:

The Formulation Report merely touches upon *in situ* "on-farm" conservation of landrace varieties (Annex 6 – Page 9), though farms are the main reservoir of agrobiodiversity.

In Melka Belo woreda, East Harerge, to compensate the lack of selected CBD resistant landraces adapted to the local agro-ecology, woreda agronomy experts and farmers are currently implementing a kind a local "crash programme" by selecting hundreds of mother trees in the plantations, collecting theirs seeds and raising seedlings in a central nursery before dissemination. If this activity could be expanded in Harerge and also in other areas, with a larger involvement of the research (for technical advice to extension staff), it could result in a real improvement of the coffee populations for CBD resistance while maintaining a significant genetic diversity. With such participatory approach, farmers would play an active role in both the conservation of traditional landrace varieties, and in assessing selected landrace varieties. Due to its low cost (compared to similar activities undertaken by research), this activity is sustainable and can continue after the termination of the CIP project.

In situ conservation, in forest zones, of wild and semi-wild populations, as envisaged in the CIP IV programme requires an integrated and participatory approach, description of which is beyond the scope of this document. It also exceeds the simple "coffee" aspect, as these forests are a reservoir of genetic resources for very rich endemic fauna and flora.

The CIP IV "Conservation" component has revealed its shortcomings and cannot pride itself on tangible results. A complete re-examination of this component by the relevant experts is necessary, taking into account the ongoing experiments (Participatory Forest Management projects, Coce project, etc.). The mid-term review should put forward proposals to that end.

- **Risk 2 (risk to be assessed):** *Dissemination of a small number of selected landrace varieties to replace traditionally grown populations could lead to an alteration of sensory characters attached to the origins considered.*

In fact, an evaluation of this risk first means defining the typicity (typical individual characters) of each of the *terroirs* considered. This is a considerable task which can only be done by bringing in a large number of players over many years. However, an initial approach could be attempted.

- *Action 6.2.1: Procure the means of evaluating the risk*

JARC is on the point of acquiring a sensory analysis laboratory geared towards selecting varieties, with a panel of judges trained at CLU, and some of them abroad. It is essential to assign a JARC researcher to this laboratory, who has good knowledge of the selection programme, of the current genetic trials, and good sensory analysis skills.

An assessment based on commercial criteria can also be carried out by the Coffee Liquoring Unit as in the past. It would also be useful to know the judgement of exporting firms operating in Ethiopia, and of European and American firms that import the coffee. They have experts with extensive knowledge of the flavour characteristics of coffee origins and who can evaluate (usually free of charge) a limited number of batches (e.g. candidate varieties for dissemination). This is practised in Latin American countries and Starbucks has laboratories in Costa Rica giving such feedback.

NIRS (Near Infra Red Spectroscopy) can also make a contribution to origin identification. However, this is a lengthy task, requiring the prior meticulous compilation of a spectral library of different origins.

- *Action 6.2.2: Evaluate "quality" at an early stage of the process in selection*

Quality tests are currently carried out in the final phase of selection in the verification trials. Once the JARC laboratory is operational, earlier tests could be carried out during comparative trials. A moderately productive coffee tree may have an exceptional cup quality and should be kept for the following selection stages.

- *Action 6.2.3: Evaluate the risk under conditions encountered on farms*

This can be done by sampling "traditional" and "improved" varieties under similar growing conditions, harvesting conditions and post-harvest processing conditions, and in several cropping systems and *terroirs*; then the sensory qualities of each sample will be analysed in a statistical design in "blind" tests.

- **Risk 3 (risk to be evaluated):** *The dissemination of selected landrace varieties under growing conditions on research stations (with fertilizers, good upkeep, and appropriate shading) could result in counter-performances (compared to unselected ones) under the extensive growing conditions usually found on farms. This could be the case for the highest-yielding varieties which risk displaying severe die-back symptoms and Coffee Leaf Rust attacks in the absence of inputs and/or shade.*

- *Action 6.3.1: Evaluate this risk by surveying farmers in different conditions/cropping systems*

With the JARC Extension Division and the regional development services, it would be interesting to find out more about what becomes of selected varieties once they have been distributed to farmers. This means referring to the exit records of the central nurseries (they contain very precise information) and carrying out sampling followed by a field survey. It will only be possible to launch this activity once the necessary resources (in particular means of transport) have been provided by the CIP project.

- *Action 6.3.2: Do not limit dissemination to only the most productive varieties under growing conditions on research stations. (see action 6.1.1 above)*
- *Action 6.3.3: Distribute varieties to farmers who are able to apply the recommended technical packages, first and foremost appropriately regulated shade.*
- *Action 6.3.4: Do not underestimate the resistance to Coffee Leaf Rust in the selection process (particularly for Harerge)*

7. Conclusions

The coffee landraces selection programme is a particularly relevant approach to maintaining the agro biodiversity found in Ethiopia, whilst introducing genetic progress in terms of productivity and resistance to diseases. Some significant results have been obtained and several landrace varieties should be available in the coming years.

However, research still has numerous challenges to take up, the main ones being:

- The mass propagation of these landrace varieties by setting up seed gardens of the promising varieties as soon as possible
- The assessment of the quality of the future released varieties and the factors that can influence it
- The integration of resistance to CWD in the selection scheme
- The continuation of *ex situ* conservation works (enrichment and duplication of the collections)
- A special emphasis on farmer participatory research (participation in the selection process, evaluation of selected varieties after distribution, *on-farm* conservation).