Quality Assurance in the Coffee Seed Sector

Technical Report on Seed Sources in El Salvador, Guatemala, Honduras, Nicaragua, and Peru

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Scope

This report and the scope of its analysis were defined by the Maximizing Opportunities in Coffee and Cacao in the Americas (MOCCA) program funded by the United States Department of Agriculture (USDA) and implemented by a consortium led by TechnoServe, in alignment with the agreed-to activity description between World Coffee Research (WCR) and TechnoServe. Data included in this report regarding the DNA analysis of materials in El Salvador comes from a 2022 study in collaboration with the Inter-American Development Bank and the El Salvadoran Ministry of Agriculture. WCR drafted this report, which covers the activities undertaken with the seed sector in five focus countries: Guatemala, Honduras, Nicaragua, El Salvador, and Peru.

The scope of this analysis also includes but is not limited to information from available bibliographies, interviews, and surveys with several market system actors such as national coffee institutes, Ministries of Agriculture, seed regulation offices, cooperatives of growers, private farmers, local researchers, and universities.

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About World Coffee Research
World Coffee Research (WCR) is a global, nonprofit collaborative agricultural research organization working to forge the future of coffee. WCR is supported by over 175 coffee companies in 29 countries, working to drive science-based agricultural solutions to urgently secure a diverse and sustainable supply of quality coffee today and for generations to come. Learn more at worldcoffeeresearch.org.

About the Maximizing Opportunities in Coffee and Cacao in the Americas Program
The Maximizing Opportunities in Coffee and Cacao in the Americas (MOCCA) Program is a five-year initiative funded by the United States Department of Agriculture (USDA) Food for Progress Program, aimed at helping more than 100,000 farmers to overcome the barriers limiting their capacity to effectively rehabilitate and renovate their coffee and cacao plants. Learn more at mocca.org,

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Executive Summary

The lack of a formal coffee seed sector is one of the most critical—and yet largely invisible—problems faced by the global coffee industry. Coffee growers, who are largely concentrated in lower-middle-income economies, often rely on informal and social relationships for propagating and obtaining material for new coffee trees, such as collecting seeds from their own fields or neighbors. They may also buy seedlings from small local nurseries that source their seeds from nearby formal or informal seed sources.

The quality of these local planting materials is often low due to a lack of phytosanitary and genetic conformity, leading to reduced yields throughout the resulting coffee tree's lifetime. Growers may seek out seeds of specific varieties based on their expected characteristics like disease resistance, high yields, or cup quality, only to find they did not receive these varieties once the coffee trees are grown.

A formal coffee seed sector would address this issue by providing verified, high-quality planting material to coffee growers, who often operate on thin margins. Higher-producing coffee trees that meet the quality requirements of the market would translate into higher income for these growers and their communities.

The lack of a formal coffee seed sector is particularly pronounced in Latin America, where coffee production depends largely on smallholders and is deeply intertwined with economic development in the region.

Genetic contamination of coffee in Latin America is common because of propagation practices and a lack of good agricultural practices, introducing major risks into the coffee value chain. The recent coffee leaf rust crisis in the region sparked interest among coffee growers in renovating their farms and switching to disease-resistant coffee trees that allow them to maintain their cup quality as well. Many governments in the region are also prioritizing support for this effort. However, given the lack of an organized and professionalized seed sector, the region has no way of guaranteeing that material sold to nurseries and producers is genetically conforming and high phytosanitary quality.

Through the MOCCA program, WCR undertook activities to strengthen the seed sector for Arabica coffee across 5 countries in Latin America: El Salvador, Guatemala, Honduras, Nicaragua, and Peru.

This report highlights the findings from WCR activities to evaluate the practices and materials of local seed lots and plantations, identify promising seed sources, and improve nursery operations in these countries.

Key takeaways

- **Over 36% of participating seed lots had very high rates of genetic noncompliance**, with 50% or fewer tested trees showing genetic conformity. Trees grown from these materials will not have the performance and characteristics sought by growers.
- **Only 26% of seed lots had high rates of genetic conformity of 90% or higher.** Three coffee varieties showed higher levels of compliance (i.e., Anacafe 14, Parainema, and Marsellesa) and seed lots that focused on producing them tended to have more true-to-type materials.
- **Even when genetic conformity was present, seed plantations still didn't always follow good agricultural practices** for seed production, such as isolation to avoid cross-pollination, traceability protocols, and adequate storage, putting their seeds at risk of contamination.
- **There exist structural challenges** like the lack of official certification tools, low profitability as many producers are not willing to pay more for quality, and limited access to technical assistance for seed production all hold seed growers back.

The journey of a seed

Seed lots are small plots where coffee trees dedicated to producing seeds of one variety are grown, there may be several seed lots in one farm. Typically, farms do not produce exclusively seed, most are designed for regular coffee production. **Nurseries** are typically privately owned and buy seed, grow it into seedlings, and sell those to producers. They are all part of a seed sector.

This information has helped WCR identify coffee sector needs including training requirements for seed growers. It has also helped identify the current genetic quality of planting materials accessible to coffee farmers in the region.

This report includes the methodologies used to reach these findings as well as country-specific findings that can inform current and future sustainability investments made by governments, the coffee industry, and local communities to strengthen the coffee value chain in Latin America to benefit local small-scale growers as well as coffee businesses and consumers around the world.

Introduction

Coffee production has been present in the Latin American region for approximately 200 years, particularly in Central America and more recently in Peru. The development of this crop is deeply intertwined with the economic development of many Latin American countries.

The challenge

According to the United Nations Food and Agricultural Organization (FAO, 2023), many farmers from developing countries still do not benefit from the advantages of using quality seed because of a combination of factors, including inefficient seed production, distribution systems, and quality assurance.

Coffee farmers in Latin America are no exception. Each country's coffee sector has distinct characteristics and individualities that create opportunities and challenges for quality seed. Some countries have specialized national research and technical assistance programs dedicated specifically to coffee, whereas others have included regulation of the sector under the jurisdiction of preexisting government entities like the Ministry of Agriculture. Further, some countries allow new varieties and planting materials to be introduced and exchanged, while others rely solely on locally developed materials.

Parallel to any formal structure from coffee sector authorities, growers (especially those near borders) have created their own channels to propagate planting material and distribute it, typically exchanging material with one another for many years. Coffee growers often create their own selection of plants based on what they observe to be the best-performing plants in their fields. They will then save seeds from these plants, reproduce them, and repeat the process over many years, creating their own unique crosses and populations. They commonly misname these coffee plants or create new names for them. This situation increases the probability of genetically mixed plants being used for seed and decreases the probability of plants performing as expected, in turn increasing risk in the coffee value chain.

In addition to these genetic contamination risks, seed plantations[1] in the region do not implement good agricultural practices (GAPs) for seed production such as reducing cross-pollination between nearby plantations, monitoring phytosanitary conditions that might affect the viability of embryos, and establishing traceability plans to ensure the seed maintains its integrity throughout the value chain.

The opportunity

As a result of the Central American coffee crisis in 2012, caused by coffee leaf rust (*Hemileia vastatrix*), many coffee-producing families became interested in renovating their plantations to plant new trees that are resistant to coffee leaf rust and highly productive.

However, an organized and professionalized seed sector in the region is needed to provide a guarantee to nurseries and producers that the material being sold is genetically conforming and high quality. This would ensure that the genetic gain created by breeding programs doesn't "escape" before the material has a chance to reach farmers.

Seed sector activities

To strengthen the seed sector in the region, WCR implemented key activities under the MOCCA program, the findings of which are included in this report. These activities include:

1) Collecting direct information about the gaps in seed plantations' implementation of good agricultural practices.
2) Diagnosing the genetic quality of the seeds available to growers in the region.
3) Locating the most genetically compliant seed sources in the region.
4) Purifying seed plantations to enable them to achieve high levels of genetic conformity, thereby increasing the availability of quality planting materials for farmers.

In total, WCR surveyed 52 seed plantations in 2023 and genotyped leaf samples to assess genetic conformity of their plants – an activity known as Seed Lot Assessment (SLA). WCR also helped clean up 22 seed lots that had previously undergone genetic assessment to eliminate plants that did not meet genetic criteria for each given variety—this is referred to as Seed Lot Cleanup Activities (CLU).

These activities helped WCR identify sector needs and training requirements in GAPs for growers as well as the current genetic quality of planting materials accessible to Arabica coffee farmers across El Salvador, Guatemala, Honduras, Nicaragua, and Peru.

Countries included in this report

El Salvador, Guatemala, Honduras, Nicaragua, and Peru

Genetic Conformity Explained

Verification of coffee varieties is important to ensure quality control of the planting material available to farmers worldwide. However, verifying coffee varieties using morphological descriptors—a process known as phenotyping—like plant height, growth habit, branching, leaf and cherry characteristics, and color poses a challenge because of the limited range of morphological differences observed among Arabica coffee varieties. Thus, the use of molecular markers to verify Arabica coffee varieties—also

[1]A seed plantation is defined as a coffee plantation that is used to collect cherries for seed and distribute the material among growers, even if not exclusively for that purpose.

known as genotyping—has emerged as an effective tool to ensure the genetic conformity of cultivated varieties (Pruvot-Woehl et al., 2020). Genotyping involves determining the genetic makeup of a plant or specific variety, otherwise known as its genotype. Industry and the scientific community regularly use genotyping tools to authenticate varieties and understand genetic diversity. Recent technological advances have created accurate, repeatable, inexpensive, and rapid options for the genetic identification of plants.

This is good news as the genetic fingerprint of an Arabica coffee variety can be quite complex. Incomplete inbreeding of most Arabica coffee varieties when they were initially released has led to significant variation within a single variety. Furthermore, some varieties share the same genetic background and parentage but have different names across countries or regions, making it complicated to differentiate them based on the genotypic data of a limited number of samples. Closely related varieties also often display very similar patterns in their molecular markers. To address these issues, the WCR protocol for collecting field samples for genotyping in seed production lots was followed across activities in this project.

Methodology

This report covers WCR's analysis of 52 seed plantations across 4 countries and 22 seed lots across 5 countries, including visual evaluation of local coffee plants.

Assumptions include: all information provided by all contacted actors is true and given in good faith; all interviewees provided information that reflects the current state of their sector from their expert point of view; and all sample collection procedures and laboratory results obtained are reliable and reflect the genetic status of the material.

Seed Lot Assessment Activities

For the SLA activity, WCR staff surveyed 52 seed plantations in Guatemala, Honduras, Nicaragua, and Peru in 2023 regarding their production characteristics and implementation of GAPs. Additionally, at the same seed plantations, WCR staff collected leaf samples to identify the genetic conformity of the varieties they produced.

Participant selection

WCR began pre-selection of seed lots in 2019 and repeated this process prior to sample collection. Likewise, staff prioritized coffee varieties for evaluation by country, based on the opinion and ranking of different actors in the value chain (e.g., export companies, research institutions, coffee experts). This report presents the results of lots sampled in 2023.

WCR selected lots that were in good phytosanitary condition at the time of sampling and visual inspection showed that the trees were true-to-type, that is, they were consistent with known visual features of the variety (e.g. tree height, leaf shape, etc.) Lots that did not meet these requirements were not sampled. Seed lots from El Salvador were also not included under this activity because WCR had previously submitted all main seed sources in the country for DNA testing in 2022 under the scope of a different study conducted in collaboration with the Inter-American Developmental Bank and the El Salvadoran Ministry of Agriculture under El Plan de Despegue Sostenible del Café.

The main activities conducted in this stage were identification of seed lots, selection of seed lots that functioned as providers for producers in their region, and collection of consent to participate through discussions of the goal and objective of the activity and addressing any concerns and confidentiality issues related to the work.

Survey implementation

WCR staff administered a 23-question survey (see Annex 1) to collect information directly from seed lot owners. Staff also conducted visual assessments of each seed plantation.

Questions focused on ascertaining the implementation or lack thereof of effective agricultural practices for seed production to identify opportunities for improvement in their production systems. Topics evaluated included: shade management, nutrition management, pest and disease management, isolation or cross-pollination reduction practices, and traceability practices during seed handling. The main activities conducted in this stage were site visitation and visual evaluation and survey administration.

Leaf sampling and evaluation

At each lot surveyed, WCR staff also collected leaf samples and sent them to a laboratory for analysis. Samples were genotyped using Single Nucleotide Polymorphism (SNP) markers to verify their general genetic conformity.

WCR followed the protocol for collecting field samples for

SNP genetic marker testing

Testing using SNP genetic markers has become the method of choice for genotyping in many plant species, including coffee (Zhang et al., 2021). This pattern of tiny variations, represented by SNP markers, dispersed through a plant's DNA sequence can be used to create a genetic "fingerprint" for a variety. While single sequenced repeated (SSR) genetic markers, also known as microsatellite markers—which WCR previously used from 2017 to 2020—are highly effective for genetic diversity studies, SNP markers offer a low-cost, rapid test alternative for confirming genetic conformity. For those seeking to buy and plant coffee trees at scale, SNP markers are a cost-effective, commercially available tool. Learn more at worldcoffeeresearch.org/snps

genotyping in seed production lots. This protocol was previously established by the WCR technical team to standardize the process of sample collection. Random samples of 20-25 plants were collected at each site and the samples were properly prepared and sent to the laboratory at Intertek for analysis.

The main activities completed in this phase included leaf sampling of the plants in each lot, sample preparation (e.g., entry to the plates, drying, documentation), shipment of samples to the laboratory and subsequent DNA analysis, and communication of results.

Seed Lot Cleanup Activities

WCR chose another group of 22 seed lots in 5 countries that had undergone prior genetic assessment for CLU activities in 2023. CLU increases the availability of high-quality seeds for farmers, providing confidence in plant performance based on variety characteristics and reducing the risk of underperformance as seen in non-conforming trees.

These activities were carried out in collaboration with coffee institutes, cooperatives, and other local industry representatives involved in the coffee seed sector.

Participant selection

Using the WCR protocol to ensure genetic conformity, WCR and its partners evaluated seed lots for their potential to undergo a subsequent "cleaning" process. A total of 22 seed sources that met the requirements were selected.

The main activities completed in this stage included identification of partners to work on seed lot cleaning, selection of candidate seed lots for cleaning, and signing of a collaborative agreement between WCR and partners, which described respective responsibilities as this activity required partner agreement for completing the cleanup after the results were provided.

Activity implementation

To create seed lots that are fully genetically compliant, this process involved sampling individual plants to identify and eliminate any tree that did not meet the genetic criteria for each given variety. The WCR protocol for collecting field samples for genotyping in seed production lots was followed. This protocol states that for a seed lot cleaning activity, all the plants in the lot need to be sampled or, failing that, a specific, clearly delimitated area of the lot should be sampled.

The main activities completed in this phase were visitation of the site for leaf sampling of the plants in the lot, preparation of samples (e.g., entry to plates, drying, documentation, etc.), shipment of samples and subsequent laboratory DNA analysis, communication of results, and seed lot cleaning (e.g., elimination of all non-conforming trees).

DNA Analysis for SLA and CLU

To address challenges related to Arabica coffee varieties, samples were chosen from reliable sources and genotyping was conducted of multiple samples of the same variety to create the most accurate SNP profiles. These SNP profiles collectively form what is known as a DNA fingerprint. With these marker profiles, WCR created a variety reference database that was used to authenticate the varieties in the seed and nursery sectors covered by the MOCCA program. All information and molecular markers were released on the WCR website for public access (worldcoffeeresearch.org/snps).

Analyses were conducted under the WCR variety identification protocol utilizing a low-density (LDP) SNP panel and the expertise of trained field personnel. The SNP LDP is designed for use at scale to verify the genetic conformity of seed lots of specific varieties. Since the objective was to drive impact at scale via identification of genetically compliant seed lots of specific varieties, WCR did not provide detailed genetic reports on the varieties being tested, but rather provided binary (Yes/No) results on whether a seed lot conformed to the declared variety. Each of the participating lots received a written report with the individual analysis of each sample collected and a description of the findings. This information is property of the farm owner and is confidential.

RESULTS

Local Seed Sector Characteristics and Challenges

El Salvador

El Salvador's geography and diversity of microclimates have favored the production of specialty and premium coffee varieties such as Bourbon, Pacas, Pacamara, Catimor, Catuaí, Catisic and Cuscatleco. The country has also maintained prestige and reverence for its coffee both in the Central American region and in the United States, Germany, Belgium, Italy and Japan, who are among the main buyers of Salvadoran coffee (Consejo Salvadoreño del Café, 2023). Salvadoran coffee is marketed as specialty and premium coffee. In 2023, the country registered 119,429 hectares (ha) of coffee plantations, representing 118,114 producers.

However, production of coffee in El Salvador has decreased significantly over the past 10 years, from 1,075,000 bags of 60 kg in 2009 to a low of 660,000 bags of 60kg in 2020 (International Coffee Organization, 2020). Total production fell from 1,985,625 quintals during the 2009-10 harvest to 955,115 quintals[2] in the 2018-19 harvest (Consejo Salvadoreño del Café, 2020).

This downward trend in national production has generated great interest in renovating coffee plantations, partly because of their poor condition as many have aging plants and phytosanitary problems that result in low productivity and yields. The government is also prioritizing rehabilitation as the coffee sector represents almost half of the country's forests.

The current government has been promoting activities as part of its coffee rescue plan, including:

- Creation of a new coffee brand, officially launched in July 2021, which aims to position the brand and enhance the specialty coffee produced in the country for international markets.
- Creation of the Salvadoran Coffee Institute (ISC), approved by the Legislative Assembly in November 2021, which will be attached to the Ministry of Agriculture and Livestock and will execute and promote scientific research, training, innovation and technological development to increase productivity and enhance quality and climate resilience.
- Development of the "Reglamento Técnico Salvadoreño[3] requisitos para la producción de semilla certificada de café" or, "Salvadoran Technical Regulation requirements for the production of certified coffee seed," by The Salvadoran Coffee Council, in coordination with the Ministry of Agriculture and Livestock, the Technical Regulatory Committee and the Salvadoran Technical Regulatory Agency (OSARTEC), with the objective of strengthening the links in the value chain, establishing procedures and requirements for production and marketing of certified coffee seed.

A survey conducted by WCR/Enveritas in El Salvador from 2019-2020 involving 370 coffee growers indicated that 68% of them are planting new seedlings in their farms, and only 17% of those growers prefer to develop seedlings themselves instead of buying them from a commercial nursery. These results indicate that, in El Salvador, there is an important difference in preference for seed acquisition procedures when compared to other countries in the region. This may be a reflection of the success of the El Salvadorian government' which is likely a reflection of the government's renovation programs.

In 2023, the government of El Salvador distributed more than 1 million plants to small-scale coffee producers to address low productivity (Consejo Salvadoreño del Café, 2023). The Ministry of Agriculture and Livestock (MAG) delivered these plants through the "Climate Resilience of the Coffee Forests of El Salvador" program. It selected nurseries that provide top-quality plants, evaluate their implementation of GAPs, and ensure the highest possible level of genetic conformity. MAG provided these nurseries with a list of seed suppliers to help them choose suppliers known for offering the highest variety conformity. Genetic conformity was assessed by WCR in 2022 in a study conducted in collaboration with the Inter-

Local regulations

This technical standard applies to all people involved in the production and commercialization of coffee seeds. It includes sections outlining the requirements that these individuals must meet to be considered seed suppliers.

The standard is divided into sections: the first section covers the requirements for the establishment of the seed lot, agronomic management in each productive stage, management during harvest, traceability of the harvested seeds, and packaging and storage of the seeds. It also includes a section for the "conformity evaluation procedures," which refers to the requirements for the registration of seed production lots and the requirements for certification of coffee seed. This certification process requires demonstration of the origin and genetic quality specific to each plant per variety. This implies that seed producers interested in becoming suppliers of certified seed must demonstrate the genetic conformity of their seed lots. Currently, this demonstration is based on the results of genetic conformity conducted by WCR and IDB in 2021.

[2]Quintals is a traditional unit of weight in the coffee sector, equal to 100 kg., [3]RTS 67.08.03:20 CAFÉ- Reglamento Técnico Salvadoreño para la producción de semilla certificada, [4]Organismo Salvadoreño de Reglamentación Técnica.

American Developmental Bank and MAG, and there are currently 63 seed lots on the government's list.

Each of these seed lots are registered and must comply with criteria related to genetic conformity and phenotypic homogeneity of each variety (for a definition on phenotype vs. genotype, see the next page). Genetic conformity is an indispensable requirement for seed supplier certification according to recent local legislation. They must also comply with certain quality control criteria associated with GAPs, such as recording the location of the seed lot area, shade management, integrated pest management (IPM), nutritional planning, and harvest management, among other criteria, to guarantee the quality of the seed produced by the certified seed lots.

The owners of these seed lots used to be members of an organized and recognized seed sector entity in the country, which was created by agricultural companies and coffee producers. For the registered suppliers, it meant being part of a legally recognized entity that had frequent meetings, was recognized as such by the competent authorities, had a board of directors that represented them, and participated in public coffee events. However, only 26% of seed lot owners were associated with this entity prior to 2020, and those involved decided to end it after that. Those who were part of this association now work individually and, despite efforts to formalize the system, informal seed commercialization in El Salvador persists.

Agronomic aspects of seed lots in El Salvador

The 63 seed lots on MAG's list are located across 34 farms. Of these, 17 are considered large farms between 43-133 ha, most of which belong to private companies. Another 17 are small farms between 0.35-28 ha. The lots located in these small farms belong mostly to producers, professionals, traders, and private companies.

The seed lots on these farms range from 0.2-14 ha and together constitute 150 ha dedicated to coffee seed production. They were planted using various distances, commonly 1.25 m between plants x 1.66 m between alleys, which indicates a very high planting density that is typical of many Central American operations, especially for varieties such as Pacamara, Parainema, and Marsellesa, which have long branches. With this close spacing, the branches cross each other and compete for light, water, and space, which can limit the plant's growth and development.

Eighty-six percent of the lots are between 3-10 years old; these are considered young plantations, which are less prone to productivity problems. The other 14% range from 11-35 years and have adult plants and varieties that are highly appreciated locally, such as Pacas, Pacamara, Bourbon, and San Pacho, which have high susceptibility to pests and diseases, especially coffee leaf rust.

Regarding the agronomic management of the plantations (e.g., shade management, weeding, nutrition, etc.), they are well managed overall and follow the recommended GAPs. According to the lot owners, the physical condition of plants is evaluated at the time of harvesting, and only the plants in the best condition are to be harvested. The lots are also highly homogenous due to the inspections they receive where farmers are required to eliminate off-type plants. This practice contributes to the maintenance of a uniform lot. Most (68%) of the lots receive calcareous soil amendments, which are regularly done once a year; 98.5% receive edaphic fertilization; and 92% receive foliar fertilization, which is commonly used to correct nutritional deficiencies in the plants.

A portion (24%) of these seed lots are located below 1,000 masl, which is considered low altitude and may increase the risk of exposure to extreme climate conditions. The remaining 76% are in areas with altitudes higher than 1,000 masl, with the highest being at 1,750 masl.

Seed commercialization and traceability in El Salvador

The main clients for seed producers in El Salvador are individual coffee producers, most of whom are also nursery operators and later sell seedlings to government programs or other coffee growers. However, not all seed produced is sold, and part of the seed produced is kept by producers to establish nurseries and replant later in the year or sell seedlings to others.

If seedlings are produced to sell to the MAG programs, material must comply with certain requirements. For example, suppliers must be registered, and operators have to submit their offer and undergo a local inspection during which the quality of the seedlings is verified. After this process, depending on the inspection results, they may be selected as suppliers and the government then announces the number of plants the program will buy from each nursery.

The origin of the seeds used to establish the seed lots is diverse. A portion (28%) came from local farms; 25% did not know the origin of the seed at all; 22% was seed provided by PROCAFÉ[5]; and 17% was purchased directly from the breeders (ANACAFE or ECOM Nicaragua, depending on the variety); and 6% was provided by the former Salvadoran Institute of Coffee Research (ISIC), which closed in 1990.

Of all the seed lots registered in the country, 30% have a conformity level of less than 50%, which means that at least half of the seed

Table 1. Range of genetic conformity of participating seed lots previously evaluated in El Salvador

Range %	Range of conformity			
	≤50%	51-79%	80-89%	90-100%
No. Seed Lots	8	11	19	25
%	13%	17%	30%	40%

[5] Fundación Salvadoreña para Investigaciones del Café, created on October 10, 1990 as a result of the application of a strategic privatization program of the Salvadoran Institute for Coffee Research (ISIC), promoted by the Government of El Salvador.

Table 2. Estimated production capacity of participating seed lots in El Salvador

Total number of seed sources identified	63
Total area of seed production (ha)	150 ha
Estimated seed production per year	434.8 kg/ha
Estimated total seed production	62,925 kg/year

and plants originating from these lots are not the expected varieties and are probably not performing as expected in the field. On the other hand, 40% of the lots met a conformity level between 90-100%, which indicates that there is potential in the country to improve producers' access to quality seed.

To comply with the local demand for seedlings, MAG declared in 2022 that all seed sources that have 80-100% genetic conformance levels are accepted and considered as suppliers for the national public programs. This process requires registering the variety and submitting to a series of requirements to be seed suppliers, including site inspections. In addition to genetic conformity results, they must meet GAP requirements.

The following estimated data of seed production is part of previous consultancy work titled the "Design and Structuring of a Traceability System for Coffee Vegetative of Coffee Material in El Salvador," led by WCR with funds from the Inter-American Development Bank in 2021. It provides perspective on the characteristics of the seed available in the country.

Production per lot ranges from 45 kg of seed in 0.2 ha for the smallest lot to 6 818 kg of seed in 14 ha for the largest lot. Concerning the post-harvest processing of the seed, each farm processes its own on-site. According to those interviewed, a group of workers is selected to harvest the lot, the de-pulping is done under the same conditions as the other lots, and the assigned staff does not receive any special training for the harvest and post-harvest process. Given this, there may be a risk that, by neglecting traceability at any of these stages in the process, commercial seed could be mixed with other seeds.
The seed lots are managed like traditional coffee production lots, and there is not enough distance between varieties to avoid the risk of cross-pollination. In most cases, the distance between one variety and another is 2-5 m and there are no protective barriers to limit each variety, which also increases the risk of loss of traceability during harvest because there are no clear limits for pickers to follow.

The lots in the field are not clearly marked, nor are records kept of the number of plants for each variety or lot, which means that there are no existing control measures to help ensure the traceability of the seed for each variety in every stage of the process. Having a record of the number of plants and seed collected per variety reduces the likelihood that a higher production is recorded and sold erroneously.

The areas used for seed storage do not have the conditions necessary to store seed and guarantee its physical quality and genetic traceability to customers. For example, there are no platforms to place the bags of seeds on to avoid direct contact with the ground, the required humidity and temperature are not controlled, and there is no clear signage. Therefore, the seed is at risk of losing viability as well as being mixed with other seeds.

Seed Lot Cleanup Activities: Key Findings in El Salvador

Coffee in El Salvador has been very important for the economic, social, and environmental sustainability of the country. Between 1995 and 2005, coffee production averaged 9.2% of total exports, contributing 160,000 direct jobs and about 500,000 indirect jobs to the economy in 2011. By 2017, coffee was the main agricultural export product of the country and has been responsible for injecting resources into rural areas, invigorating rural trade. For many years, coffee has allowed rural populations in El Salvador to have more adequate local infrastructure, such as roads, schools, and access to basic services, among others. Globally, coffee from El Salvador has been characterized by its potential for high cup quality.

Before the crisis caused by rust (Hemileia Vastatrix) in 2012, 68% of the coffee area cultivated in El Salvador was of the Bourbon variety, 29% was Pacas, and only 3% was established by other varieties. This distribution contributed significantly to the impact of coffee rust, which devastated the coffee sector of El Salvador, coinciding with an unusual weather phenomenon that led to the spread of the disease. Not only did coffee rust impact coffee production in the country, but it also impacted producers economically (Coffee Forum, 2017).

According to the Special Report on the impact of coffee rust on the coffee sector in Central America, El Salvador was the most affected country, with a 70% decrease in its harvest between the years 2010/2011 and 2013/2014 (PROMECAFE, 2016).

The impact was immediate, as rust caused a 58.5% drop in production from 1.2 million bags of coffee in 2012/13 to 0.5 million bags in the 2013/14 coffee year. For that reason, El Salvador's coffee production has been struggling to recover the devastated coffee plantations and, thus, the lives of producing families. With this, the government of El Salvador launched the "Program to Strengthen the Climate Resilience of El Salvador's Coffee Forests" at the end of 2021 to rejuvenate the coffee industry (MAG, 2022).

The initiative aims to renew 25% of the original coffee area (approximately 34,900 hectares), which involves making 24 million rust-resistant plants available to farmers over the next 5 years. This will complement an existing effort, which began in 2016 and has renewed about 20,000 hectares. As a result of the rejuvenation program, production increased by 0.7 million bags of coffee in the year 2021/22, and this initiative has allowed a transition between the use of older varieties—such as Bourbon, Pacas, and Pacamara—to more resistant varieties (Valladares et al., 2019).

According to the results of a study of the coffee value chain in El Salvador by the Alliance of Bioversity International and CIAT (Camilo et al., 2022), where a sample of 380 producers were surveyed, most of the producers surveyed use plant material provided by the government through its different entities (e.g., CENTA, MAG, CSC). Although it is common for producers to conserve areas with older varieties (e.g., Pacamara and Bourbon) due to their higher quality and bean size, these are gradually being replaced by more resistant varieties such as Catimor, Sarchimor, Cuscatleco, Costa Rica 95, Marsellesa, and Anacafe 14, among others.

In general, 40% of the varieties sampled have a level of conformity lower than 50%, while only 60% have a level of conformity higher than 80%. The varieties with a genetic conformity higher than 80% are Pacamara, San Pacho, Cuscatleco, and Marsellesa, while the main varieties with genetic conformity lower than 50% are Pacas and Catisic. In general, the higher the percentage of genetic conformity in the lot, the greater the homogeneity, and the greater the capacity to produce conforming seed.

Main challenges and implications identified

The main challenge identified by the seed growers when interviewed was the frail stability of the market. Seed producers cited that there is a dependence on a single client, putting the business at risk. This is because, in most cases, seed producers sell their seed to nurseries, and these depend almost exclusively on plant purchases made by MAG. Producers also mentioned that the number of seeds they sell is limited compared to the total amount they can produce. Most of the seed harvest is sold as traditional coffee fruit.

Seed producers do not typically engage in the seed production business as their main economic activity since it is not profitable on its own. Seed producers often engage in other activities that generate more income such as marketing of agricultural inputs and machinery and nursery production of coffee, fruit, timber trees, and more. Producers also mentioned that the prices they receive for seed often do not compensate for the high maintenance costs they incur to comply with inspection requirements. This is especially true in cases where producers have varieties that are susceptible to pests, diseases, and climate change. In these cases, keeping a plantation in good condition requires investment in additional inputs and management, which increases production costs. In El Salvador, there is little farmer awareness of the importance of investing and prioritizing quality seed, and therefore the offered prices are seen as too expensive by customers.

Producers also mentioned that the varieties they plant are susceptible to pests and diseases and are not resilient to the various climate changes they have faced in recent years. They believe that, in El Salvador, there has not been an acceptance in the market of new varieties that maintain quality but also have resistance or tolerance to climate conditions in the country. In other words, seed producers continue planting the susceptible materials because that is the material demanded by their customers.

Based on the work carried out by MAG with the identification,

registration, and certification of nurseries and seed lots in El Salvador, steps have been made to improve the guarantee of genetic conformity of plants offered to nursery operators who buy seed and to coffee producers. These actions should be a high priority for a country focused on the production of quality coffee since having certainty of the variety that is being produced and how to manage it properly will support potential cup quality.

While El Salvador has a much more organized seed sector compared to other countries in the region, there is a lack of professionalization in this important arm of the coffee supply chain. Compared to years prior to 2020—and before quality control tools (such as the SNP panel) were available to the sector—seed producers are now able to provide seed with better genetic conformity. However, this alone is not enough; it is also very important that all GAPs for seed production are implemented. Some of these include: the sufficient spacing between one varietal lot and another, maintenance of detailed records of activities in the seed lots, ensuring seed traceability in harvesting and processing to avoid contaminating one seed lot with another, and more. These recommendations are detailed in the "Reglamento Técnico Salvadoreño de Producción de Semilla Certificada de Café" (Salvadoran Technical Regulations for the Production of Certified Coffee Seed), which facilitates the proper management of seed lots and allows both lot owners and workers to gain awareness of the importance of maintaining the traceability of each variety in all phases of the production cycle.

HONDURAS
Pages 14-18

Honduras

Honduras is the leading coffee producer in Central America, and coffee is the country's main export product. Honduras accounts for 31% of total coffee production in the Caribbean, Central America, and Mexico with 6.2 million bags harvested in 2020-21. However, in 2021-22, production fell 11% to 5.5 million bags, with a consequent drop in market share to 28%. Multiple factors explain this decline and its intensity: the impact of biennial production, lower rainfall during fruit growth, high incidence of rust because of hurricanes Eta and Iota, and production stagnation after the coffee leaf rust epidemic of 2012 (International Coffee Organization, ICO 2023).

Given the importance of coffee growing in the country, farmers need to replace plants that are old, sick, and susceptible to sudden changes in the climate with new, higher-quality plants. According to the Association of Coffee Exporters in Honduras, in the 2021-2022 production cycle, 321,000 hectares of coffee were planted, with 67% of these areas located in 5 departments: El Paraíso, Comayagua, Santa Bárbara, Lempira and Copán. However, this data is not confirmed by official entities in the country and could not be verified at the time of this report. In Honduras, there is no updated registry of the total amount of hectares, however, the IHCAFE cited online the existence of 7 coffee-growing regions in 2021 totaling 231,581 ha.

In addition, there was no documentation of the origin of the seed used to produce the previously mentioned harvests, and there are no seed suppliers or registered nurseries in the country. Therefore, producers have no certainty of the phytosanitary quality or genetic conformity of the material they plant.

Honduras, like most coffee-producing countries, does not have an organized sector or infrastructure to produce large quantities of genetically conforming seeds. One primary reason is that, culturally, most coffee growers establish their own nurseries with seed taken from their own farms in a higher proportion than in other countries. A previous survey done in Honduras by WCR/Enveritas found that in 2019-20, 74% of the 1,660 surveyed farmers who were planting new seedlings preferred to develop them themselves (Sources of Planting Material and Replanting Practices, 2019–2020). Unlike other countries, most seed lots in Honduras are newly established, with most of them being between 3-8 years old.

Table 3. Estimated production capacity of participating seed lots in Honduras

Total number of seed sources identified	15
Total area of seed production (ha)	23.7 ha
Estimated seed production per year	1028 kg/ha
Estimated total seed production	24,385 kg/year

Quality and traceability are difficult as the seed lots surveyed were not registered with any entity in the country that recognizes them as a seed supplier. As a result, they are not required to keep or present any type of written documentation, submit to inspections, or comply with any requirements.

In the case of seed lots belonging to private companies, most of the seed produced is used to establish the company's own nurseries and eventually these plants are delivered as an investment or financed to the producers with whom these companies work. Small seed producers are usually members of or associated with these companies or cooperatives. When seed is requested, they process and sell the quantity needed or, in some cases, establish their own nurseries and sell the plants to these companies that, in turn, deliver them to other coffee producers.
Of the 8 seed lot owners surveyed, 7 had participated in training processes for seed production, including with private companies that offer this training. We found that both those who have and those who have not received training manage their seed lots in the same manner as the rest of the farm coffee production.

Agronomic aspects of seed lots in Honduras

Fifteen seed lots spread across 8 farms participated. Of which, 10 seed lots were located on large farms ranging from 235-756 ha and belonging to IHCAFE (Honduran Coffee Institute) and exporters BECAMO, Molinos de Honduras, and CAFICO. The remaining five seed lots were located on small farms ranging from 1-35 ha that belonged to small producers who occasionally market seed within their communities. Only 2 of the 8 farms were fully dedicated to coffee production; the other 6 grew coffee as well as basic grains and species for animal consumption. The size of the seed lots ranged from 0.2-11 ha, with a total area of 23.77 ha dedicated to the production of coffee seed across lots.

The seed lots were in zones with altitudes ranging between 850-1200 masl. All lots had permanent shade trees with shade management cycles once a year, which allowed for control of relative humidity and severe fungal diseases. Fungicide applications were also carried out as part of pest and disease management and, in general, the plants were in good condition at the time of the site visit.

Plant vigor and growth levels varied between some farms. Private company farms were in better condition as they invested more in inputs and efficient farm management than some of the smaller producers. As a result, not all seed lots were producing in the same conditions nor adhering to standardized qualities. Producers who did not have access to private company seeds therefore lacked

access to the best quality material. The lots used different planting distances, commonly 2 meters between plants by 2 meters between rows, with a density of 2,500 plants per ha—a low density compared to that of other producers in the region. Interviewees explained that this density allows them to facilitate management activities, especially with varieties such as Parainema and Anacafe 14 that, with higher densities, experience branches interlocking with one another and compete for light, water, and space, which limits plant growth and development.
Interviewees estimated their production was 1,028 kilograms per hectare on average. They only sold 3% of production (955 kilograms) that year as seed.

Seed commercialization and traceability in Honduras

In Honduras, there are three ways to obtain seed:

1. IHCAFE (The Honduran Coffee Institute). This is the main seed supplier in the country and the official entity for the dissemination of planting materials. However, according to interviews with local actors, IHCAFE's supply is not sufficient to cover the planting material needs of all producers in the country given high demand for seed material and plants and the extension of coffee-growing areas. IHCAFE does not have an exact record of how many unofficial suppliers of planting materials exist in Honduras.

2. Private companies. Some coffee trading companies and cooperatives have their own seed lots. These lots provide seed or seedlings to producers within their value chain. However, this relationship only includes the group of producers they work with, and many producers do not have access to these benefits.

3. Independent private producers. Some producers sell planting materials in the areas where they live; they are identified and recognized within their community as seed or seedling suppliers.

None of these three types of suppliers of genetic material in the country have traceability plans, nor is there an entity that regulates them as seed producers and controls the traceability and quality of the seed being marketed. Current suppliers emerged in the market because of the existing need for seed and have taken advantage of the opportunity to provide this service to producers in a growing market that demands quality materials in high quantities.

Private companies often keep the seed they produce to establish their own nurseries and distribute seedlings to their associates. For small producers, their main customers are neighboring producers, and in some cases, the companies or cooperatives with which they are associated. The rest of the seed that is produced and not sold is used to establish nurseries and develop seedlings for replanting on the same farms or is sold as commercial coffee.

Table 4. Seed lots sampled in 2023 for assessment in Honduras

No.	Variety	Location	% Genetic Conformity	Seed Lots Areas
1	Catuaí	Morocelí, El Paraíso	84%	0.2 ha
2	Lempira	Siguatepeque	44%	2 ha
3	Parainema	Siguatepeque	72%	2 ha
4	Parainema	Rancho Pedro, Santa Barbara	36%	1 ha
5	Parainema	Concepción del Norte, Santa Barbara	92%	0.5 ha
6	Parainema	Concepción del Norte, Santa Barbara	96%	0.35 ha
7	Anacafe 14	La Fé, Santa Barbara	40%	0.30 ha
8	Anacafe 14	La Fé, Santa Barbara	52%	0.30 ha
9	Parainema	La Fé, Santa Barbara	96%	0.30 ha
10	Anacafé 14	Santa Rosa de Copan	88%	11 ha
11	Maragogype	Santa Rosa de Copan	32%	4.5 ha
12	Marsellesa	Corquin, Copan	32%	0.20
13	H1 Centroamericano	Corquin, Copan	100%	0.12
14	Catigua MG2	Corquin, Copan	0%	0.5 ha
15	Anacafe 14	Corquin, Copan	0%	0.50

Table 5. Range of genetic conformity of participating seed lots in Honduras

Range %	Range of conformity			
	≤50%	51-79%	80-89%	90-100%
No. Seed Lots	7	2	2	4
%	47%	13%	13%	27%

According to the owners of these lots, they do not have to comply with any criteria or requirements in the country, inspections by government agencies, or register anywhere. There is legislation that prevents them from producing and marketing seed in the country.

Of the participating 15 lots, none were established with certified seed and, therefore, there was no guarantee of the genetic conformity of the lots. Prior to the analysis performed by WCR, 5 lots were established with seed from IHCAFE lots (lots that, before 2020, had no results of their genetic conformity). The other 10 lots were established with seed from private farms that was determined only by visual inspection of the variety they sell with no genetic testing.

Each farm processed its own seed and there were no records or traceability controls. Harvesting is done by the same workers with the same machinery; there is no implementation of good practices to guarantee seed traceability.

The seed lots were managed like any other coffee production lot, with no specific practices for seed production. No labeling or demarcation was found to describe the variety produced, nor was there any type of barrier or isolation measure between one variety and another to reduce the risk of cross-pollination. During the field visit, plants found within the same lot were used for seeds that do not correspond to the age or phenotypic characteristics of the commercialized variety, which means that at least two different varieties were found within the same lot. This creates a significant risk for cross-pollination between materials with different genetic characteristics.

There was also no record of the number of plants per lot (e.g., live, dead, and replanting) and estimates were based on the number of plants initially established. There were also no records detailing the number of seed produced by existing plants, number of varieties, processes carried out, person responsible, client, etc.

In most cases, the areas used for seed storage did not provide adequate conditions to guarantee physical and genetic quality to customers. There were no platforms to keep the seed bags from touching the ground; humidity and temperature were not monitored; seed bags were mixed with bags containing other varieties without labeling or marking; and more.

Seed Lot Genotype Assessment in Honduras

DNA analysis was carried out on 8 different varieties and 15 seed lots located in the departments of El Paraíso, Comayagua, Santa Bárbara, and Copán. They are among the top 5 areas in Honduras that planted the most coffee in 2021-2022.

The 8 varieties analyzed are among the most grown varieties in Honduras: Parainema, Anacafe 14, Lempira, Icatú, Maragogype, H1 Centroamericano, Marsellesa, Catigua. They have resistance to pests and diseases, specifically coffee leaf rust; high yield potential; and, in some cases, high cup quality potential.

The two varieties that growers had the greatest interest in knowing the genetic conformity of were Parainema and Anacafe 14. The first four of the varieties sampled in the list above were among the main or most important varieties in Honduras, according to the 2020 Varietal Consultation process developed by WCR with various stakeholders in the country.

The varieties with higher conformity levels were Parainema and Anacafe 14. The high percent of genetic conformity below 79% could mean that coffee plantations are being replanted or rehabilitated with the wrong variety or with highly non-conforming materials, which may result in plants with low yields. It could also mean they are using different varieties than expected, leaving coffee production susceptible to disease and climate change.

Seed Lot Cleanup Activities: Key Findings Honduras

Coffee is key to the Honduran economy as approximately 100,000 families are highly economically dependent on the crop, and around 300,000 jobs are generated by the crop each year (IHCAFE, 2023). To maintain the economic income generated by coffee production, issues currently faced by the value chain need to be addressed. Genetic improvement may be an answer to these problems. Improved varieties are, in general, more productive and have greater tolerance to pests and disease.

In the 1960s, the area cultivated with traditional varieties (Typica and Bourbon) was estimated at 80%. Twenty years later, between 1990 and 2000, about 60% of the area was cultivated with improved varieties and 40% with traditional varieties. Coffee breeding work aimed to develop cultivars with high productive efficiency and quality, resistance or tolerance to the main diseases and pests present and adapted to the particular conditions of coffee-growing areas in Honduras like soil acidity, low fertility, low moisture retention capacity, and relatively dry environments. At the time, IHCAFE-90 and Lempira were considered the most appropriate varieties (Santacreo, et al., 2012).

In 2012 and 2013, an accelerated growth of coffee leaf rust (*Hemileia vastatrix*) was detected throughout the country due to climate change and poor agronomic management. This resulted

in large economic losses: The 2012-2013 harvest saw an estimated $600 million decrease, of which $216 million was directly related to the rust epidemic (Alonso et al., 2013).

After the rust crisis, in 2013, IHCAFE reported 25% of all coffee plantations were affected—70,000 ha of the total of 280,000 ha of coffee production registered at that time. As a result, 21,000 ha needed total renovation of coffee plantations and 49,000 ha needed to be rehabilitated, representing an investment of more than $166 million (Alonso et al., 2013).

The current state of the coffee value chain in Honduras remains complex and, since 2018, the country has experienced a significant drop in coffee production (ICO, 2023). The 2022/2023 harvest was marked by coffee leaf rust damage on many farms. The saturation of soils by a high volume of rain caused drainage of nutrients from coffee plants, generating high levels of rust. This situation put the Honduran coffee sector on alert: The high incidence of rust affected 20% of coffee production during the 2022/2023 cycle (IHACFE, 2023).

Parainema, Lempira, and Anacafe 14 generally tend to present a higher level of genetic conformity based on WCR's evaluations and these varieties are found in most coffee plantations in Honduras. There is no documentation of the origin of the seed used to establish these seed sources though.

WCR identified the main supply lots of planting material and only 40% of them had a genetic conformity higher than 80%, which could indicate seeds from these lots have a fairly high degree of contamination. The risk or vulnerability of farms and coffee-producing families to rust or any other disease caused by climate change continues to be high.

Cleaning seed lots can serve as a lifeline for seed suppliers and the entire coffee value chain. Identifying the genetic conformity of plants and subsequently eliminating genetically non-conforming plants can help guarantee a better and proven selection of seed. The resulting plants that reach farmers' hands may be able to withstand the threats of pests and disease in the face of climate change.

Main challenges and implications identified

The main challenge mentioned by interviewees was maintaining genetic conformity within seed lots since there are no traceability processes in place and their customers do not know (or, perhaps, are not interested in knowing) the origin of the seed they are acquiring.

The second most important challenge was the lack of awareness of customers—in this case growers—about the importance of buying quality plants from seed lots that have and implement traceability processes. Seed suppliers often face customers that are unwilling to pay a fair price for seed with a guarantee that it is, in fact, the

[6]Norma Técnica Obligatoria Nicaragüense 11-045-14 "Certificación de Semilla Sexual," [7]Ley de producción y comercio de semillas, 1997

variety they expect. Growers usually decide to buy the seed at the lowest possible cost, regardless of quality.

Another challenge mentioned by seed suppliers is that there is no institutionalized process to certify their seed lots, and as such, they do not know the requirements they need to meet to be characterized as seed producers. Therefore, they are also unaware of the correct steps for producing quality seed with genetic traceability. Not all of them produce under the same conditions and the quality of the seed they sell varies greatly.

Most of the interviewees considered seed production operations to be unprofitable. Even so, they understood that it is an emerging business and expressed hope that, in the future, the activity will have a greater importance in the coffee sector.
Owners of the seed lots are generally interested in knowing and maintaining the genetic conformity of their seed lots to guarantee their clients quality plants. The work developed with WCR has awakened an interest in knowing the genetic conformity of their seed lots and in carrying out subsequent activities to maintain or improve the genetic conformity of the varieties they grow.

However, most seed producers do not have the capacity to conduct genotyping of their lots with their own resources. This new technology is relatively unknown in the country and the procedures for sampling and shipping can be costly for most (both the payment for the laboratory service and operational activities for the collection of the samples). In addition, overall, the contact information of the laboratories that provide these services is also not widely known.

There is also interest in being able to formally certify seed sources as seed suppliers in the country. However, this mechanism does not currently exist, and most producers are unaware of any type of regulation or requirement to do it properly. The advances in the formalization of the seed sector in neighboring countries such as El Salvador and Nicaragua could awaken the interest of organizations or governmental entities in Honduras to also initiate this process.

The activity of having seed lots identified, registered, and equipped with results of genetic conformity is an important first step toward the implementation of a national traceability system.

The recognized or identified seed lots in Honduras are not specifically managed as seed lots and do not implement the necessary traceability practices along the different production phases, from harvesting and processing to end sale. Likely, the seed or plants that are reaching producers from these lots do not possess the expected genetic quality.
As a result, there is a high probability that producers are planting their farms with varieties that are not of interest or that are not suitable for the conditions present on their farms. This means that the plants may not live up to their potential and the work being done by the breeders who develop these materials loses a lot of value.

It is necessary for the material generated in plant breeding programs to be distributed in the correct way for it to be effective and generate value for the sector. Producers must be able to have access to these planting materials to reduce the risk of productivity losses and establish resiliency to the effects of climate change in the field. It is essential that seed suppliers (where the coffee supply chain flow begins) are registered or accredited in the country, and that those that have production lots registered and inspected as lots with genetic conformity are certified.

NICARAGUA
Pages 19-23

Nicaragua

Nicaragua has seen an increase in production in the last decade. In the 2020–21 harvest report from the CETREX (Centro de Trámites y las Exportaciones, 2020/21), the country produced a total of 3.08 million bags (45.45 kg/bag). The Nicaraguan government stated that there was also an increase in the cultivated land designated for coffee, estimating 126,154 hectares planted and ongoing expansion to 147,000 hectares.

The main government institution involved in coffee production is Nicaragua is INTA (Instituto Nicaragüense de Tecnología Agropecuaria), which was created in 1993, although it is not an institute exclusively dedicated to coffee. INTA has published a national strategy for coffee, which states that there is an interest in the government in promoting the planting of new seedlings and introducing new varieties to enhance productivity (Gobierno de Nicaragua, 2020).

There is also another government entity called the Instituto de Protección y Sanidad Agropecuaria (IPSA) which has a mandate of its responsibility to "inspect, supervise, register and certify the quality of seed for national production," for which it has created the Nicaraguan Mandatory Technical Standard 11-045-14 "Certification of Sexual Seed"[6] as a means of managing the production of quality seed for the coffee sector. The law for the production and commercialization of seeds[7] was published in 1998 and was later reinforced by the 2016 publication of the "Certification of Sexual Seed" that states all technical requirements needed for the production of sexual coffee seed for companies and farmers. Among the dispositions, the regulation stated that any seed producers must register in the Seed Department of IPSA and that they can only produce registered materials (i.e., must provide a certificate of origin of the seed). The law also states that producers must have access to technical assistance and seed plantations need to be between 7-20 years old. This regulation also includes GAPs recommended for seed producers and explanations regarding the corresponding inspections to be performed by the government agencies (Certificación de Semilla Sexual Café (*Coffea arabica*), 2015).

Table 6. Estimated seedling production potential of participating seed lots in Nicaragua

Variety	Kg/seed	Seedlings Potential (Million)
Marsellesa	60454	132.4
Obata	839	1.8
Pacamara	4272	9.4
Parainema	19,908	43
Costa Rica 95	3950	8.6
Anacafe 14	2954	6.5
Catuai	1818	3.9
Total		205.6

Despite the increase in production and the creation of local legislation, the seed and nursery industry in Nicaragua is still very nascent. Some commercial nurseries are registered as seed and seedling providers with IPSA, like Transplanta from MERCON and La Cumplida from ECOM, but there are few of these operations and the registration procedure has a cost, which discourages the registration of smaller producers. Since most growers prefer to produce their own seedlings, seed generally comes from their own farm and there is not generalized access to certified seed. A previous WCR/Enveritas survey stated that 78% of a total of 363 surveyed farmers produce their own nurseries, and 96% of those farmers collect seed from their own plantations (Sources of Planting Material and Replanting Practices, 2019–2020).

Agronomic aspects of seed lots in Nicaragua

In Nicaragua, producers primarily consider two important traits when selecting coffee varieties from which to produce seed: productivity and resistance to pests and diseases. These are characteristics that they look for to increase the sustainability of their coffee production. However, some producers focus on cup quality—a trait that, to them, signifies profitability and sustainability because they can command better market prices and produce high-quality seeds from these materials for the sector that requires them.

Regarding the nutrition programs implemented, the interviewed producers do apply calcareous amendments every two years to manage soil acidity to allow greater availability of nutrients, which has a positive impact on production. Fertilization includes edaphic and foliar nutrition (boron, zinc, calcium, magnesium, etc.) along with fungal applications to reduce pests and diseases, mainly directed at controlling coffee leaf rust and coffee leaf spot. Although fertilizer doses are low (6 ounces per plant per year), they are below the recommended dose for achieving highly productive

plants (between 8 and 10 ounces per plant per year distributed in four applications).

Due to the altitude of the sites where the seed is produced (ranging from 1000 masl to 1200 masl) and given that it is located at latitude 12.86 and longitude -85.20, there is a greater incidence of daylight hours. Permanent shade for the coffee is managed with species of Ingas spp. and Erythrina spp., which also supply nitrogen to the soil. However, there are plantations where no shade is used, specifically those with a better soil fertilization of 9 ounces/plant/year, and this type of management is preferred because it induces better flowering and production.

The seed lots sampled range in size from 0.5 to 6 hectares, usually with planting distances of 1 meter between plants and 2.5 meters between rows (there are also plantations that use 1m x 2m and 1m x 3m). It is usual for producers to opt for high-density planting per hectare in the attempt to achieve higher yields; however, plantations in this style have a short life cycle due to plant competition for space and light. High levels of damage were observed in the branches due to the presence of pests such as the leaf miner, and this mainly occurs in the summertime when there is greater presence of this pest, especially when the plants are closer to each other.

In younger seed lots, producers apply densities consisting of wider rows and closer distances between plants so that the plant has a better development, aeration, and expression in production, but overall, this practice is uncommon in coffee production in Nicaragua.

Seed commercialization and traceability in Nicaragua

The following table presents the potential volume of seed production and the scope of seedling production of the sampled lots. The following production potential varies according to the yields per lot obtained by the producers and the estimate is derived from the assumption that, for each pound of seed, an average of 1,000 seedlings is obtained.

Even though some producers have been trained in the good management of seed lots and seed production by the IPSA and companies like EXPASA (of the ECOM group), it is evident that there is a lack of isolation practices currently being implemented in the seed lots (either through live barriers or distancing to avoid cross-pollination). Rather than producing high-quality seeds, the plantations are focused on producing high volumes of fruit.

Some farms lack labeling of their varieties and, since these are found next to each other, this presents a risk to traceability. A lack of establishment of live barriers to prevent cross-pollination, as mentioned before, was also observed. The existing ones serve as a requirement for certification processes of sustainable production (to prevent the drift of agrochemicals that directly affect the quality of the seed produced).

The coffee seed producers that were interviewed know with certainty the origin of their seedlings. Some came from recognized nurseries such as Finca La Cumplida of EXPASA or, in other cases, were obtained from farms of producers recognized in

Table 7. Results of the genetic conformity of different seed sources assessment in Nicaragua

No.	Variety	Location	% Genetic Conformity
1	Parainema	San Rafael del Norte, Jinotega	88%
2	Marsellesa	Las Cuchillas, Jinotega	96%
3	Marsellesa	El Dorado, Jinotega	48%
4	Pacamara	El Dorado, Jinotega	100%
5	Obata (red)	El Dorado, Jinotega	32%
6	Marsellesa	Santa Isabel, Jinotega	84%
7	Obata (red)	Santa Isabel, Jinotega	24%
8	Parainema	El Sarayal, Jinotega	68%
9	Pacamara	Jinotega, jinotega	80%
10	Anacafe 14	Jinotega, jinotega	100%
11	Catuai	Jinotega, jinotega	80%
12	H1 Centroamericano	Jinotega, jinotega	100%
13	Parainema	Abisinia, Jinotega	76%
14	Obata (red)	Abisinia, Jinotega	4%
15	Costa Rica 95	Abisinia, Jinotega	56%

the community for their level of agronomic management and production at a national level. Alternatively, others obtained their seed from coffee institutions in neighboring countries in the Central American region such as ANACAFE and IHCAFE.

As is the case in most of the countries in the region, producers in Nicaragua mentioned that they do not have a certificate of genetic conformity of the plants received because they do not have a certifying entity for the material received (with the exception of IPSA, which verifies through phenotypic traits the variety from which the seed comes) or the verification of a traceable record of the origin of the seed.

Table 8. Range of genetic conformity per number of seed lots in Nicaragua

Range %	Range of conformity			
	≤50%	51-79%	80-89%	90-100%
No. Seed Lots	4	3	4	4
%	26.66%	20%	26.66%	26.66%

The cost per pound of seed produced is approximately $10 USD if it is free of imperfections and with a humidity between 25-30% (to be highly viable for germination). However, seed producers cited that buyers are commonly unwilling to pay that price, preferring to obtain from their own farms or friends at a lower cost but with degraded quality guarantees.

On the other hand, the establishment of large and prestigious nurseries such as EXPASA's Finca La Cumplida and Grupo MERCON's Transplanta, which have more developed technology to produce seedlings, creates market incentives for the establishment of high-conformity seed lots given the demand for seedlings.

Seed Lot Genotype Assessment

In May 2023, WCR staff collected samples from 15 seed lots of different varieties in Nicaragua to conduct a genetic analysis of the varieties used by producers as a seed source. In addition, interviews and on-site observations were conducted on the farms visited in the sectors of El Dorado, El Cuá-Abisinia, Las Cuchillas, all in Jinotega, Nicaragua in relation to seed production. The varieties that were genotypically evaluated and produced were Marsellesa, Pacarama, Parainema, Obata, Catuaí, Anacafe 14 and Costa Rica 95 (see Table 7).

From the table above, it can be inferred that producers claim to have a variety defined by its phenotypic characteristics, but the results frequently show differences in terms of genetic conformity. The following table shows that only 26.66% of the evaluated lots correspond to high-quality genetic conformity (90%-100%) (see Table 8).

Seed Lot Cleanup Activities: Key Findings in Nicaragua

Nicaragua's Ministry of Agriculture and Livestock (MAG) reported on January 15, 2023, that there were 168,000 ha dedicated to coffee growing, of which 84% correspond with small producers located mainly in the northern region of Nicaragua (Estelí, Nueva Segovia, Jinotega, Matagalpa, Boaco) and a small area in Jinotepe on the Pacific Coast.

According to the Nicaraguan Foundation for Social and Economic Development (FUNIDES) in 2018, the main species planted is Arabica and the top-demanded varieties are Catimor, Caturra, and varieties from the Sarchimor group (Parainema and Marseillaise). The establishment of varieties from the Sarchimor group arose in 2012–2013, when the coffee leaf rust pandemic hit Central America. Coffee plantations in Nicaragua were already renovated, which prevented the devastating effects of coffee rust felt elsewhere, according to the Famine Early Warning Systems Network in 2016. This made Nicaragua the Central American country least affected by the rust epidemic, as the nation experienced a less significant decrease in production (11% between 2011/2012 and 2012/2013) than its counterparts.

Figure 4. Level of genetic conformity in seed sources in Nicaragua

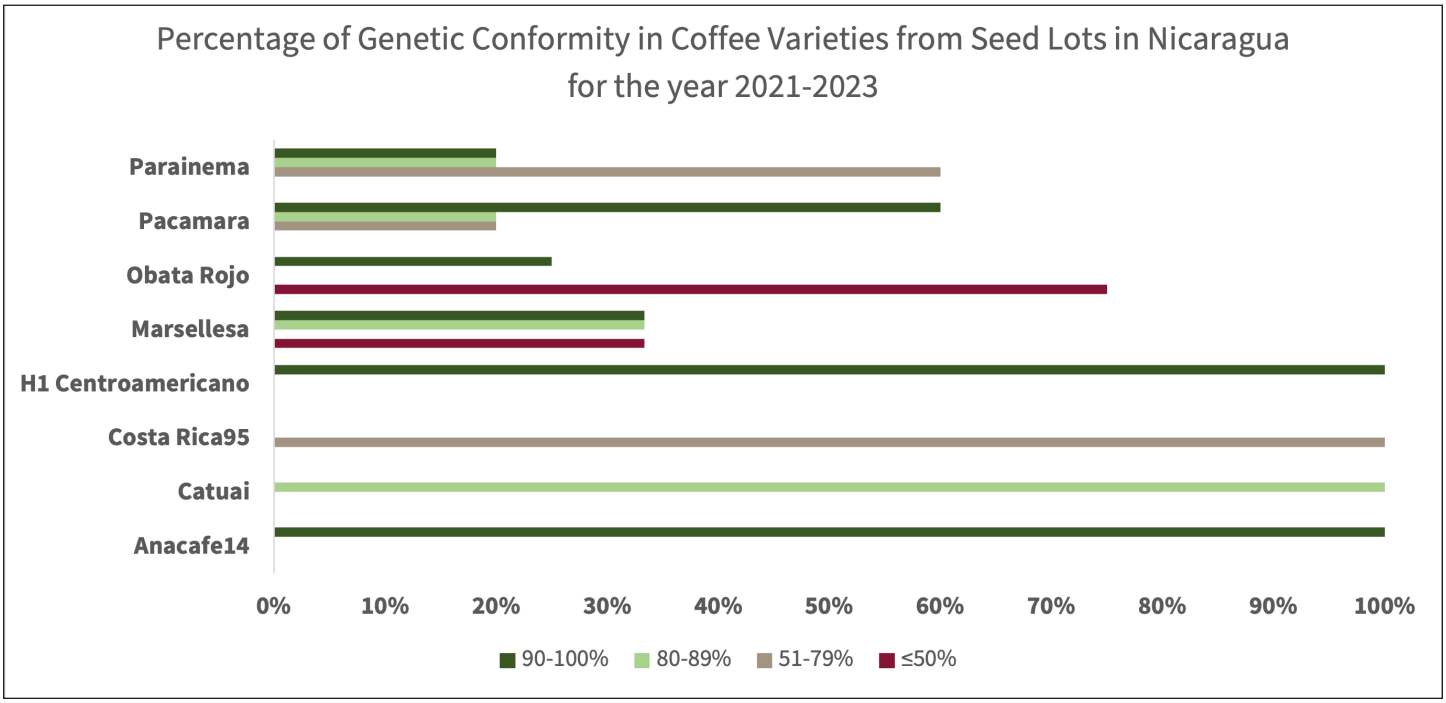
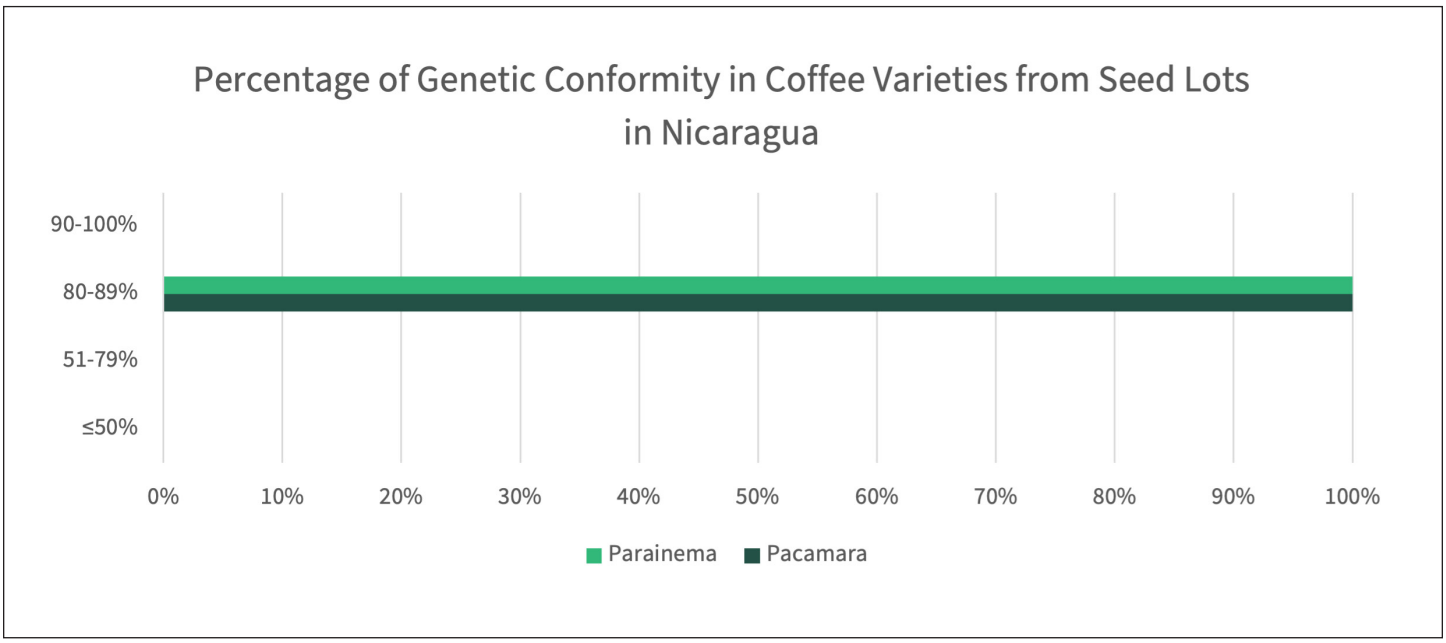


Figure 5. Level of genetic conformity in seed lot sources for CLU in Nicaragua



It was during this period of increased rust prevalence that producers became interested in new varieties with greater resistance while remaining focused on achieving cup quality and high yields. This led to the emergence of varieties from the Sarchimor group such as Marsellesa, developed in Nicaragua by Exportadora Atlantic of the ECOM group, as well as Parainema from Honduras, developed by IHCAFE. In the interviews conducted with seed producers of the participating 15 seed lots, they confirmed that the main quality producers seek is rust resistance, followed by high productivity and yields. However, some producers are also focused on obtaining cup quality—mainly those who export directly to roasters.

Even so, the first producers that introduced these varieties did not and still do not implement GAPs to maintain the genetic quality of materials, such as lot protection practices to avoid cross-pollination.

In the following figure, we observe the level of genetic conformity of the varieties represented in Nicaragua. Some varieties, such as Anacafe 14, have high genetic conformity (followed by the H1 Centroamericano), but for other varieties, such as Marsellesa, only

33% of the lots exhibited high conformity (90-100%), with others achieving 33% in a medium range (80-89%) and the remaining 33% demonstrating less than 50% of genetic conformity.

Only 20% Parainema seed sources in Nicaragua have of high genetic conformity (90-100%), while another 20% fall in the subsequent conformity range (80-89%), and a third group indicates that 60% of the sampled lots only comply with a conformity range of 51-79% of genetic conformity. This points to the conclusion that, even if highly conforming mother plants had been brought in at the beginning, the material has not been protected from contamination. This leads to a heterogeneous production with plants susceptible to rust and even cup characteristics that are not typical of the variety itself, but rather from crosses with other nearby varieties.

Due to this problem, it is necessary to perform a "genetic cleaning" of the varieties to achieve highly conforming plants that conserve the characteristics desired by the producers. It is important to mention that, during this process in Nicaragua, it was difficult to locate available producers who were willing to submit their lots to this process. Only two producers accepted, stating that they knew the origin of their plants. These producers obtained a conformity range of 80- 89%. In such cases, it is important to proceed to the elimination of plants and the protection of the seed lots with live barriers that prevent and/or reduce the contamination of the seed by cross-pollination in these plantations to increase the level of genetic conformity.

Main challenges and implications identified

According to those surveyed, seed production in Nicaragua is not a profitable business, since most producers obtain seed from their own farms, from a member of their community, or by bartering seed for cherry coffee. This, in their opinion, puts those producers who have been verified by IPSA and who comply with national seed production regulations Nicaraguan Mandatory Technical Standard 11-045-14 "Certification of Sexual Seed" at a disadvantage.

Some producers mention that as climate change has caused changes in temperature, relative humidity, and rainfall, the demand for the number of seed marketed has decreased, as producers have chosen to migrate to other areas of agricultural production. From the production characteristics described above, there are basic GAPs that are not being implemented (despite having received training and follow-up by private companies and the government), such as:

- The delimitation by means of physical barriers to reduce the possibility of cross-pollination with coffee varieties adjacent to the seed lot, or the planting of the seed lots at considerable distances from other plantations.
- Proper labeling of the plantations indicating which variety is being produced and the area and/or number of plants in the lot, which is especially useful during the harvest season to prevent coffee pickers from getting confused and mixing fruit from different lots.
- Differentiation of the de-pulping equipment for seed processing to avoid contamination with other seeds of different varieties or, failing that, a cleaning procedure to avoid contamination with previously processed fruit.

There is no nationwide training program for producers to raise awareness about the problem of informality in the seed sector and to explain the importance of having highly genetically conforming seed and its advantages in production. Additionally, training on the management and production of hybrid materials is something that producers are not very clear about, despite these materials being readily available in the country. More information and training are needed so that growers know that producing hybrid seedlings from seed is not a good practice because the characteristics of the mother plant are not preserved.

For the coffee seed sector, producing seed without imperfections that is highly conforming represents quality and prestige, and establishes certainty that producers have access to varieties with their desired characteristics. According to one of the growers from whom samples were collected, good seed in the future represents productive stability and cup quality, however, despite obtaining seeds from prestigious sites or producers in the trade (in an irregular, not traceable way), there is uncertainty about whether they really have the right material or the desired variety. He explained, "Since in many cases, we are assured we buy seed from a certain variety, but the cup quality and production correspond directly to attributes of another variety. In this sense, the genotypic analysis would confirm which is the variety we have."

According to the results obtained from the seed lots evaluated in different sites in Nicaragua, the cost of a kilogram of seed is around $20 USD. However, the variability of the genetic conformity found in the field represents a risk for the producer to lose this additional income, since many cannot guarantee a stable and profitable production.

GUATEMALA
Pages 24-28

Guatemala

Guatemala's coffee production has remained reasonably stable in the last decade, with a total of 3,835 thousand 60 kg bags reported in the 2009–10 harvest, whereas in 2018–19, the country reported 4,007 thousand bags of 60 kg (International Coffee Organization, 2020).

Another strength is that Guatemala has a national coffee institution: ANACAFE. This is a public service institution founded in 1960 that is autonomous from the government and operates with private funds. ANACAFE's main objective is to strengthen the national economy through the production and export of coffee, with activities representing the coffee sector at a national and international level. ANACAFE extends export licenses, develops, and executes the coffee regulation policy, and promotes Guatemalan coffee. This institution reports 125,000 coffee growers and 305,000 hectares of coffee production. The annual reported exports in the 2018–19 harvest totaled 3,550 thousand 60 kg bags, more than 80% of total production (ANACAFE, 2018).

Even though Guatemalan nurseries and seed producers have a series of advantages compared to other countries (e.g., a coffee institution that represents the sector and an established tradition of producing seed and seedlings), this sector still encounters many challenges. There is no official registration for all nurseries or seed producers operating in the country, although ANACAFE does have an estimated number from a study performed in 2008–2011 of the major nurseries and seedling producers in each region. Commercial nurseries are not organized or represented in a specific organization or institution.

The previous WCR/Enveritas survey from 2019–20 in Guatemala of 1,743 coffee growers indicated that 54% of them are planting new seedlings in their farms. However, since 43% of those farmers prefer to grow seedlings themselves instead of buying these from a commercial nursery, the demand is limited for commercial nurseries. Additionally, 89% of the growers that produce their own seedlings use seed from their own farm and not from national programs or other commercial sources, which also limits the demand of seed (Sources of Planting Material and Replanting Practices, 2019-2020).

The selection of varieties established by seed producers arises from the need for characteristics such as resistance to pests and diseases, mainly to rust (*Hemileia vastatrix*). Other important characteristics for producers include yield and cup quality, specifically in Guatemala, which is an origin that enjoys international recognition for its quality production. As a result, growers look for varieties with high cup quality potential to obtain better prices on the local and international markets.

Agronomic aspects of seed sources in Guatemala

Regarding the implementation of nutrition plans, the producers interviewed indicated that they usually apply calcareous amendments to manage soil acidity to allow the availability of nutrients to the plants at a rate of 200 gr/plant/year, which has a positive impact on the assimilation of nutrients by the plants and on production. Likewise, fertilization is mainly based on edaphic and not foliar nutrition, except for fungal applications to reduce pests and diseases such as coffee leaf rust and coffee leaf spot. Overall, the plantations were in good nutrition and phytosanitary conditions.

The altitude of the sites where coffee is produced is over 1,000 meters above sea level and is located at latitude 15.78 and longitude -90.23, so the solar radiation is not direct, and producers do not use very dense permanent shade. Producers implement permanent shade at a light density as it provides good nutrition that supports the vegetative needs of the plant, as well as the induction of good flowering and production. Among the most common shade species used in Guatemala are species that provide nitrogen, including Grevillea, and different species of Inga that allow the entry of light, planted at a density between 10m x 10m to 12m x 12m between trees.

The surveyed seed lots ranged in size from 1-6 hectares with distances of 0.5 meters between plants and 3 meters between rows; there are also lots with distances of 2mx1m and 1.2mx1.5m. The distances between rows tend to bring the plants closer together to facilitate the installation of drip irrigation systems for better yields. In general, seed producers report receiving direct training from ANACAFE on the management of seed lots and planting distances, as well as seed selection and processing to obtain high-quality seed (homogeneous, without imperfections). Likewise, producers associated with cooperatives such as Volcancillos and companies such as Volcafe have received training covering these topics.
Planting density relates to plantation yield since it influences the development of the plant and exposure to the sun, as having more space between plants encourages better development of branches. However, when producing seed, plant density within the lot is not the only factor to consider, but also the proximity to other plants from surrounding plantations. It is necessary to protect each seed lot with living barriers or forest strips that prevent contamination of the seed by cross-pollination from other materials. All visited lots had no separation of the sort.

Seed commercialization and traceability in Guatemala

According to the interviewed group of producers, each pound of seed typically produces 1,000 seedlings. The following table shows the potential seed production volume and the possible seed germination potential in the production of seedlings.

Regarding traceability practices, the seed or seedlings used to establish these seed lots were from reputable sources such as ANACAFE, Hacienda Buen Jardim in Brazil, and, in other cases, were obtained through financing from Nestlé to producers associated with Volcafe. Even so, producers mentioned that although there is some certainty regarding the origin, they do not have a certificate of genetic conformity of the plants received.

There is no mechanism and/or certifying entity for the material received (local or imported), and this is a very important piece in determining if the material really is of the variety that is expected to be produced and marketed. It is not sufficient to only rely on the reputation and prestige of a company or organization for this determination.

During the field visit, the lack of implementation of traceability practices was evident. The facilities lacked labeling of varieties in some farms (since the lots are located next to each other) and did not have live barriers, both of which risk cross-pollination between one lot and the next.

Regarding the commercialization of the seeds they produce, the producers mentioned that it is not a very profitable activity given increases in labor costs. The interviewees mentioned that the only way to make it profitable is by increasing the price for the customer, which would go from $10 USD per kilogram of seed to a "minimum of $12-15 USD per kilogram of parchment."

Table 9. Estimated seedling production potential of participating seed lots in Guatemala

Variety	Kg/seed	Seedlings Potential (Million)
Anacafe 14	1600	3.5
Parainema	5963	13.1
Pacamara	1250	2.7
Marsellesa	1800	3.9
Catuai	7000	15.4
Caturra	1500	3.3
Total		41.9

The common practice of many producers to save seed from their own coffee plantations causes a contraction of the seed market. This is a recurrent situation in the region, where growers traditionally have a preference to self-supply seeds, acquire seeds from informal systems, or even get them from other countries through unofficial channels.

Seed Lot Genotype Assessment

In March 2023, WCR staff collected samples from 14 seed lots of different varieties in Guatemala to conduct a genetic analysis of the varieties used by producers as a seed source. At the same time, interviews and on-site observations were conducted on the farms visited in the sector of Huehuetenango (San Pedro Necta), Baja Verapaz (Volcancillo), and Fraijanes in Guatemala in relation to seed production practices.

The varieties that were genotypically evaluated and produced were Anacafe 14, Pacamara, Marsellesa, Parainema, SL28, Catuai, Caturra,Tekisic and Maragogipe; a collection very similar to the varieties established throughout the country according to the Revista Fórum del Café 2018[8].

Table 10 shows the results obtained from the genotypic evaluation of the varieties described above and their respective locations. Based on these results, it is evident that the producers in the country have access to seed that has a low percentage of genetic conformity. Of the 14 lots, only two lots had a range of 90%-100% of conformity, and the majority reside in the subsequent range of (80%-89%) of conformity (see Table 11). Therefore, 85% of the lots evaluated lack good or excellent genetic conformity and there is great risk to the consumer who receives the seed as they may not be planting the variety they think they bought.

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Seed Lot Cleanup Activities: Key Findings in Guatemala

Throughout history, Guatemala's coffee has been described as unique (La Revista Forum del Café, 2018). About 90% of farms are located above 1300 masl, which guarantees unbeatable conditions for the cultivation of this product. Coffee is one of the country's main sources of income and Guatemala is one of the 11 main coffee-producing countries in the world (Central American Business Intelligence Report, 2021). Given the economic importance this crop represents for the country and producers, it is crucial to compare the variety characteristics producers need

Table 10. Results of the genetic conformity of different seed sources in Guatemala

No.	Variety	Location	% Genetic Conformity
1	H1	Fraijanes	96%
2	Anacafé - 14	Fraijanes	80%
3	Obatá	Fraijanes	0%
4	Tekisic	Fraijanes	20%
5	SL-28	Fraijanes	0%
6	Maragogype	Fraijanes	88%
7	Caturra	Fraijanes	4%
8	Catuaí	Fraijanes	80%
9	Parainema	San Pedro Necta, Huhuetenango	64%
10	Anacafe 14	San Pedro Necta, Huhuetenango	84%
11	Pacamara	San Pedro Necta, Huhuetenango	92%
12	Marsellesa	San Pedro Necta, Huhuetenango	56%
13	Parainema	Volcancillo, Baja Verapaz	80%
14	Marsellesa	Volcancillo, Baja Verapaz	84%

Table 11. Range of genetic conformity per number of seed lots in Guatemala

Range %	Range of conformity			
	≤50%	51-79%	80-89%	90-100%
No. Seed Lots	4	2	6	2
%	28.57%	14.29%	42.86%	14.29%

to maintain the currently expected level of quality and what the market has available. Likewise, it is necessary to highlight the differences between a variety that is resistant to rust and one that is not since growers are also interested in this trait due to climate change, rainfall, and temperatures that affect the crop.

According to the interviews conducted in Guatemala in the regions of Huehuetenango, Baja Verapaz, and Fraijanes, in general, producers are looking for highly productive varieties with resistance to rust and good cup quality. They desire these traits mainly to obtain better market prices given the window of opportunity that Guatemala presents at the international level as a quality producer (Central American Business Intelligence, 2021).

Most of the materials obtained by producers come from ANACAFE as it oversees the national coffee industry in Guatemala, but there is no documentation that fully confirms the genetic conformity of plants. There are materials that come through projects associated with cooperatives via Volcafe and financed by Nestlé; the sale of seedlings from recognized nurseries in the sector such as Popoyán, and other private producers. However, even though the material comes from reputable sources, there is no entity that verifies that the variety delivered is genetically compliant.

In the process of evaluating genetically compliant materials, WCR collected samples from 2020 to 2023 from 41 seed lots of 13 different varieties. In general, the ranges of genetic variability that exist among the varieties vary greatly. It is interesting to note that all Pacarama sources that were evaluated exhibited 100% genetic conformity, as did H1 Centroamericano. On the other hand, the Caturra variety had a conformity range of 90–100% in 75% of the lots, and 25% of the remaining lots exhibited a conformity status of less than 50%. In the case of SL-28 and Tekisic, genetic variation was quite high, presenting a conformity of less than 50% genetic conformity, indicating a degree of contamination for these varieties.

In the case of the varieties from the Sarchimor group (Marsellesa, Parainema, and Obata) about 27% of the samples presented a degree of conformity between 90-100% except for Obata, which presented a lower range of conformity between 80–89%, with 33% of the Obata samples being less than 50% genetically conforming.

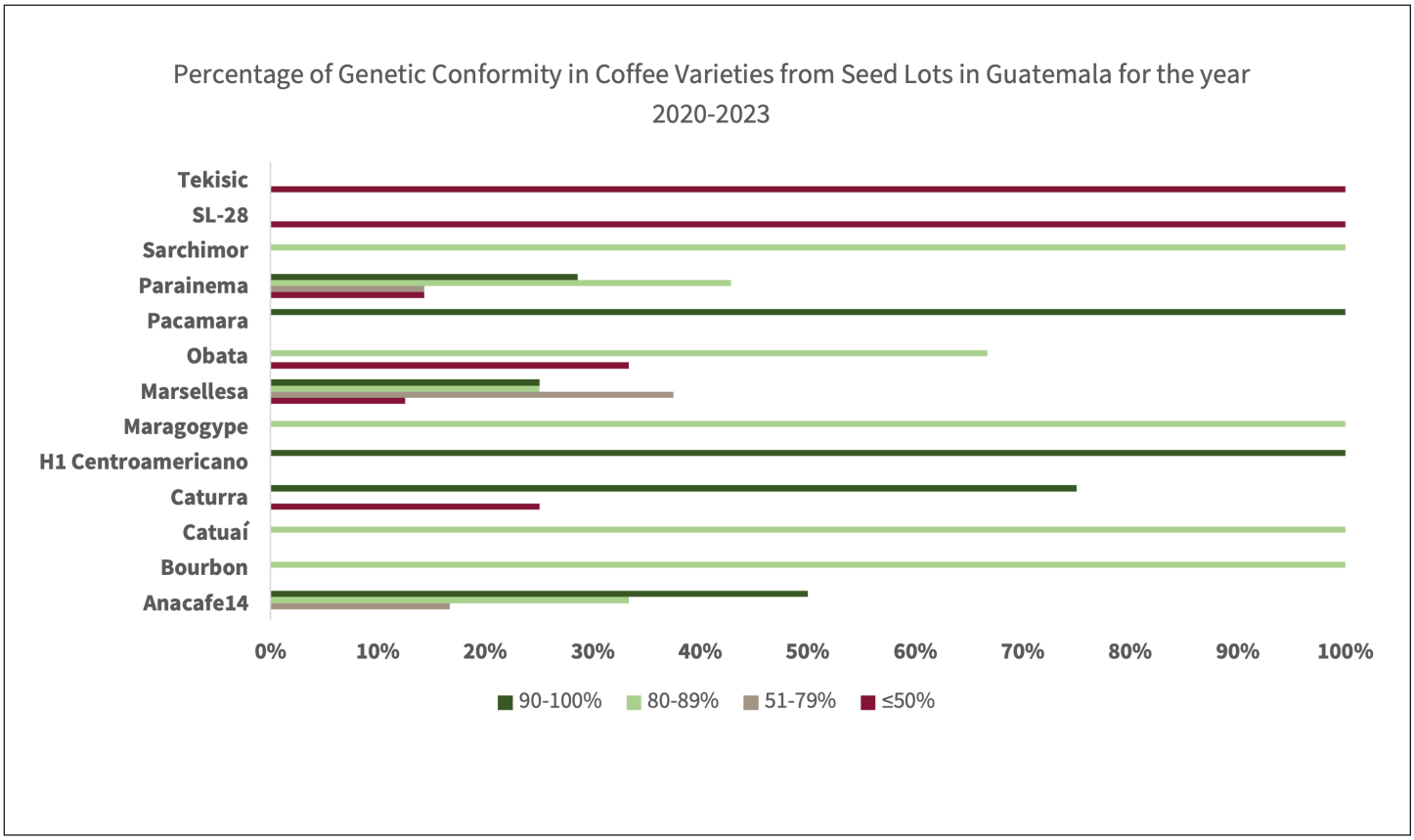
Even though the Anacafe 14 variety has been developed and distributed in Guatemala, only 50% of the samples (3 seed lots) fall in the high conformity range located between 90–100%. The rest lies in the lower range.

Overall, of the 41 seed lots sampled during the duration of MOCCA in Guatemala, the highest percentage of genetic conformity is in the 80-89% range, followed by 34% in the 90-100% conformity range (see Table 12).

To increase the availability of high-quality seed in the country, seed lot cleanup activities were implemented, particularly with the Anacafe 14 variety where 6,016 samples were collected in the seedling stage with the purpose of establishing a 100% conforming seed lot. From the samples, 95% of the seedlings were found to be Anacafe 14 and only these plants will be used to establish a new seed plantation, which will then have 100% genetic conformity. Although all trees in the new lot are genetically conforming, this does not guarantee that the seed distributed from the site will maintain this status, as maintenance will depend on good management practices for planting, traceability, harvesting, seed handling, and protection of the lot with live barriers to avoid contamination by pollen from another nearby varieties.

[8]Revista Fórum del Café, 2018. El café de Guatemala. http://www.forumdelcafe.com/noticias/cafe-guatemala

Figure 6. Level of genetic conformity found in seed sources in Guatemala



Main challenges and implications identified

Traceability practices to improve include the establishment of living barriers since producers do not consider the risks of cross-pollination or are unaware that, although the plant is self-pollinated, pollen can also cross-pollinate with another variety by wind, bees, and more. Likewise, plants within a seed lot should never be replanted with other varieties or with seed of an unknown origin. For example, in a particular case where samples of the Catuaí variety were to be collected, it became evident during the field inspection that the seed lot had already been replanted with Anacafe 14, which prevented the possibility of this being a conforming seed lot due to the high risk of genetic contamination between materials with different traits.

Table 12. Ranges of genetic conformity of seed sources in Guatemala

Range %	Range of conformity			
	≤50%	51-79%	80-89%	90-100%
No. Seed Sources	6	5	16	14
%	15%	12%	39%	34%

Most growers believe that *C. arabica* plants are exclusively self-pollinated (autogamous). While this is indeed the case for most flowers produced, there exists a percentage of flowers that do not self-pollinate and are instead commonly pollinated with another variety near the seed lot. Without the protection of living barriers or considerable distance between one variety and another, the percentage of these latter-type plants will increase. This is crucial for ensuring a seed production operation that guarantees all its marketed seeds are conforming. Another key factor for producing seed and establishing certainty of the variety produced is the traceable reference of the origin of the seed. Currently, as aforementioned, producers use the common saying, "It comes from a certain prestigious place," or "A farm where they manage quality," substituting reputation for official references.

In addition, it is important to maintain the labeling of the lots so that there is no confusion at the time of harvest or from personnel when indicating which plantation the seed comes from.

Overall, growers indicate that the genetic conformity of the plant is of importance since it ensures certain characteristics and qualities that are unique to each variety (e.g., highly productive, resistant to rust, good cup, etc.) are present. However, without

quality assurance tools readily available for growers, these qualities can only be observed and determined after two or three years when production begins. The material established by the producers cannot guarantee that it will reflect the characteristics of the progenitor plant of the seed since the seed could have been crossed with another neighboring variety and present other traits not desired by the producer.

Therefore, most producers doubt which variety is really being produced, which, in some cases, leads to growers making statements about the material such as “This variety is not useful or does not perform well,” or “This variety is more resistant to pests and diseases,” without knowing for sure whether the material obtained was the result of a cross-pollination with another variety and only now reflects characteristics that are not typical of the mother plant.

Due to the high variability of genetic conformity in the seed lots available to growers, most of the seedlings or seed acquired by growers represent a risk to their economic sustainability, as they do not have a stable yield nor produce the desired cup quality.

PERU
Pages 29-33

Peru

Seed production technology, particularly for coffee, is still underdeveloped in Peru. This is evidenced by the lack of identification of coffee seed materials, the lack of a protocol that certifies the quality of coffee seed, and the lack of manuals or training on coffee seed production. This dearth of information for adequate seed production, as well as of human resources trained in seed production, is another factor that delays the development of the national coffee sector (Borjas et al., 2023).

Prior to the rust epidemic in Peru (which occurred from 2012–2013), there was no regulatory framework in the country that specifically addressed coffee seed production. Given the devastation caused by rust in the Peruvian coffee sector, interest arose in using varieties tolerant to the disease. In many cases, these materials were brought from other countries. This, in combination with the implementation of a coffee plantation renovation program (PNRC-MIDAGRI), motivated the government to promulgate regulations for producing coffee seeds and seedlings and importing materials, among other regulations, that sought to support the coffee seed sector in the country, which are still in force to date.

Since 2020, the seed authority SENASA ("Servicio Nacional de Sanidad Agraria del Peru") has been in place to "regulate, promote, supervise, and oversee the activities carried out by the actors of the national seed system such as researchers, seed producers, certifying agencies, samplers and traders at the national level" (Borjas et al., 2023). INIA ("Instituto Nacional de Innovación Agraria") previously served as the seed authority, though SENASA had always overseen the generation of appropriate technologies for agro-industrial and agro-export crops, including coffee.

To date, the registers of both seed producers and coffee seedlings seem to be of limited accessibility since it is not easy to reach them through virtual means. In addition, the current format is difficult to interpret, as the general register for seed producers includes all crops, making it arduous to identify those that specialize in coffee. One of the most immediate ways to improve this system and decrease friction would be to facilitate access to information that already exists.

Coffee producers in Peru traditionally save seeds from their own farm, from neighboring plots, or from plots close to the production area, using mother plants that visibly show a better performance in the field than others, both in productivity and tolerance to pests, as criteria for selection. In some cases, they also utilize a reference of the cup quality of the plot.

A group of seed producers have formalized their operations by registering in SENASA's seed producers' registry and their production processes align with current regulations. In general, the producers registered with this mechanism are mostly individual producers and are leaders in their production area. In 2019, according to the registry of coffee seed producers managed by INIA, 96% of registered producers corresponded to private producers/companies (i.e., the participation of the private sector is predominant in coffee seed production in the country).

In 2019, there were 48 producers registered as coffee seed producers in SENASA's registration mechanism.

In regions such as Amazonas and Cajamarca (which are the main impact zones for the MOCCA program), innovation in coffee varieties and seed production is being promoted mainly by cooperatives representing the zones. Some of them have their own farms and directly manage the seed lots, and in other cases, it is the farmer members who manage the seed lots within their farms and the commercialization is done through the organization.

The geographic location of (formal) seed producers in the country is centralized in only 4 regions: Pasco, Junín, Cusco, and Cajamarca. Pasco, particularly the area of Villa Rica, is where 58% of the registered producers are located.

Thus, the presence of seed lots in the country is limited and concentrated in certain areas, since in Peru, coffee is produced in up to 17 regions and primarily in 12 of them, and according to the last agrarian census in 2012, there were 223,000 coffee growing families that manage 425,400 ha of the crop.

In addition, the "Plataforma Multiactor del Café de Cajamarca" analysis of the status of coffee seed production and supply in northern Peru (PMACC, 2023) noted that the supply of quality coffee seed is scarce and is characterized by the informality that prevails in the sector. It is only in the last decade that coffee plantations have been expanding to varieties formally imported into the country, thanks to private sector initiatives.

Agronomic aspects of seed sources in Peru

The size of the seed plots sampled varied from a hundred plants to sites of more than 1 ha. It is estimated that the smaller plots were installed as seed plots or as sites to observe the performance of a new variety at that time. According to the current Peruvian standard on coffee seed production, a seed lot must have at least 0.25 ha.

Many of the current seed plots were initially installed with the purpose of being commercial coffee production plots. Later, due to the good field performance of the variety and the growing demand for seed, the production of seed became an additional business on the farm.

Regarding the age of the lots, those sampled ranged from 2 to 10 years, with the majority being between 3 and 4 years old. According to Peruvian regulations for coffee seed production, a seed lot should not exceed 10 years of age.

Two trends were observed in terms of the variety chosen for seed lot production. Those farmers who leaned toward tolerance to rust and productivity typically chose the Sarchimor and Catimor group of varieties. Those that leaned toward cup quality typically chose varieties such as Caturra and Bourbon.

The seed lots were mostly in good condition and there were no generalized nutritional deficiencies of note nor incidence of pests or diseases at levels that affect production or jeopardize the quality of the coffee seed—denoting that they likely had a good nutrition and integrated pest management program. It is important to note that all seed lot owners have the support of an organization or had it at some point, in most cases a coffee cooperative.

Most seed lot owners worked with solid fertilizers applied to the soil, and in the case of foliar fertilizer applications, these were usually complementary or due to observation of nutritional deficiencies that needed to be corrected quickly. Liquid (drench) fertilizer applications were not mentioned.

The lots sampled were between 1,250 and 1,800 masl, with most of them above 1,500 masl. The Peruvian coffee seed production standard recommends that a seed lot should be installed above 1,200 masl. Currently, in Peru, coffee cultivation is recommended above 1,000 masl, and coffee plantations can be found up to 2,000 masl in some areas. Zones between 800–1,200 masl would be considered low-altitude areas, where the pressure of pests and diseases (such as coffee berry borer (CBB) and coffee leaf rust) is very high.

As for pest and disease management, the location of most of the lots was above 1,500 masl and therefore the severity of rust and presence of CBB was lower, and fungicide applications (organic or conventional) together with good agronomic practices were sufficient to prevent pests or diseases from causing damage above the economic threshold. Usually, the sites visited included some organic farming practices (e.g., use of permitted products for pest and disease control, organic fertilizers) and conventional farming (e.g., fertilizers) in their crop management practices.

Since most of the sites were located above 1,500 masl, the recommended shade level was lower due to the light, temperature, and humidity conditions found in these areas. The shade level was between 0–20%, and usually, more than one shade species was found in the coffee seed lots. The most common permanent shade species were leguminous plants (mainly of the genus Inga sp.), pines, and other native species.

The density of the lots ranged from 3,333 to 5,556 plants per hectare, with the most common spacing being 2x1 m. The tall varieties typically had lower densities and, in the younger lots, wider spacings had been implemented in the rows and smaller spaces between plants (3x0.7 m, 2.5x0.8 m).

Table 13. Estimation of seedling production potential in participating seed lots in Peru

Varieties	Area (ha)	Potential seed production per year (kg)*	Potential area for renovation per year (ha)**
Obata (red)	0.250	112.500	56.25
Obata (yellow)	0.100	15.000	7.50
Oro Azteca	0.250	112.500	56.25
Red Bourbon	0.125	15.000	7.50
Yellow Bourbon	1.050	488.925	244.46
Costa Rica 95	0.250	112.500	56.25
Catisic	2.250	1,026.000	513.00
Pacamara	0.250	165.000	82.50
Yellow Caturra	2.500	480.000	240.00
Total	**7.025**	**3,797.000**	**1,263.70**

*Potential seed production per year = estimated based on the productivity data provided by the seed lot owner of which it was considered that 30% of the total production of the lot could be used for seed.
**Potential area for renovation per year = it was considered that 2 kg of seeds are required for planting 1 ha of coffee.

Seed commercialization and traceability in Peru

In the case of traditional varieties such as Bourbon and Caturra, the origin of the seed is generally the same farm or a nearby area, so the initial origin of the seeds is unknown. In the case of newer varieties for coffee growers (Sarchimors, some Catimors), several of these seed lots are managed by organizations and have been imported—mainly from Central America—so, in most cases, there is documentation that proves the origin of the seeds. In other cases, INIA has provided the seed to the producer.

The interviewees indicated that most of their clients are producers who establish direct contact for the purchase of the seed; in the case of organizations (cooperatives) that manage seed lots, most of their clients are members of the same organization. Another important type of client for these organizations are other cooperatives and associations of seed producers.

Based on the information provided by the owners of the seed lots in the interviews in 2023, the potential production of coffee seedlings per variety was estimated (see Table 13), taking into consideration the productivity of each seed lot.

In the plots managed directly by organizations (cooperatives), traceability practices such as labeling—both in the field and in the warehouse—were mostly implemented. However, the sites managed directly by producers lacked labels identifying the plot and the application of other types of traceability practices could not be verified. Since most of the plots were not initially installed for seed production purposes, most of these sites lacked a clear delimitation from other plots and were not sufficiently isolated to avoid cross-pollination with neighboring plots of other varieties.

Seed Lot Genotype Assessment

Four coffee seed lots had more than 90% genetic conformity (see Table 14). However, another 4 lots did not correspond at all with the variety the owner identified them as. This represents a very high risk for the Peruvian coffee sector, as there may be a large percentage of farmers who acquire seed of varieties that do not exhibit the expected characteristics in the field or cup that they were seeking.

Seed Lot Cleanup Activities: Key Findings in Peru

In Peru, most coffee plantations are planted with varieties of the Catimor group that cover an estimated 70-95% of the area, depending on the coffee-growing region. This growth in Catimor group varieties began after the rust epidemic in the country, between 2012 and 2013. A large percentage of producers prefer these varieties, given their tolerance to the disease, their favorable levels of productivity, and their wide adaptability to the climates of coffee-growing areas in Peru.

However, many producers and even technical teams cannot identify which specific variety of the Catimor group is present on coffee farms, likely due to the lack of a formal seed sector. Of the coffee plots that can identify the variety in this group, some state they have Costa Rica 95, and some who claim to have Colombian varieties that presumably entered in a non-formal manner. Among these are Castillo and Colombia.

Table 14. Results of genetic conformity in participating seed lots in Peru

No.	Variety	No. of plants in lot	Lot area (ha)	% Genetic Conformity
1	Costa Rica 95	800	0.25	100%
2	Red Bourbon	400	0.125	0%
3	Oro Azteca	800	0.25	91%
4	Pacamara	800	0.25	0%
5	Red bourbon	500	0.25	0%
6	Yellow Caturra	2000	0.50	92%
7	Yellow Caturra	3000	1.00	96%
8	Yellow Caturra	3000	1.00	0%

After the rise of Catimor varieties across Peru's coffee sector, criticism began to emerge (the strongest coming from organizations representing the national coffee guild) regarding its cup quality. In general, cup quality is not one of the outstanding characteristics of Catimor varieties and, at the time, this was seen as damaging to the image of Peruvian coffee. Therefore, a reevaluation has begun of varieties that are susceptible to coffee leaf rust, such as Bourbon and Caturra, which, on average, have a better cup quality than the Catimors. There is also interest in varieties that are highly recognized at a global level for this characteristic, such as the Geisha.

Currently, the production of varieties with high cup quality is concentrated in zones above 1,500 masl, where the incidence of coffee leaf rust is lower. However, most coffee growing continues to be located between 1,000 and 1,500 masl, and it is here where there is still a preference for cultivating varieties that are tolerant to rust and have good productivity, which is essentially what the average Peruvian producer is looking for.

Faced with this situation, some organizations have taken the initiative to bring materials from other countries. Among those that are being adopted in good proportion are the varieties of the Sarchimor group. The most common varieties in the northeastern zone of the country (Cajamarca and Amazonas) are Marsellesa, Parainema, and Obata. In addition, varieties such as Cuscatleco and Tupi can be found with some frequency, especially in the Central region (Junin and Pasco). These varieties are considered to be good options for coffee growers looking for productivity, tolerance to rust, and, on average, better cup quality than the Catimor group.

Table 15. Seed lots participating in Cleanup activities in Peru

No.	Variety	No. of plants sampled in lot	Lot total area (ha)	Type of sampling	% Genetic conformity
1	Marsellesa	1034	1.00	Foundation lot	94.39%
2	Parainema	1974	1.00	Foundation lot	89.72%
3	Marsellesa	940	N/A	Nursery	93.30%
4	Obata (red)	470	0.125	Census	0.00%
5	Parainema	1034	0.25	Census	91.30%
6	Costa Rica 95	564	0.25	Foundation lot	90.78%

The seed lots in Peru were generally not planted with the exclusive purpose of producing seeds or, at least, this was not the initial objective when establishing the plantation. Rather, they were coffee production plots for varieties that showed good field performance and whose harvests were later, in part, sold as seed. Therefore, many of these lots did not meet the technical criteria for seed production at the time of establishment, such as barriers to avoid cross-pollination or isolation of the lot from other plots. It is likely that this type of information was not known by the technical teams at the time since coffee is typically considered to be self-pollinating.

Some seed lots have better technical management and implement some GAPs for producing coffee seed. Usually, these are located within farms managed directly by cooperatives, which have consistent technical support and for whom the strengthening of the seed sector is essential for the sustainability of coffee production.

As interest increased in the introduction of varieties of the Sarchimor group, starting in 2017, cooperatives initiated the establishment of plots of these varieties. Among them were plantations with an orderly design, clear demarcation between lots, and even signs that identified them, which facilitated sampling and will also facilitate cleaning.

The sampled lots (see Table 15) correspond to varieties that are in good demand in the seed market in the respective areas where the cooperatives that participated are located. All these varieties stood out for their productivity potential and tolerance to rust, and, except for Costa Rica 95, all belong to the Sarchimor group. As for the results, it is worth noting that all the lots, except those containing red Obata, possessed previous information on genetic conformity in samples of 20 plants per site. In the case of nursery plants, it was known that the origin of the seed was from the breeder, so it was assumed that the correspondence would be high.

The results indicated that 5 of 6 lots tested had a percentage of conformity between 89% and 94%, which indicates that contamination within the lots is relatively low, and that the elimination of non-conforming plants is viable and will not cause significant economic losses. In the case of the red Obata lot, for which there was no previous information regarding its conformity, none of the plants corresponded to the variety. This shows the importance of having previous information on a lot before starting work that requires a major investment, such as seed lot cleanup.

The constant use of seeds from the farm itself or from nearby farms that are not managed with technical criteria for seed production causes producers to plant their farms with material that does not have the desired genetic traits, as there is a reasonable probability that some of them are the result of cross-pollination. Oftentimes, the choice of mother plants without supporting documentation or evaluation of genetic correspondence causes the propagation of seeds that reproduce plants with traits far different from those expected from the variety.

This has likely happened with the population of the Catimor group, of which seeds have been constantly reproduced from farm to farm, resulting in the loss of characteristics such as tolerance to rust. It is important to note that loss of this characteristic may also be a natural occurrence as pathogens evolve and exert greater pressure on the crop, but the process is accelerated with the use of genetically inferior materials.

Main challenges and implications identified

There is low demand for coffee seed at the local and national level in Peru and a level of informality in the coffee seed sector. The practice of producers using seed from their own farms is still very common, so the importance of using seed from accredited seed production lots needs to be disseminated and underscored. Although there is already a certain percentage of producers that buy seed, a good part of this group buys it from producers that are not registered with SENASA and resort to unauthorized marketing. These producers are acquiring material of dubious origin, with a high risk that these plants will not perform as expected.

Changing trends in the coffee market affect producers and cooperatives greatly. According to the areas where sampling was carried out (Amazonas, Cajamarca), the current local trend in the coffee market is toward coffees with high cup quality, which leads producers to buy seeds that are marketed with this characteristic. In many cases, seed producers who started their activities before 2020, when the trend toward rust-tolerant varieties was more predominant, have seen a reduction in their sales.

Importing new varieties is very common. Since the country does not generate its own varieties from breeding processes carried out by research institutions, several organizations in the sector need to innovate to meet the varietal needs of farmers and could take advantage of advances in other countries in Latin America.

There is also a lack of quality control tools to verify genetic conformity. Current management of seed lots does little to guarantee the genetic conformity of the variety produced.

Some interviewees noted one challenge is the establishment of regulations for variety registration. in accordance with. In this regard, Borjas et al. (2023) indicate that, in the case of coffee, there is no production of certified seeds because there is no specific standard as there is for cotton, quinoa, rice, grain legumes, corn, potato, and cereals. Therefore, the coffee seeds marketed are non-certified seeds. There is no protocol that certifies the quality of these seeds even when they are declared to a competent authority. All lot owners interviewed agreed that seed production is a profitable activity since the sale price is at least 4 times the price paid for commercial parchment coffee. Some of them say that the sale value should be around $45 USD to be considered profitable.

KEY FINDINGS
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DNA Authentication of Varieties: Key Findings

While the previous section focused on country-specific results, the information below looks across countries. High levels of conformity were most prevalent in El Salvador (49% of seed sources scored 90% or higher). Comparatively, the cases of Honduras and Peru are interesting as it seems most seed sources in these countries either score higher than 90% or below 50%. This indicates that many growers either have access to higher genetic quality seed or none, with little in between, depending on who they source their seeds from.

Based on the results obtained from the seed lot assessment and cleanup activities conducted in 2023, we observed a notable difference in compliance percentages. Specifically, the cleanup activity exhibited a 16% higher overall compliance rate than the compliance percentages observed in the seed lot assessment (see Figures 13 and 14), which was to be expected as all seed sources selected for cleanup activities were previously filtered as candidates for higher conformity levels.

The Marsellesa and Pacamara varieties had the highest percentage of compliance in the cleanup activity at 94%. However, the number of samples genotyped for these two varieties was relatively low, with 1,974 for Marsellesa and 940 for Pacamara, in contrast to the substantial sample size of 15,596 for Anacafe 14. The overall percentage of compliance of Anacafe 14 was 83%, with Guatemala having the highest percentage of compliance at 95% (see Figure 14).

Conversely, the cleanup activity revealed that the varieties CatiguaMg2 and Obata had the lowest compliance percentages, both registering at 0%. The sample sizes for these two varieties were also comparatively smaller, with 1,222 for CatiguaMg2 and 470 for Obata (see Figure 15). A compliance rate of zero suggests that these two varieties do not match the claims made by nursery producers and that the seeds used to propagate these varieties were not properly obtained and managed.

The SLA revealed that, on average, the compliance rate was 53%. It's noteworthy that certain varieties, such as H1-Centroamericano, exhibited remarkably high compliance rates, reaching as high as 99%. This exceptional level of compliance in H1-Centroamericano can be attributed to its clonal propagation method, which highlights the distinction between varieties propagated from seeds and those propagated clonally. Among the seed-propagated varieties, Oro Azteca had the highest compliance rate at 91%. However, many varieties fell within the range of 60-70% compliance (see Figure 15). We also observed, yet again, that certain varieties had a compliance rate of zero, including Bourbon, CatiguaMg2, and SL28. Additionally, varieties like Caturra (4%) and Tekisik (20%) exhibited notably low compliance rates (see Figure 15).

Figure 14. Percentage of genetic compliance for the cleanup activity conducted in 2023

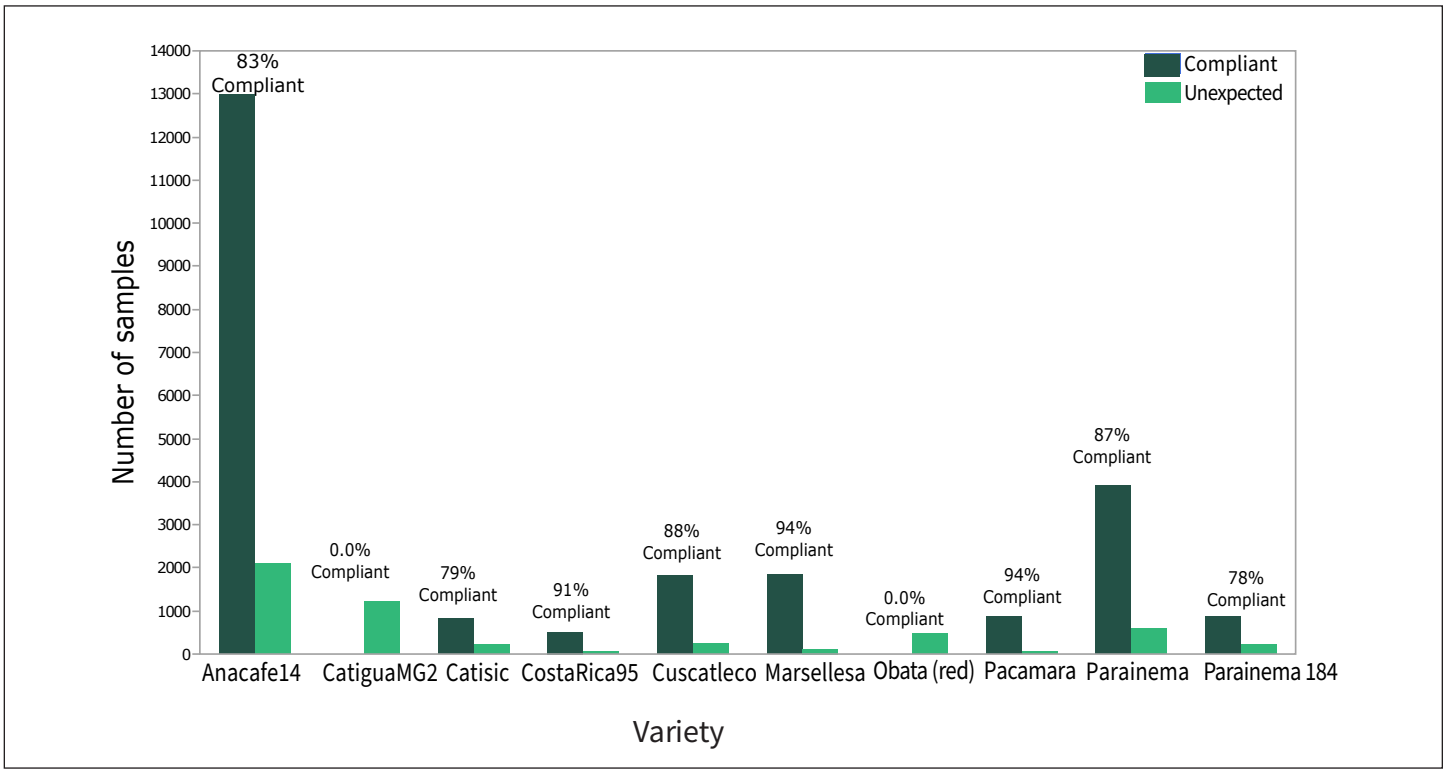
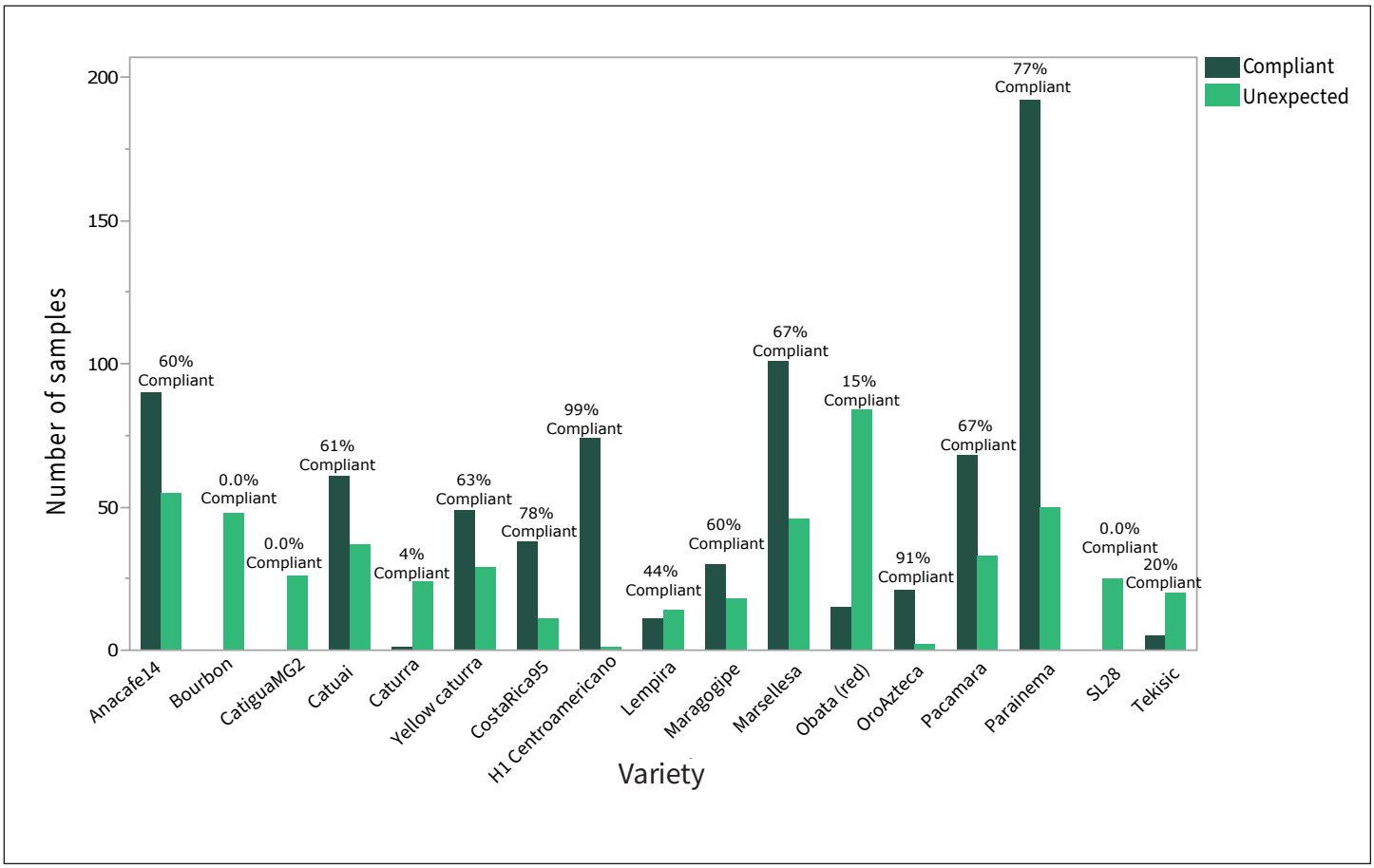


Figure 15. Percentage of genetic compliance for the seed lot assessment conducted in 2023



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Annexes

Annex 1. Farmer Survey used in Seed Lot Assessment activities

1. What is the name of the farm?
2. What is the name of the producer?
3. Is the entire farm dedicated to coffee production?
4. What is the size of the seed lot in hectares?
5. What is the seed lot planting density?
6. What variety of seed is produced?
7. How many kg of coffee are produced in the lot?
8. How many kg of the lot production is sold as seed?
9. Does the farm itself process its own seed? (micro-benefit module, etc.)
10. Where did the seed used to plant the lot come from?
11. How many years has the lot been planted?
12. Has the lot been renovated?
13. Where did the plants for the renovation come from?
14. Do you use certified seed?
15. Who is your main buyer of the seed?
16. Does the farm also have nursery production?
17. Why did you choose to plant that variety?
18. Do you have to meet any requirements to be a seed producer? If yes, what are they (registration with any authorities, special permits, government visits, etc.)?
19. Are you part of any kind of cooperative or producer association?
20. If you belong to a producer association or organization, are there any training programs in seed production management?
21. What are the main challenges you face as a seed producer?
22. Do you consider the seed production business to be profitable?
23. During the visit, which of these practices are observed in the seed production lot?

    • Good nutrition program (no nutritional deficiencies).
    • Good Integrated Pest Management (no diseases or pests affecting production).
    • Implementation of traceability practices (labeling lots, trained personnel, clear demarcation, etc.).

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