Baseline Assessment and Gap Analysis of Current Systems for Applied Agricultural Research

Prepared by Coffee Quality Institute
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1. Introduction

Coffee is the most important crop in Timor-Leste in terms of export revenue, providing the largest source of income to thousands of rural households. However, it has received little research attention; in contrast, grain and horticultural crops have benefited from research and seed technology at the Ministry of Agriculture and Fisheries (MAF). There is a great opportunity for improving yield and quality potential of Timor-Leste coffee by systematic variety development, improving agricultural practices, and decreasing post-harvest losses. This requires research; thus, we propose that a research program be initiated at MAF to meet future requirements of the coffee sector and to improve the general well-being of those producing and processing coffee. MAF has the administrative structure to include coffee research activities, but funding has not been available to hire the staff required to initiate necessary programs. Rather, emphasis has been placed on food security rather than on export crops such as coffee.
2. Assessment of Current Systems of Applied Agricultural Research

The MAF’s research efforts have been focused on food crops. However, they are now planning to begin research on coffee as it is a key crop. Land in a government plantation has been identified as a research site for this work. MAF has a lab facility for soil analysis and has ongoing programs supporting composting and the use of cover crops for food production. This has yet to be extended to coffee production, but it can be. To date, there has not been any systematic research on the yield response of the MAF-supported rehabilitation and replanting programs. The National University of Timor-Leste (UNTL) has done some socioeconomic research related to coffee, but has not done any agronomic research due to funding constraints.

The extent to which other industry stakeholders are capturing data in a formal and structured way is not clear. This will need to be confirmed. Planning for the agricultural census is moving ahead. A pilot will be implemented (possibly in early 2018, followed by a wider rollout at the end of 2018). There may be scope to capture information on the coffee sector during the census.

2.1 Current Research in Crops Other Than Coffee at MAF

Although research on coffee is lacking, research on crops other than coffee has been supported at MAF, primarily by the Australian Centre for International Agricultural Research (ACIAR) and the United States Agency for International Development (USAID). These agencies and others have worked with MAF in several programs since the early 2000s to help develop food crop variety selection, seed production programs, and forestry products. Most prominent have been the ACIAR Seeds of Life project, the more recent Al-Com project, and the USAID/University of Hawaii Agricultural Rehabilitation Program.

- **Seeds of Life (ACIAR) – Ended 2016**
  - Worked with MAF to identify superior varieties of maize, rice, and cassava
  - Demonstrated plot research techniques
  - Established seed production and distribution programs
  - Established baselines for soil and weather in important agricultural regions
  - Reports: [http://seedsoflifetimor.org/research/](http://seedsoflifetimor.org/research/)

- **Al-Com (ACIAR, University of Western Australia, UNTL, and World Vision) – Launched in May 2017**
  - Collaborates with MAF research group, UNTL, and others on innovation for communities for intensified sustainable farm systems in Timor-Leste
  - The program is designed to convert Timor-Leste farmers from subsistence to sustainable farming systems
  - Rehabilitation of the agricultural facility at UNTL
  - Building R&D capacity
  - Luis de Almeido (Head of Agronomy Department, UNTL) presented a poster paper on improvements in maize culture in Timor-Leste at the International Tropical Agriculture Conference TropAg 2017, Brisbane, Australia. Also attend by Claudino Nabais, Research Director, MAF
USAID/University of Hawaii College of Tropical Agriculture and Human Resources. Agricultural Rehabilitation, Economic Growth and Natural Resources Management

- Collaborated with MAF and UNTL on a wide range of agricultural research projects
- Significant increases maize yields from 1.5 tonnes/Ha to 4.8 tonnes/Ha and rice yields from 2.0 tonnes/Ha to 4.9 tonnes/Ha. These increases were achieved not simply by adding fertilizer, but by enabling the Timor-Leste Ministry staff to diagnose nutrient deficiencies with soil test kits and eliminate the cause for the low-crop yields.

2.2. The Seed Research and Production Program

The seed research and production program are especially important developments demonstrating MAF’s research capability. Except for certain horticultural crops covered under patent, the program supplies all seed requirements of Timor-Leste and was developed as a cooperative project between Seeds for Life, a program of ACIAR and MAF. Significantly, the program has sought assistance from the CGIAR, a group of international research institutes.

The techniques and knowledge gained in MAF’s well-designed seed production programs and yield trials for the annual grains legumes and cassava will be helpful for the development of coffee research; however, the specific processes will be quite different for the perennial coffee. Seed production is a five-step process beginning with small quantities of pure breeder’s seed, usually received from outside Timor-Leste, and resulting in self-sufficiency for commercial and community seed. The five categories of seed are:

- **Breeder seed.** This must be of high purity and usually originates from international organizations. In Timor-Leste, breeder seed is used as a nucleus for developing foundation seed. It is considered 99.9 percent pure.

- **Foundation seed.** Also high in purity, this increase of the breeder seed produced by the MAF research department. The foundation seed is provided to a contract grower for production of certified seed. It is considered 99.9 percent pure.

- **Certified seed.** This seed is produced by contractors in carefully maintained plots for the purpose of increasing the foundation seed. It is considered 98 percent pure.
  
  - Breeder, foundation, and certified seed are not for public use and are not used for food production. This occurs in the next stages of increase.

- **Commercial seed.** This seed is produced for farmers for food production as an increase of certified seed by registered commercial producers. It is considered to be 95 percent pure.

- **Community seed.** This seed is of lower cost to farmers and of lower quality. Growers are not certified, and there is not guarantee for purity.
3. Timor-Leste Research Infrastructure

As part of this assessment, the CQI team visited MAF and other facilities that could support the development of a coffee research program. Meetings were held with Claudino Nabais, Director of the National Directorate for Research, Statistics, and Geographical Information, and Fernando Santana, the Director of the National Directorate of Coffee and Industrial Crops (NDCPI). The CQI agronomist traveled for one week with Juliao dos Santos, who manages the coffee section of NDCPI. Sites visited included the laboratory in Dili, coffee nurseries, and coffee demonstration sites. In addition to field visits, the CQI team followed up with Skype calls focused on research.

3.1 MAF Soils Laboratory

MAF maintains a soils laboratory at its headquarters in Dili. The lab can analyze for soil minerals but does not have equipment to efficiently analyze leaf tissue, which is a better measure of plant health. The lab is an important asset that will support future coffee research activity. MAF also distributed soil testing kits to farmers and others in the early 2000s.

3.2 MAF Coffee Nurseries

The MAF coffee nursery at Fatuquero is a major infrastructure asset that will be important in the establishment of a coffee research program. This nursery currently supplies large numbers of coffee seedlings and shade trees to farmers. Another nursery in Liquica, when restored, will supply additional seedlings and provide another potential research site.

3.3. MAF-Managed Coffee Demonstration Sites

MAF maintains several sites where practices such as coffee regeneration and pruning and compost-making are demonstrated. These sites, along with a 100 Ha site currently being prepared for planting, will be invaluable resources for use in a research program.
3.4. Other Institutions Expected to Play a Role in Coffee Research

The National University of Timor-Leste (UNTL) includes an Agronomy Department headed by Luis de Almeido and maintains a research facility in Hera, which previously included a nutrition laboratory. During a June 2017 visit, the lab was not being used for analysis work, although it could quickly be reactivated with necessary funding. Work at the Hera facility was said to center on forage and animal husbandry. Coffee research, other than socioeconomic aspects, is not conducted by UNTL. However, it is the best location for students to be trained in the principles of agricultural research and production, and the graduates are well-suited for participating in the agricultural industry of Timor-Leste. Under the recently established Al-Com project, UNTL is a member of the food crops research team. UNTL would also be the best location to find professional staff who could serve in both education and research functions.

The East Timor Coffee Institute (ETCI) is another potential source of agriculturally trained personnel. Partners such as the major coffee-processing companies (CCT, Timor Global, and Olam) and NGOs could offer resources useful in a research program. NGOs from the United States, Australia, New Zealand, and Japan have worked in Timor-Leste and can aid in research work through the groups they advise.

3.5. Hibrido de Timor

An important part of the research baseline is the Hibrido de Timor (HDT) variety, which is considered a national treasure in Timor-Leste. HDT is a natural hybrid of *Coffea arabica* (a Typica variety of the Arabica species) and *Coffea canephora* (Robusta), which conferred coffee leaf rust (CLR) resistance in Timor coffee during the Portuguese administration. Seedlings of HDT, which became available in 1955, are widely planted in Timor-Leste, and HDT was used in hybridization programs with Caturra and other varieties around the world, becoming the basis of CLR resistance in modern coffee varieties. There is a great opportunity to further select among HDT seedlings in Timor-Leste to develop stable varieties by self-pollinating, crossing, and selecting for desirable traits and by making additional crosses. The original HDT is extant, although in poor condition, in Mata Nova, suco Fatubissi, in the Emera district of Timor-Leste.\(^1\)

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\(^1\) Unpublished report, Vincente de Paulo Correia et al, 2013. Original Coffee Plant ‘Hibrido De Timor.’ Cuttings were taken from HDT in 2012 and are growing at East Timor Coffee Institute (ETCI). Modern techniques have been used to further track the origin of HDT. Refer to the peer reviewed papers by Wellington Ronildo Clarindo et al, 2013.
The HDT in Timor-Leste differs from hybrids produced in other countries that were made by crossing HDT with the dwarf Bourbon mutant Caturra and called Catimors. In contrast, the HDT in Timor-Leste is a hybrid of Robusta and Typica, both tall varieties. As far as it is known, the variety was not purposely back-crossed to Typica or any other variety. This remains to be done. The proposed genetic testing should clear up some of the remaining questions. The advantage of selecting among the Timor-Leste seedlings of the HDT is that they would be selected under low inputs, reducing the cost of production. On the other hand, selecting under low inputs may limit the yield potential.

3.6. Key Issues That Would Benefit From Research

Based on a series of field visits and focus group sessions², the CQI team compiled a list of some of the key areas that would be considered priority areas of focus under a national coffee research program. These include:

- **Genetics and variety selection.** There is uncertainty about which varieties are currently grown. This is especially true for Arabica. The history of the spread of the Hibrido de Timor (HDT) variety means that there is likely to be significant genetic diversity within the current plantings. The stability/homogeneity of the varieties being raised in nurseries is not clear. There seem to be few or no organized programs to identify elite local varieties or test the performance of foreign varieties prior to wider distribution. Genetic analysis of leaf samples would be needed to characterize the extent of local variability. When trialing new varieties, a decision will have to be taken on whether to assess their performance under an optimal production system, or on the low-input systems that are typical for most producers here.

- **Soil fertility and response to pruning.** Many plants appear undernourished and show signs of mineral deficiencies. In some areas, soil fertility appears to be very low. This can affect yield, quality, and the response to pruning. There appear to few or no programs focusing on soil fertility improvements. It is not clear if there has been a formal evaluation of the response/yield increase following pruning and stumping efforts.

- **Pests and diseases.** There appear to be significant problems with pests, including coffee leaf rust and coffee berry borer. Coffee stem borer has been observed in the field, and there may also be problems with nematodes. It is not clear if there is any ongoing research on disease issues.

- **Organic production.** A commitment to applying organic production across the industry will limit the options for managing fertility and pests and diseases. The agronomist sought clarification on

² See Annex 1 for a summary of research and development focus group sessions.
whether there is a strong commitment to continue with organic production. There was discussion stating that commercial fertilizers were used on horticultural crops.
4. Gap Analysis for Research Focus

Based on field visits, discussions with MAF administration and staff, and group discussions in research focus group Skype calls, the team has developed a list of coffee-centered research gaps. Table 1 below outlines the most important gaps:

Table 1. Gap Analysis of Research Priorities

<table>
<thead>
<tr>
<th>Gap</th>
<th>Reason for Gap</th>
<th>Comments/Solutions</th>
<th>Responsible Organizations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of coffee research in MAF and other in organizations and lack of documentation of work already done</td>
<td>Funding. Determination of responsibility, personnel</td>
<td>Research is essential to move the coffee sector forward, and MAF is the logical place to locate this function. Coffee research can build on the experience obtained for other crops in cooperation with international aid groups such as ACIR and USAID. Inclusion of the UNTL Agronomy Department is advised.</td>
<td>MAF, Financial institutions, UNTL</td>
</tr>
<tr>
<td>Positions dedicated to coffee research including coffee consultants</td>
<td>Lack of funding. Recent realization of the importance of this position</td>
<td>It’s critical that a coordinating coffee agronomist position be established at MAF if research is to be conducted. The research program is expected to be advised by consultants. Professional research/teaching positions at UNTL should also be considered.</td>
<td>MAF, financial institutions, UNTL</td>
</tr>
<tr>
<td>Genetic analysis of currently planted coffee and coffee in nurseries and sources of seed</td>
<td>Lack of knowledge of process and funding</td>
<td>Will determine the genetic makeup of currently planted coffee, important information for proposed variety selection within HDT, and subsequent breeding. $130 per sample for 20 samples. $100 per sample for 100 samples.</td>
<td>MAF, World Coffee Research (WCR), International Technical Assistance</td>
</tr>
<tr>
<td>Systematic introduction of varieties from programs in other countries</td>
<td>The importance of the gap is recognized but activity not funded. High expense and long-term if carried to completion</td>
<td>This is an important activity for the future of the Timor-Leste coffee industry. There are many new, high-yielding, high-quality, rust-resistant varieties that need to be evaluated. Contact WCR for cost and details.</td>
<td>WCR, MAF</td>
</tr>
<tr>
<td>Topic</td>
<td>Brief Description</td>
<td>Importance</td>
<td>Responsibility</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Systematic variety selection program within elite Timor-Leste HDT</td>
<td>The importance of the gap is recognized by MAF but activity not funded. High expense and long-term if carried to its completion.</td>
<td>In the short term, this is a very important activity that will lead to the development of Timor-Leste varieties based on HDT. Need to take advantage of HDT rust resistance and adaption of HDT to Timor-Leste conditions. Requires a large commitment of time, expertise, and funds.</td>
<td>MAF, International Technical Assistance</td>
</tr>
<tr>
<td>Breeding program</td>
<td>The importance of the gap is recognized but activity not funded. High expense and long-term if carried to its completion.</td>
<td>This is an important activity that will lead to stable high-quality varieties that are resistant to CLR. Long-term commitment of time, expertise, and funding</td>
<td>MAF, International Technical Assistance</td>
</tr>
<tr>
<td>Knowledge regarding the extent of coffee diseases, especially CLR</td>
<td>Activity not funded, need for survey not appreciated.</td>
<td>Knowledge of the extent of the diseases will direct control measures.</td>
<td>Pathologist consultant, MAF</td>
</tr>
<tr>
<td>Knowledge regarding the range and extent of damage caused by insects and other pests including nematodes</td>
<td>Activity not funded. Need for survey not appreciated.</td>
<td>Knowledge of the extent of pests will direct control measures such as sanitation in the case of the CBB and grafting in the case of nematodes</td>
<td>Entomologist consultant, MAF</td>
</tr>
<tr>
<td>Knowledge regarding the mineral content of the soil and coffee plants</td>
<td>Activity not funded. Need for survey not appreciated.</td>
<td>Knowledge of soil and plant minerals will guide farmers in the application of amendments and fertilizer. Follow up with replicated plots.</td>
<td>MAF, outside lab for tissue analysis</td>
</tr>
<tr>
<td>Upgraded laboratory including pathology lab</td>
<td>The MAF laboratory is equipped to analyze soil but will require upgrades in equipment to analyze tissue from plants and pathology.</td>
<td>Coffee leaf analysis is the best way to determine the health of the plant. Soil analysis gives important information, but it is not complete without tissue analysis</td>
<td>MAF, International Technical Assistance</td>
</tr>
<tr>
<td>Survey pruning and regeneration plots installed by CCT</td>
<td>Activity not funded</td>
<td>Although many demonstrations have been made, there is no summary of the results. Follow up with replicated plots.</td>
<td>MAF, International Technical Assistance</td>
</tr>
<tr>
<td>Knowledge of grafting</td>
<td>Unrealized potential for improving vigor of Typica and other varieties</td>
<td>Grafting has the potential to improve the vigor of coffee growing in Timor-Leste,</td>
<td>MAF</td>
</tr>
<tr>
<td>Lack of a technical library for coffee information</td>
<td>Need to collect and organize production and technical information on coffee and other crops from within Timor-Leste and from other countries</td>
<td>Provides critical technical information on current status for crops of interest.</td>
<td>MAF</td>
</tr>
</tbody>
</table>
5. Identification of Short- and Longer-Term Priorities

The success of initiatives to upgrade production, improve quality, and develop specialty markets hinges on close coordination across the value chain and between government, the private sector, and other stakeholders. The process of initiating a coffee improvement program will require a step-by-step approach. Although a variety improvement program will be a longer-term goal, certain activities can begin almost immediately to jumpstart the program.

5.1. Short-Term Options for Implementation

Based on field visits by the team and discussions with MAF and others in research focus group discussions, we propose the following options for short- and longer-term implementation:

Activity 1. Review of Ongoing and Previous Coffee Research Studies

In order to develop a research baseline, the team recommends a thorough review and preparation of annotated summaries of all coffee research including the Portuguese and Indonesian studies. The reviews should include statistical data on practices and productivity. The collected information and additional information from outside Timor-Leste would be collected in a library accessible as both hard copy and electronic copy where possible.

Activity 2. Determine Required Staffing and Facilities/Lab Equipment Required for a National Coffee Research Program

Lack of dedicated staffing is a key constraint to establishing a viable coffee research program. First, the program will need a coffee horticulturist/agronomist with experience in the establishment of experimental plots and in the science of plant improvement through breeding and selection. The horticulturist needs to be supported by a staff knowledgeable in replicated plot establishment data collection and maintenance. Experience with plant improvement through breeding and selection is required. Having a pathologist on the staff with laboratory support is desirable; another option is to defer to UNTL. Lab equipment for analysis of soil minerals is in place; however, for several reasons, soil analysis does not give the farmer information about the nutrient health of the plant. This information is learned from analyzing the leaves of plants, which requires additional equipment. This analytical equipment will be very useful for determining the mineral status of crops in addition to coffee.

Activity 3. Visits to Research Projects in Other Countries

The CQI team recommends both administrators and technicians visit coffee research facilities in other countries such as China, Colombia, Costa Rica, and the United States (Hawaii). Reciprocal visits from these countries is also recommended.

Activity 4. Pest and Disease Surveys

Pests and diseases are damaging Timor-Leste coffee; however, the severity of the damage and distribution of the pests are not known, and learning this information requires surveys. The survey information will serve to direct control programs. The primary insect pests to be surveyed are coffee berry borer (CBB), black stem borer, and green coffee scale; however, at the time of the surveys,
observations will be made for additional pests affecting the coffee. The primary diseases to be surveyed are coffee leaf rust (CLR), cercospora leaf spot, berry blotch, and fusarium diseases. Incidence of other diseases will be noted. The surveys will require the services of a professional or professionals familiar with coffee diseases and pests. A well-equipped pathology lab will aid in the identification of the diseases. The surveys will help with the design of control programs such as farm sanitation, better nutrition, and approved chemical control, if required.

**Activity 5. Sampling for Soil and Plant Mineral Sufficiency**

A primary reason for the low yield of Timor-Leste coffee is a lack of sufficient minerals required for the growth and development of the coffee tree. Also affected are the flowering and fruit development. A survey of the physical and chemical status of the soils where coffee is grown will result in knowledge of how to correct the deficiencies. Likewise, sampling the leaves will determine the nutritional health of the plants. The current practice of either applying no nutrition or applying only plant-based compost is not adequate for significantly improving coffee yield. The compost serves to improve the soil properties so that minerals are more available to the trees, but compost alone cannot supply the quantity of minerals required, nor supply them in the correct proportion at different stages of development (vegetative growth, flowering, and fruit filling). We recommend the establishment of replicated plots to measure yield and quality of coffee fertilized by different methods. The plots will be established in newly planted coffee as well as regenerated coffee. These are not demonstration trials and need to be conducted under controlled conditions with replication.

Fertilizers such as urea, potash, and phosphate, even in small quantities in the presence of compost, will have a large positive effect on coffee yield and will improve resistance to diseases such as cercospora leaf spot. The classification of coffee as organic is likely not worth the penalty paid for having such low yield, and changes in practice are recommended based on the results of proposed trials where commercial fertilizer is compared with no treatment and compost alone. We recommend that soil analysis kits be made available with instruction for use to coffee farmers as they were for other crops.

**Activity 6. Plant Population (Stand) and Regeneration Studies**

Next to nutrition, the most important reasons for low yield are the low population of producing trees and lack of regeneration. Like the nutrition studies, stand and regeneration studies need to be conducted under controlled conditions at MAF sites. We recommend conducting the experiments starting with planting seedlings. The treatments are defined as differences between row and plant spacing. Evaluate several possibilities. For example:

<table>
<thead>
<tr>
<th>Between-row spacing (m)</th>
<th>Plant spacing (m)</th>
<th>Plants per Ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>2,500</td>
</tr>
<tr>
<td>2.5</td>
<td>2</td>
<td>2,000</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1,666</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>1,111</td>
</tr>
</tbody>
</table>

Evaluate yield and quality for three to five harvests. Regeneration is lacking and needs attention. We propose that comparisons be made of the different heights of cutting in the regeneration process. These would be carried out in research plots where data is recorded. Compare different heights of regenerative cutting at .30 cm, 1 m and 1.5 m, and record data for two cycles of regeneration. These are
not demonstrations, but would be expected to generate publishable data and provide training opportunities for students. In addition, studies are needed on the frequency of regeneration and replanting. The information obtained would be presented and demonstrated on the farms through the extension service. In addition to the experimental work, the team recommends a survey and analysis of the previously conducted regeneration studies.

Activity 7. Genetic testing (fingerprinting) for the source of seed in MAF Nurseries

The genetic background of the seedlings in MAF and other nurseries is not known. We propose to test the source plants and a sampling of the seedlings in the nursery to determine the genetic makeup. Of specific interest are the percentages of *C. canephora* and *C. Arabica*, the genetic sources of HDT. Also of interest is the amount of variation that is found among the source plants for the nurseries. This is a short-term project requiring the proper sampling of coffee leaves and sending the leaves to France for analysis through a program of World Coffee Research (WCR)\(^3\). Contact with WCR has already been made; thus, this program can start immediately when funds are made available. A sampling of 25 plants will cost $130 per sample, and discounts are available for a larger number of samples. Standards are needed for the sourcing of coffee seed with the establishment of a certified seed program, especially as new varieties are developed. The program should be managed by MAF, as the organization has done for the grain and horticultural crops.

5.2. Medium-Term Options for Implementation (five years including three years of evaluation and yield data)

Based on field visits, discussions with Claudino Nabais at MAF and Vicente de Paulo Correia at UNTL, and our own analysis, there is reason and support for selecting superior individual HDT plants with the goal of producing a unique Timor-Leste variety. We propose a two-stage program: one medium-term and the second long-term.

- Identify 30 elite individual HDT plants on farms in all coffee-growing regions. The selection will be based on appearance, production potential in the current year, and vegetative extension of the laterals for the following year’s crop. Genetically profile the plants and establish a common garden for evaluation. Make notes on disease and insect damage.
- Plant 20 seedlings from each of the 30 elite plants, propagate vegetatively (cuttings), or both.
- Plant in a common garden and evaluate based on growth, yield, rust resistance, and cupping for three years, starting in the third year following planting.
- Select five of the best selected plants out of the 30 plants after three years of evaluation.
- Distribute seed of the five as numbered entries such as TL-1-2018. These are not varieties; we are just segregating populations at this point.)

5.3. Long-Term Options for Implementation

- The five selected plants in the medium-term activity described above will be the basis of developing a Timor-Leste variety in a long-term program requiring 15 to 20 years, which in addition to selfing and selecting, include back-crossing to Typica and crossing to Bourbon or Caturra, both having a high yield potential.
- Investigate grafting as a technique to improve vigor and reduce nematode damage to Typica and HDT coffee. Grafting in coffee is practiced for two purposes: to reduce nematode damage and to

\(^3\) [www.worldcoffeeresearch.org](http://www.worldcoffeeresearch.org)
increase the vigor of selected varieties such as Typica. Grafting is done on Robusta or Liberica rootstock. The technique is practiced widely in other countries, and with some training, is easily accomplished. Compare grafted and non-grafted plants in a replicated test.