WORLD COFFEE RESEARCH

PROMECAFE
Por el Desarrollo de la Caficultura Regional

GOOD PRACTICE GUIDE

COFFEE NURSERY MANAGEMENT

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WORLD COFFEE RESEARCH

10940 SW Barnes Rd #334

Portland, OR 97225

www.worldcoffeeresearch.org

This guide was developed in consultation with experts from across Central America and the Caribbean, with special thanks to the following contributors:

Philippe Courtel (ECOM-Nicaragua)

Emilie Dardaine (Fundación CIMS)

Melissa Menocal (Fundación CIMS)

Henry Vilchez Lara (ECOM-Costa Rica)

And the following reviewers:

Francisco Anzueto – Scientific Coordinator Central America – WCR (former)

Stephen Cox – Director of Strategic Alliances – NSF

Frederic Georget – Researcher – CIRAD

Mario Mendoza – General Manager – J. Hill and Company

Christophe Montagnon – Chief Scientific Officer WCR – (now RD2 Vision)

Carlos Mario Rodríguez – Director Global Agronomy - Starbucks

Paulo van der Ven – RD2 Vision

Miguel Barquero Miranda - ICAFE

Rafael Alberto Velásquez Orozco - ANACAFE

Arnold Pineda - IHCAFE

Emilia Umana - WCR

Design:

Irene Issa El Khoury

Fabian Porras

ABOUT THE GUIDE

The investment coffee farmers make in planting new plants has long-term implications and includes a significant opportunity cost at the time of planting. It is essential for farmers to make sure not only that they are selecting the right variety, but also that the seeds/seedlings they are planting are all of their chosen variety, and that each one has the best physical and phytosanitary quality to attain its highest production potential.

World Coffee Research (WCR) and a network of collaborators have created two guides: one on the production of coffee seed and one on nursery management. These are intended to (1) help reduce the risk coffee farmers face when buying seed/seedlings and (2) encourage planting of healthy plants to ensure growth and future production. These guides are intended to attain two key goals:

Plant Health resulting from healthy, strong seedlings reaching their maximum potential yield with a minimum mortality rate of seedlings planted. In this regard, the guides focus on describing appropriate seed production and nursery management techniques with good agricultural practices at each stage.

Genetic Purity of the material, so that farmers may be confident that they are planting in their fields the variety they chose, with desirable genetic characteristics and no risk of cross-pollination. To do so, the guides include specific portions on traceability, ranging from the purchase of seeds or plants to produce mother plants to the sale or planting of the seeds or plants produced.

The guides complement the WCR *Arabica Coffee Varieties* catalog describing the characteristics of over 50 different varieties and allowing coffee farmers to select the optimum varieties for their farms. The catalog is available at https://varieties.worldcoffeeresearch.org

These guides and catalogues contribute to a broader effort to strengthen and professionalize the coffee nursery industry, born of a common desire to reduce the risks faced by coffee producers by improving the quality of plants available to them.

Such efforts must include technical support for the renewal and renovation of coffee plantations, training, improved access to credit, among other factors. In the long term, the professionalization process is expected to result in lower risk for all involved in the coffee value chain: from growers to buyers.

This coffee nursery management good practice guide is intended to serve as a useful tool for nursery owners, managers, and technicians, helping them identify ways to improve their practices for excellent results. It highlights critical steps and factors applicable in most producing countries. It is not intended to serve as a comprehensive guide to nursery management as this requires much more detail and adjustment to context.

Some practices are shown under different levels of technical development as follows:

Gold level stands for excellent practices.

Silver level stands for good practices.

Bronze level stands for basic practices, usually requiring minimal investment.

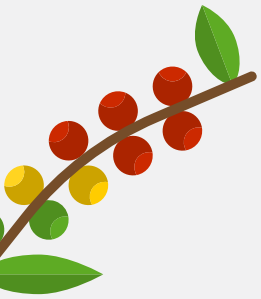
MODULE 1

COFFEE VARIETIES

MODULE 1 - CONTENTS

INTRODUCTION

Selecting what variety to plant is **one of the most important decisions** farmers face. Good varieties can ensure future production over the productive life of the tree (20-30 years), while poor varieties can "lock in" poor production for decades. Each variety is suited for different conditions and farming approaches. Factors to consider include:



- Productivity/yield potential
- Disease resistance
- Cup quality potential
- Plant size (tall/dwarf)
- Year of expected first harvest
- Overall vigor

To analyze in detail the characteristics of different varieties and make a decision about which variety to purchase according to the needs of each farm, see https://varieties.worldcoffeeresearch.org

A summary of diverse varieties with critical points is given below.

Table symbols:

Quality potential shown

Poor ☕☕☕☕☕ Exceptional

Yield potential

Low 🫘🫘🫘🫘🫘 Very high

Nutritional requirements

Low demand NPK NPK NPK High demand

Susceptibility

Resistant
Tolerant
Susceptible

VARIETY	QUALITY POTENTIAL SHOWN	YIELD POTENTIAL	YEARS TO FIRST HARVEST	NUTRITIONAL REQUIREMENTS	SUSCEPTIBILITY: COFFEE RUST	SUSCEPTIBILITY: ANTHRACOSIS	SUSCEPTIBILITY: NEMATODES
CATIMOR 129	☕☕☕	🫘🫘🫘🫘🫘	2	NPK NPK NPK	🟢	🟢	🔴🔴🔴
GEISHA (PANAMA)	☕☕☕☕☕	🫘🫘	4	NPK NPK NPK	🟡🟡	🔴🔴🔴	🔴🔴🔴
JAVA	☕☕☕☕	🫘🫘	3	NPK NPK NPK	🟡🟡	🟡🟡	🔴🔴🔴
ANACAFE 14	☕☕☕	🫘🫘🫘🫘	2	NPK NPK NPK	🟢	🔴🔴🔴	🔴🔴🔴
BATIAN	☕☕☕☕	🫘🫘🫘🫘	2	NPK NPK NPK	🟡🟡	🟢	🔴🔴🔴
CENTROAMERICANO (F1 HYBRID)	☕☕☕☕	🫘🫘🫘🫘🫘	2	NPK NPK NPK Very high	🟢	🟡🟡	🔴🔴🔴
K7	☕☕☕	🫘🫘🫘🫘	3	NPK NPK NPK	🟡🟡	🟡🟡	🔴🔴🔴

VARIETY	QUALITY POTENTIAL SHOWN	YIELD POTENTIAL	YEARS TO FIRST HARVEST	NUTRITIONAL REQUIREMENTS	SUSCEPTIBILITY		
					COFFEE RUST	ANTHRACOSIS	NEMATODES
MARSELLESA	●●●○○	●●●●○	2	NPK NPK NPK	●○○	●●○	●●●
MILENIO/H10 (F1 HYBRID)	●●●●○	●●●●●	2	Unknown	●○○	●●○	●●●
MUNDO MAYA/EC16 (F1 HYBRID)	●●●●○	●●●●○	2	NPK NPK NPK	●○○	●●○	●○○
OBATÁ ROJO	●●●○○	●●●●○	3	NPK NPK NPK	●○○	Unknown	Unknown
POP3303/21	●●●○○	●●●●○	2	NPK NPK NPK	●○○	●●○	Unknown
RAB C15	●●●●○	●●●●○	2	NPK NPK NPK	●○○	●○○	Unknown
RUIRU 11	●●●○○	●●●●●	2	NPK NPK NPK	●●○	●○○	Unknown
STARMAYA (F1 HYBRID)	●●●●○	●●●●○	2	NPK NPK Mid-sized demand	●○○	Unknown	Unknown

Investing in a variety that is poorly suited to the farmer's needs can result in years of low productivity, damage from pests, and low or no profit from the plantation.

If the nursery engages in selling seedlings, it must select the seedlings to be produced in line with potential customers' needs and characteristics. In other words, it must take into account criteria such as altitude, the climate/weather conditions, disease prevalence, harvest time, and so on.

Some factors to be known about coffee varieties are explained below. A better understanding about coffee varieties and how they grow is part of coffee growers' background and allows them to understand better the recommendations about varieties made by local agronomists and organizations.

A. TRADITIONAL VARIETIES

HISTORICAL SUMMARY OF COFFEE VARIETIES

Coffee plants originated in Africa. Two major species exist, *Coffea arabica* and *Coffea canephora* (also called Robusta).

From a business standpoint, *C. arabica* enjoys better reputation and cup quality. It stands for about 62% of world production.

C. canephora is a more hardy shrub with better resistance to disease. It is used mainly for blended coffee or instant coffee. Its production cost is lower than that for *C. arabica* due to its rusticity and higher productivity.

Coffea canephora

It is a strong shrub growing up to 3 meters tall, blooming irregularly. Flowers take up to 11 months to mature and result in oval fruits. It has better yield (higher productivity per hectare) than *C. arabica*, but with a more bitter and acidic taste.

Coffea arabica

Currently, more than 80% of the world production of Arabica coffee comes from Latin America. The genetic basis of Arabica coffee brought into Latin America in the 19th century is limited to two slightly different populations (Bourbon and Typica). Bourbon and Typica compose the most culturally and genetically important groups of *C. arabica* coffees in the world.

Bourbon lineage

1. Taken from Yemen to Bourbon Island (now La Reunión) in early 1700s.
2. Taken to Africa from 1840 on.
3. From Africa it was taken to Brazil in 1860 and from there in spread to Central America.

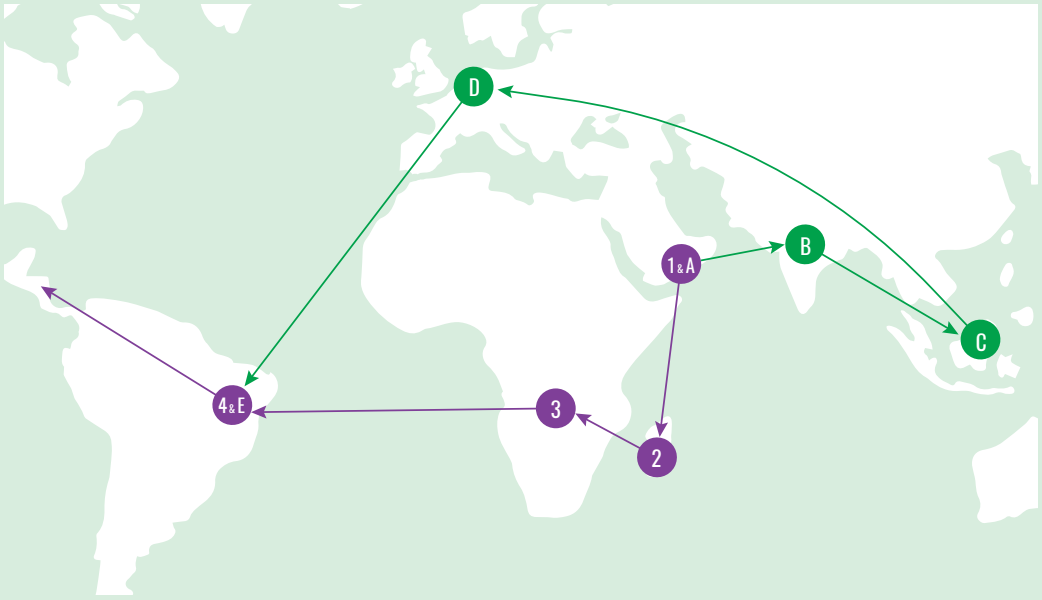
Typica Lineage

A. Taken from Yemen to India starting in 1600.

B. Sent from India to Indonesia.

C. From there coffee shrubs were sent to The Netherlands in 1720 where reproduction and selection took place.

D. Later they were brought to Suriname, French Guyana, and Brazil. Then to the rest of South America and Central America.



Until the 1940s, most Central American plantations consisted of Typica. Since this is a low-yielding variety highly susceptible to most coffee diseases, it was gradually replaced in many regions in the Americas with the Bourbon variety. However, significant Typica plantations still exist in Peru, Jamaica, and the Dominican Republic.

EVOLUTION OF COMPACT STATURE MATERIALS SELECTION

FIRST STAGE:

During the Green Revolution in the 1950s, researchers created varieties/lines adapted to crop intensification, with excellent cup quality. These included the **Caturra and Catuaí** varieties, with compact stature (different from the tall stature typical of wild *C. arabica*) and good organoleptic quality, but susceptible to coffee rust.

SECOND STAGE:

In view of coffee rust, the resistance of *C. canephora* was transferred to improved Arabica varieties. A natural cross between *C. arabica* and *C. canephora* resulted in the rust-resistant **Timor hybrid**, which became the basis for a worldwide program to create "introgressed" rust-resistant Arabica varieties, resulting in two main groups of resistant varieties called **Catimors** and **Sarchimors** (+ **Colombia**). This research was led by the Centro de Investigacao da Ferrugem do Cafeeiro ([CIFC] in Oieras, Portugal. Multiple varieties resistant to several diseases such as coffee rust were obtained and released in the 1990s, although their cup quality is typically lower than recent standards.

THIRD STAGE:

From 1990 on, with market demands for higher quality and advances in biotechnology, a new type of variety began to be developed: F1 (first-generation) hybrids. A collaborative breeding proram was launched in Central America between PROMECAFE, CIRAD and CATIE. F1 hybrids were created by crossing wild African Arabicas (with good organoleptic quality) and improved introgressed varieties (productive and resistant to coffee rust). They were selected for high adaptation to agroforestry agriculture. After 20 years of experiments in controlled environments or at growers' farms, F1 hybrids are producing 30-40% more than the best fixed-line varieties in agroforestry systems, with good organoleptic quality, early maturation, and good response to coffee leaf rust.

Growers are encouraged to plant/renew their farms as much as possible with improved varieties resistant to coffee rust (varieties derived from the Timor hybrids) or with F1 hybrids to ensure their environmental, social, and above all economic sustainability.

B. IMPROVED VARIETIES

VARIETIES/LINES

WHAT IS A VARIETY/LINE?

In plant breeding, a "line" is an individual or group of individuals descending from a progeny by self-fertilization, which is homozygous. Homozygocity means that each allele of a given gene encodes the same information. Alleles can be either dominant or recessive.

In other words, it is a lineage continuously keeping constant characteristics through generations of sexual reproduction, either by self-fertilization or by cross-fertilization with other plants in the same line.

There are different variants of varieties or lines. These are called:

- **Pure-line,** when they come from a progeny by self-fertilization of the same variety
- **Fixed-line**, in the case of a pure line that has passed through several generations (typically 8) of self-fertilization, such that the variety is stable from one generation to the next (segregation <1%)
- **Composite**, if a mixture of lines takes place (examples inlude: Castillo, Batian)

HOW ARE LINES OBTAINED?

Lines are obtained through selection of the best plants in a given generation (with the characteristics growers wish to perpetuate, such as productivity, organoleptic quality, bean size, and resistance to rust), while eliminating lower-performing or non-conforming individuals from the population.

REPRODUCTION

The best plants are selected as described above, and then reproduced by seed. Only the most interesting individuals obtained are conserved and reproduced again. The same is done with the new generation, and so on. In order to create a "fixed" line, the process can take 8 - 9 generations or 20-30 years. This type of selection results in lower vigor due to successive self-fertilizations carried out over time (consanguinity), but it increases homozygosity. Once you have reached eight generations of self-fertilization (F8), a very low percentage of segregation (heterozygous variants) is obtained, around 1%.

Only uniform varieties (homozygous, fixed pure lines) should be reproduced by seed, such that the resuling offspring have the same characteristics as the mother plant. For more details, please see WCR's *Good Practices Guide: Coffee Seed Production*.

VARIETIES/LINES - ADVANTAGES

- Lower cost of reproduction
- Increased accessibility for small and medium-sized farmers to reproduce the variety
- Well-managed reproduction technology

VARIETIES/LINES - DISADVANTAGES

- Lower productivity as compared to F1 hybrids
- Some possibility of segregation
- Limited genetic improvement

Several fixed-line varieties are mentioned below:

MARSELLESA	
PARAINEMA	**GEISHA**
LEMPIRA	**T5175**
CR 95	**ANACAFE 14**
IAPAR 59	**OBATA**

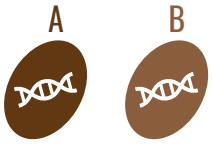
F1 HYBRIDS

WHAT ARE F1 HYBRIDS?

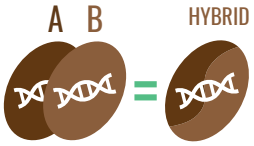
F1 hybrids are a new generation of coffee varieties. An F1 hybrid is created by crossbreeding two genetically different *C. arabica* parents. Many of these relatively new varieties were created to combine the best traits of both parents, including high cup quality, high yield, and disease resistance. Hybrids are notable because they tend to have significantly higher yields (30-40%) than traditional varieties.

HOW ARE F1 HYBRIDS OBTAINED?

To obtain F1 hybrids two steps are taken:



First, two genetically distinct varieties/lines with desired traits are obtained.



Next, the two lines are crossbred.

The first wave of F1 hybrids created by PROMECAFE, CIRAD and CATIE in the 2000s resulted from induced crossbreeding between traditional varieties grown in Central America (such as Caturra, Catimors, and Sarchimors) and wild or landrace varieties from Ethiopia such as Rume Sudan, among others.

A key characteristic of F1 hybrids is that their superior performance is only obtained in the first generation. Seeds taken from hybrid plants will not display the same characteristics as mother plants, with potential loss in terms of yield, resistance to disease, quality, and other agronomic traits.

It is important for coffee growers to know that F1 hybrids should only be purchased in certified nurseries, with totally reliable traceability systems.

Several F1 hybrid varieties currently available in Central America are:

CENTROAMERICANO/H1	
MUNDOMAYA/EC16	**STARMAYA***
MILENIO/H10	

*Starmaya is the first F1 variety that can be multiplied by seed in seed gardens. Read here for more information.

CONTROLLED POLLINATION FOR F1 HYBRIDS

1. Select flower still closed.
2. Emasculate -receiving plants (mother plants). (Remove flower stamens/staminoides before they open).
3. Collect pollen from donor (father).
4. Pollinate manually.
5. Protect plant with a bag.
6. Once controlled manual pollination is carried out, a sibling population is obtained. That population is evaluated in subsequent years in order to obtain the best plants.
7. The selected plants, with all desirable characteristics ("mother plants") are reproduced through vegetative propagation via somatic embryogenesis, grafting or horticultural multiplication, in a specialized, certified laboratory.

F1 HYBRID BREEDING PROGRAM CENTRAL AMERICA

1992

CV 1 x S1
CV 2 x S2
CV 3 x S3

1993

100 hybrid families

X II X X II

2000

20 Hybrids

IIIIII **20 HYBRIDS** IIII

2006

Pre-selection and final selection of promising hybrids

CONTROLLED POLINATION

CV = Commercial Variety (Caturra, Catuaí, Catimor)

S = Wild (Ethiopian)

FIELD EVALUATION OF F1 HYBRIDS

- **Production**
- **Pest and disease resistance**
- **Defects of fruit**
- **Cup quality**
- **Semi-commercial reproduction of best specimens**
- **Regional tests**
- **Coffee cupping**

ADVANTAGES OF F1 HYBRIDS

- Higher productivity (+30-40%)
- Improved resistance to disease
- Good adaptation to climate change
- Larger bean size (screen # 17)
- Cup quality
- Early production (second rather than third year)

DISADVANTAGES OF HYBRIDS

- High propagation cost
- High investment required
- Demanding in terms of nutrition
- They should be reproduced by seed

C. ORIGIN OF SEEDS – TRACEABILITY

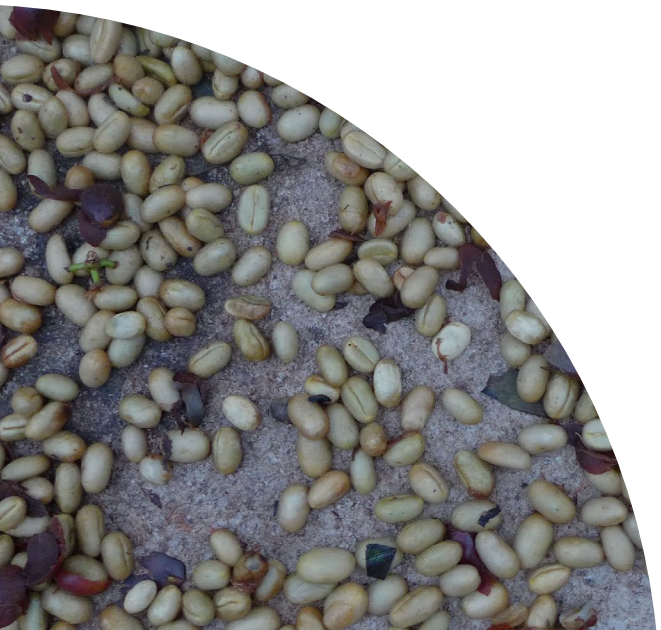
To make sure seeds capable of growing into healthy, strong seedlings with genetic purity are obtained, it is advisable for nurseries to purchase only established, well described varieties (see the WCR Arabica Coffee Varieties catalog for a list). Seed/seedlings should be purchased from certified seed growers.

CRITICAL POINTS IN SELECTING VARIETIES

Complies	Does not comply	Critical Point
		High productivity
		Pest and disease resistance
		Top cup quality
		Purchase of seedlings or seeds from certified companies or nurseries ensuring seed traceability and quality
		Variety adapted to edaphoclimatic conditions in the area

MODULE 2

SEXUAL REPRODUCTION



MODULE 2 - CONTENTS

Module 2 analyses the method of sexual propagation by seed, with a number of good practices to be followed for nursery owners. Module 3 delves into the asexual propagation of seed.

A. SEED

PHYSIOLOGY OF COFFEE

Buds

The buds that give rise to inflorescence are basically distributed axillary in the lateral branches, at the base of leaves in each node with a potential of 32 - 40 flowers per node.

Coffee buds about to bloom

Flowers

C. arabica flowers are complete, hermaphroditic and self-fertile. This makes coffee an autogamous plant with a high percentage of self-fertilization (above 85% -90%). Therefore, before flowers open, some antennae have already released pollen internally. As a result of the union of pollen grains with both ovules (inside the ovary) a fruit normally containing two seeds.

Coffee flower

The success of the nursery process depends on the quality of the seed sourced. Nurseries should obtain seed produced following guidelines in *Good Practices Guide: Coffee Seed Production.*

Fruit

Thirty-two weeks (224 days) elapse, on average, from flowering to maturation of the fruit. The fruit takes 32-40 weeks (220 to 280 days) on average to develop, depending on the area and the species. The fruit passes through different stages while developing, as stated below.

STAGE 1

1-7 weeks (0 – 50 days) after blooming. Slow-growth stage; the fruit is as big as the tip of a match.

STAGE 2

8–17 weeks (50–120 days) after blooming. The fruit grows quickly; the seed has a gelatinous consistency.

STAGE 3

18–25 weeks (120–180 days) after blooming. The seed completes its development, acquires a solid consistency and gains weight.

STAGE 4

26–32 weeks (180–224 days) after blooming. Fruit is physiologically developed and begins to mature.

After week 32 (more than 224 days), fruit over ripens and turns dark purple. Finally, it dries.

Fruit of coffee

B. CHARACTERISTICS OF PROPAGATION BY SEED

GERMINATION OF SEED

Seed germination is key to reproduction. Some requirements exist from the beginning of the process and there are also risks during germination.

Traceability requirements to propagate seeds

1. Seeds to sow must be certified to ensure both quality and genetic purity of plants.
2. If producer wishes to germinate seeds from different varieties, this should be done in different greenhouses or in physically separated areas in order to ensure seed traceability.

Risks in propagating seeds

- Mixing varieties if traceability requirements are not met.
- Risk of pest and disease if substrate is not disinfected.
- Heterogeneous plants due to improper selection of germinated seedlings.
- Little to no germination due to improper management.

PREPARING GERMINATION AREAS

Specific areas are selected, meeting all minimum conditions required for coffee seed germination. The types of structure needed are detailed below. To learn more about proper infrastructure for germination areas, see Module 5.

GERMINATION BEDS

Seeds: Based on space available. To facilitate work, germination beds 1.25m x 24 m long (30 square meters) are recommended.

Bed structure: Beds raised from the ground are the most appropriate ones. These can be supported by boards, bamboo or even concrete. Even though germination can take place on beds on the ground; this practice is not recommended because the plants are more prone to pests, impact from run-off or animals.

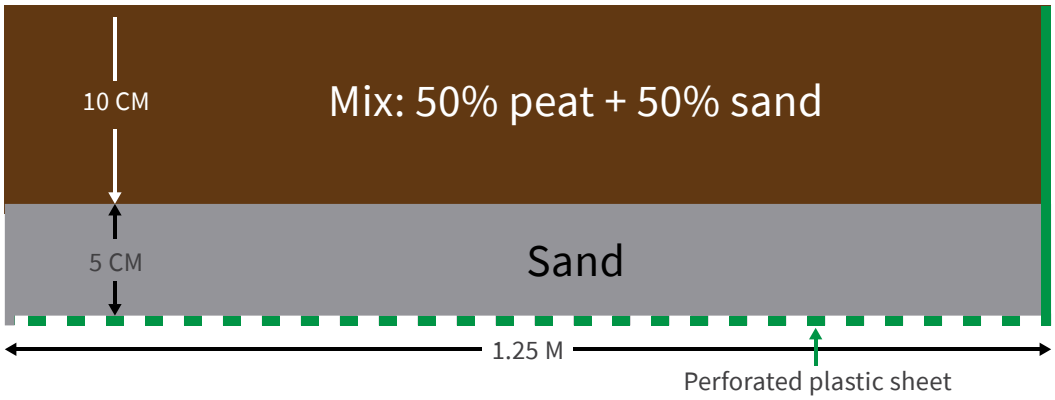
If beds are placed on the soil, a perforated plastic sheet must be placed under them to reduce those risks and allow drainage of water drain.

Substrates for germination: A bottom of volcanic sand (1 mm in diameter) is recommended. To ensure drainage, the layer should be at least 5 cm thick. The substrate must preferably be made of peat mixed with sand or only fine sand. Sand quality is essential. It must not be too thin to avoid compaction, nor too thick to avoid problems of root development and germination due to lack of moisture.

Steps to build a germination bed

1. If the bed is on the ground, place a perforated plastic sheet at the bottom to avoid diseases, insects, and animals coming from the subsoil.
2. Include 5 cm of volcanic sand 1mm wide and disinfect with organic or chemical fungicide.
3. The next day the bed is completed by placing the chosen substrate (preferably 50% peat and 50% sand, or only sand) to a depth of 10 cm.

Graph illustrating the conformation of a germination bed



Choosing the right sand is key. It should not be very thin nor too thick to avoid compaction or porosity issues.

The germination bed can be used for several cycles with the same substrate, as long as there was no problem with a disease in the previous cycle. If so, change the mix. To reuse substrate, disinfect again to eliminate pathogens and screen it to eliminate seed residues that could harm the new batch.

TRACEABILITY

Each bed must be labeled to indicate the variety/seed lot.
For further detail see Module 6 – Traceability.

C. SUBSTRATES (PREPARATION AND MIXTURES)

This section deals in detail with inert substrates and handmade mixtures. These can be used for germination beds, mother plants, transplant, and maintenance.
For the different stages the seedling goes through, it is recommended to adjust substrate percentages and provide adequate nutritional management in each phase. The process from germination to maintenance is detailed in this Module 2 and in Module 3.

CHARACTERISTICS

There is a wide variety of substrates. The most commonly used is topsoil mixed with sand and organic matter, prepared by the nursery owners themselves, or commercial inert substrates.

The substrates must be spongy, with good capacity to absorb water, preferably sandy or with a clear texture, with good drainage and good aeration, light, to facilitate germination of seeds and good growth of roots. The substrate (soil) must be free of solids (pebbles or objects) harming root growth.

Substrate must be made with top-quality raw materials. In addition, it must be properly stored to prevent contamination or degradation of quality. Also, it must meet strict quality standards when received, if purchased. The same holds for raw materials if the substrate is made onsite. There should also be quality controls during storage.

Phytosanitary criteria to be checked when inspecting substrates (and their raw material), are as follows:

- No nematodes
- No phytopathogens such as *Rhizoctonia solani, Fusarium spp,* and *Pythium spp*
- No pebbles/debris
- Not very humid

GOLD LEVEL: INERT SUBSTRATES

To handling from germinators to maintenance it is advisable to use mixtures already tested with coffee such as peat, sand, gravel or stone, etc.

However, also previously disinfected handmade mixtures can be used.

Sand

- Sand is very helpful in substrates, as it helps keep the mixture loose and ventilated.
- Sand with 1 mm diameter grains is recommended. It requires sifting prior to using.
- Some sand types must be washed before use to get rid of impurities. Thus, commercial aquarium sand is recommended.

Gravel (stone)

- Gravel keeps soil drained and ventilated.
- Quartz and pumice stone are very popular.

Peat

- There are different peat suppliers, each with different formulas.
- Generally peat has high water retention, good porosity and it is inert (free of pests and diseases). It does not require disinfection the first time it is used.
- Peat's caliber will differ depending on its formula. Fractions of 5-6mm +/- 2mm must be used in seedbeds.
- Peat is a standardized product, with constant characteristics.

SILVER LEVEL: HANDMADE MIXTURES

Handmade mixtures are made in many farms due to lower cost and high availability of raw materials. To find the optimal mixture, it is advisable to perform tests at ach nursery, varying material percentages to determine the mixture best meeting the needs. Due to variation in terms of type and quality or raw materials available, no specific mixture can be recommended.

A list of the main substrates used and their characteristics follows:

Compost

- Results from aerobic and anaerobic biological decomposition of organic waste under controlled conditions.
- Improves the physical properties of the soil, provides moisture, nutrients and helps drain the soil.

Coal

- Improves soil porosity.
- Levels the pH of soils making them more alkaline.

Vermicompost

- Organic fertilizer obtained from earthworms by digesting vegetable waste, among other materials.
- Provides nutrients such as nitrogen, calcium, magnesium, phosphorus, potassium, and essential micronutrients.
- It improves the physical condition of soils including porosity, infiltration, and aeration.

Bokashi

- Fermented, semi-decomposed organic fertilizer.
- Provides nutrients, moisture, and porosity.
- Made from low-cost raw material.

Coconut fiber

- Can retain a water volume up to 3 - 4 times its own weight.
- Slightly acidic pH and good porosity.
- Must be washed prior to use to remove salt.

Other usable materials include rice husk and macadamia seed, among others.

It is key to carry out chemical analysis of the raw material to be used or to request it from the supplier. At least, pH and electrical conductivity must be measured. The pH of substrate must be kept between 5.6 and 6.2 and electrical conductivity must be less than 1.0ms.

Substrates may have high amounts of salts resulting in production issues including inhibition of seed germination, significant reduction of growth, and edge burning.

STORING SUBSTRATES

To store substrates,

1. Choose an enclosed space, with a roof, walls and concrete floor to prevent previously disinfected substrate from coming into contact with pathogens.
2. Label each substrate indicating mixture type and disinfection date.
3. If possible, store it in bags.
4. In the case of handmade mixture, disinfection is recommended once or twice per year. Peats generally do not require it.

TRACEABILITY

When using purchased substrate, keep:

1. Purchase order.
2. Lot number.
3. Supplier name and quantity received.
4. Specifications of purchased substrate to ensure traceability and substrate quality.
5. Labeled substrate is stored and updated, written inventory is kept.

If substrate is made on site, keep a list of raw materials, quantities, and origin.

DISINFECTION

An indispensable condition for success in plant production is disinfecting substrates (soil health treatment) to avoid problems from diseases such as *Rhizoctonia solani, Fusarium spp* and *Pythium spp*, which are the main phytosanitary problems at coffee seedbeds.

Phytosanitary treatment can be biological, chemical or physical, according to nursery owners' preference. However, effective treatment must be ensured through periodic monitoring.

Soil disinfection is a practice intended to mitigate the negative impact of fungi, nematodes, insects, bacteria and weed seeds in the soil which affect plant germination and development.

Disinfectants (fungicides, bactericides, nematicides) allowed in the country are generally used and the guidelines of the safety sheet for each product, also called MSDS (Material Safety Data Sheet) are followed.

Natural alternatives for soil disinfection can also be used (see options at right).

BOILING WATER TECHNIQUE

1. Get metal buckets.
2. Add the substrate (sand, soil, natural fibers) to be disinfected.
3. Add plenty of boiling water to soak the entire contents.
4. Cover the container with plastic sheet to keep the temperature until the material cools.
5. Drain and let dry; substrate is ready to use.

SOLARIZATION TECHNIQUE

1. Place the substrate on a black plastic and spread a uniform layer.
2. Irrigate the substrate until 50% humidity is reached. It is recommended to use a tensiometer to measure humidity.
3. Cover the substrate with a transparent plastic, stretch it well to avoid air bubbles, and close the edges so that the heat does not escape.
4. Leave it for a week or more under the sun.

VAPOR TREATMENT

Vapor treatment requires the installation of pipes running below the seed bed, through which steaming water is run.

1. Heat water in a boiler to 90°C.
2. For in-depth vapor treatment, cover the area with a plastic sheet. For superficial treatment, just cover it.
3. Treatment time depends on treatment focus (fungi, bacteria, or nematodes).

D. PLANTING SEEDS

PREPARING SEEDS - PRE-GERMINATION TREATMENT

Steps to sowing

1 One day before sowing, check seed moisture. If seed moisture is 20% or less, leave it at least 12 hours in water to rewet the seeds. (The update of water by a dry seed is called imbibition.) If moisture exceeds 20%, seeds can be soaked for four hours before planting. It is recommended to add amino acids to water, as this energizes seeds to germinate.

Soaking seeds

2 On the day of sowing, place the seed randomly and homogeneously in the previously moistened substrate. Then, cover the seed with a 50% / 50% (substrate/sand) mixture. Covering the seed is key: if it is covered with a very thick layer, germination is delayed and is uneven. If it is very thin, the seed can dry partially and not germinate. A layer of substrate 0.5 cm to 0.7 cm. thick is recommended to cover the seeds.

Acclimatization microtunnel

3 Once this process is over, water the germination bed. If needed, add substrate to areas where the water may have uncovered the seeds. Cover the bed with a white plastic sheet to allow light to enter, in the form of a microtunnel. This plastic sheet retains heat to favor the germination process, and avoids substrate dehydration. For further information see Module 3, Acclimatization.

Watering the sowing bed

DENSITIES

Seeds per square meter: It is advisable to have 1 - 1.5 kg of seeds per square meter. Typically this will produce approximately 3,500 viable seedlings.

E. HANDLING GERMINATORS

IRRIGATION

Water germination beds frequently. Do not water in excess to avoid fungi and root rotting.

There are different ways to water germination beds:

Water appropriately both in terms of water amount and in terms of frequency to improve plant development.

GOLD LEVEL

Micro sprinkling: Provides enough moisture and does not impact seedlings.

SILVER LEVEL

Water sprinkler: irrigate using water sprinkler or a hose with a micro sprinkling device; water softly and evenly to avoid damaging seedlings.

FERTILIZATION

It is preferable not to fertilize during the germination process. Seeds contain all the nutrients they need for germination and germinated seedlings are harvested and quickly transferred to another container.

If substrates like compost, bokashi or vermicompost are used, they are analyzed to find the nutritional contribution of each mixture to avoid plant toxicity. Keep pH between 5.6 and 6.2 and the EC (Electrical conductivity) under 1.0ms

SHADE

When planting seeds, transparent plastic is used as a cover at 50cm-1m above the bed, for the first three weeks. When germinated seedlings appear, then the plastic sheet is removed. The goal of the plastic sheet is to create a microclimate fostering germination.

As stated before, it is most effective to have germination beds in greenhouses under shade net roofs to control light intensity. Also, many growers cover germination beds with jute bags, (canvas) or banana leaves. When jute bags are used, they must be disinfected to avoid spreading pathogens. Optimal light levels are between 20% and 40%.

Shade to create a micro-climate favoring germination

DISEASE AND PEST CONTROL

It is important to check daily the health of seedlings in germinators to control for outbreaks of *Rhizoctonia solani, Fusarium spp* and *Pythium spp.*, which are the main phytosanitary problems in coffee seedbeds. Therefore, the previous stage of substrate disinfection is essential.

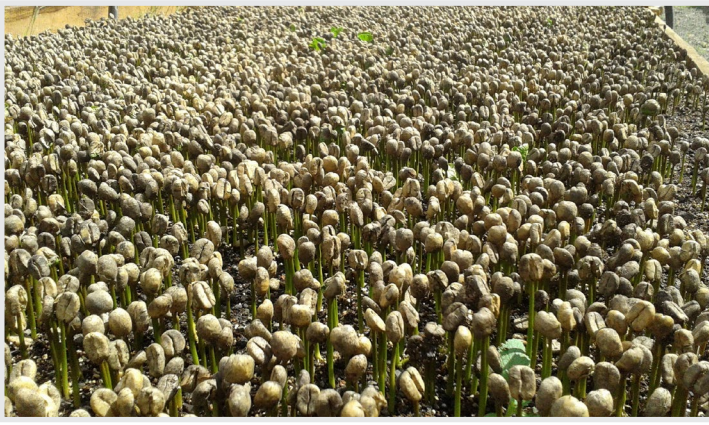
Preventive applications of contact fungicides such as strobilurins, carbamates and cupric fungicides from germination stage to seedling harvest are carried out every 7 days. (It is better to avoid triazoles as they tend to intoxicate the seedlings.) Biological control such as *Thichoderma spp*. can also be applied weekly. In case of finding fungal diseases, carry out a sanitary cleaning, discard affected seedlings, and apply fungicide.

Damping off may result from several different fungi types including *Rhizoctonia solani, Fusarium spp* and *Pythium spp.*

GROWTH CONTROL

Once sowing is done, germination must be monitored to detect any problems. The first radicles should emerge from the seed after 20 days. To monitor, remove substrate on the seed at several points to check. After 30 days seeds is lifted off the soil by the growth of the hypocotyl axis, and the seeds have become germinated seedlings. At this time, germination is ensured.

If these states fail to appear, several factors can be responsible for non-germination or delayed germination of the seeds, including very low levels of seed moisture (low viability), poorly controlled substrate moisture, seed rotting by pathogens, and unsuitable climate conditions.



TRACEABILITY

Growth must be recorded in each plot to monitor germination including data such as type of substrate used, pH, shade levels and continuous control of substrate moisture as well as soil and environment temperature to optimize the growth of each variety of coffee. Also germination rates. For more details see Module 6 - Traceability.

F. PREPARING SEEDLINGS/GERMINATED SEEDS

CHOICE OF MATERIALS

Seedlings are harvested for two different purposes:

1. **SEEDLINGS:** Seedlings are are transplanted directly into bags or tubettes to later plant them in the field (to be used as new plants in their own right).
2. **GRAFTING:** Seedlings are grafted onto the rootstock of a different germinated seedling of another variety (typically Robusta, which confers greater root vigor and/or nematode resistance)

Key recommendations for harvesting germinated seedlings from seed beds:

STEP 1

Harvest them carefully to avoid damage to the primary root, with a flat blade loosen the substrate to facilitate the removal of the germinated seedlings, being careful to hold them from the neck at the time of removal.

STEP 2

Discard poor quality seedlings. Staff in charge of harvesting must be able to select material meeting with the minimum requirements. For more information see subchapter Seedling Selection and Disposal.

STEP 3

To avoid seedling dehydration, place harvested seedlings into a container with a tight lid and store away from direct sunlight.

STEP 4

Spray water with a sprayer to keep them hydrated when harvesting and before taking them to the preparation workshop.

STEP 5

Store them in a tightly sealed container in a cool location and transplant as soon as possible.

SEEDLINGS FIT TO SOW - CHARACTERISTICS

Main characteristics of seedlings to plant include:

- Healthy plants, with no traces of disease
- Straight hypocotyl (stem)
- Large, straight root with secondary roots
- Sorted by size

Butterfly fit for transplantation

Seedling fit for transplantation

SEEDLING SELECTION AND DISPOSAL

Seedlings are strictly selected to ensure they meet the characteristics above for optimal growth. Then they are sorted by size for uniform production.

Undesirable characteristics include:

Double root

Forked root

Small, hairless root

PACKING

Seedlings are stored at a cool site, protected from sunlight. Recommendations follow.

Maximum storage time for germinated seedlings: 2 days

Storing temperature: 18-20°C

However, they should better be planted on the same day to ensure a good start and avoid shrinkage and high morality rate.

1. Discard poor quality seedlings (see Section Selection and Disposal) and count.
2. On a tray put wet paper towel or newspapers and pack germinated seedlings. Seal with plastic and adhesive tape.

Note: Between 2,500 and 3,000 germinated seedlings are packed in a 30 cm *25 cm *15cm tray. A worker can select, count, and pack 8,000 – 9,000 per day.

Packing germinated seedlings

Once the germinated seedlings are packaged they are moved to the reseeding area. They can be planted in bags, tubettes, or substrate blocks. Seedling structures and containers must optimize seed germination and growth of transplanted seedlings, as well as ensure their health. Thus, package must have certain characteristics and it must be stored properly to prevent contamination or degradation of quality. In addition, it must undergo quality control upon receipt and during storage.

For further detail see Module 3.

CRITICAL POINTS INRELATION TO GERMINATION OF SEEDS

Complies	Does not comply	Critical Point
		Seeds to sow must be certified to ensure plant quality and genetic purity.
		If seeds from different varieties are going to germinate, this should take place at different greenhouses or physically separate areas to ensure seed traceability.
		Reproduction structures must meet minimum requirements.
		To avoid pest/diseases, it is key to comply with substrate disinfection.
		Meet requirements related to structure and proper management of germination beds.
		Comply with selection criteria for germinated seeds (aka “butterflies”) after harvest to maintain consistent quality.
		Follow packing criteria to maintain useful life of germinated seeds. Otherwise, dehydration and death can occur.
		Continuously irrigate seeds to ensure good germination.

TRACEABILITY

For more information about traceability cards and recommended Excel tables see Module 6 – Traceability.

MODULE 3

ASEXUAL REPRODUCTION (VEGETATIVE PROPAGATION)

MODULE 3 - CONTENTS

A. ASEXUAL REPRODUCTION (VEGETATIVE PROPAGATION)

DEFINITION

In asexual reproduction methods, plants are produced using material from a single parent and as such there is no exchange of genetic material. Asexual reproduction methods (often called "vegetative propagation") produce plants that are identical to the parent. There are different types of asexual propagation methods, which have different technical requirements and costs.

Arabica coffee is an autogamous (self-fertile) species normally reproduced by seed. But as discussed in Module 1 of this guide, improved F1 hybrid varieties—because of their heterozygous genetic structure—should not be be propagated by seed (they will not be true-to-type if sown from seed). F1 hyrids offer coffee farmers excellent advantages in adapting for climate change, sustainable agroforestry, and overall performance.

Any variety of coffee can be propagated via vegetative methods, but because the cost is higher, typically only F1 hybrids are reproduced this way (the higher cost is offset by their superior performance). There are four main methods of asexual multiplication to propagate F1 hybrids:

1. **In vitro multiplication**: Meristems (tissue of undifferentiated cells) of the mother plant are introduced under sterile conditions and then multiplied in vitro to create new bud shoots.
2. **Somatic embryogenesis**: An innovative tissue culture technique that allows millions of cloned plants to be obtained from only a few leaf fragments of a mother plant. This technique allows large-scale replication of F1 hybrids, but requires technically advanced nurseries.
3. **Horticultural ex-vitro multiplication (mini-cutting)**: Cuttings are obtained from mother plants and rooted in horticultural trays or in germinators. Low cost and low technical proficiency method. Mass multiplication is limited per mother plant per year.
4. **Grafting**: Cuttings are obtained from mother plants (as above) and grafted onto Robusta rootstocks.

In this guide, we will only deal with grafting as it represents the most common technique and requires less investment.

In addition, grafting is recommended for trees destined for low-elevation areas where Arabica has less adaptability (<1000 masl) and for any trees in areas infested by phytoparasitic nematodes (most robusta rootstocks tolerate nematode attacks). Grafting Arabica cuttings onto Robusta rootstocks provides the variety with tolerance to drought, greater anchorage, adequate strength and tolerance to nematodes.

When grafting, nurseries should be certain that any purchased buds or scions from mother plants originate from certified laboratories.

Grafting consists of the physical union of two plants. The part providing the root is called rootstock, and the main part, which will grow into the above-ground coffee shrub, is known as the bud or scion. The union is successful as long as the vascular tissues of both plants (called cambium) are joined properly, allowing circulation of sap between them. When united, both grow as a single individual. Though an Arabica variety may be grafted onto Robusta rootstock, it retains its Arabica characteristics, while gaining from the vigor of the Robusta roots.

ADVANTAGES OF ASEXUAL REPRODUCTION

- Characteristics of mother plants can be reproduced identically
- Increase productivity and pest and disease resistance
- Better adaptation to climate change
- Improved coffee production worldwide through improved productivity

DISADVANTAGES OF ASEXUAL REPRODUCTION

- High degree of plant mortality if procedure is improperly conducted
- Highly qualified staff and adequate facilities required
- Incompatibility risk
- High cost of reproduction

B. PREPARING ROOTSTOCKS

As mentioned above, the rootstock is the part of the plant providing the root. In coffee grafting, rootstocks of the *Coffea canephora* species are generally used, due to their strong root system and resistance to nematodes.

If the Robusta rootstock comes from seed, it should be planted two weeks before the scion variety because the Robusta stem is slower to develop. This ensures the diameters of the stems of both plants are the same at the time of grafting.

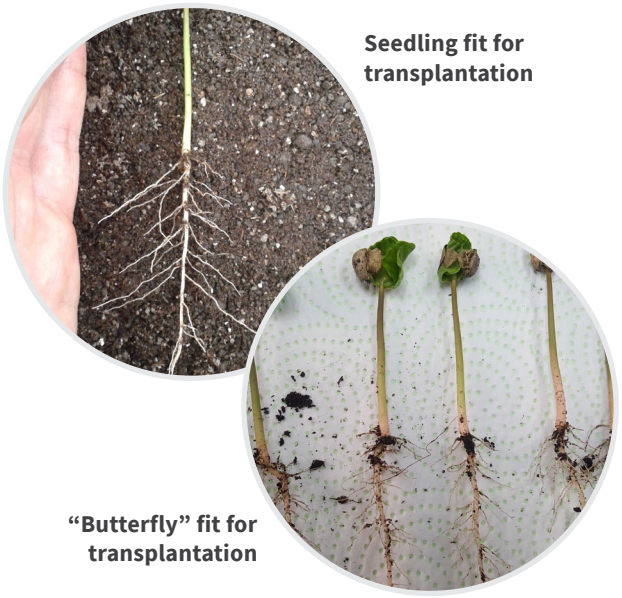
NOTE: This information applies to grafting using rootstock from germinated seedlings. It is considered that grafting with germinated seedlings is more practical, economical, generates better performance, and has a high percentage of viability. Also, it is the most common practice in coffee countries that use the grafting technique.

For more information on how germinated seedlings are harvested, hydrated, washed, packaged, and destined for grafting or transplanting, see Module 2 of this guide.

SELECTING ROOTSTOCK MATERIAL FIT FOR GRAFTING

Prior to transplant, trained staff should check rootstock seedlings to ensure they meet all quality requirements and discard those that have defects. It is ideal to check twice: Once at the time of harvest, and again before transplant.

The rootstock used for grafting may be in the seedling stage (sometimes called "butterfly" stage). Commonly, it is done once the seedling has hardened a little more and when its stem diameter coincides with the diameter of the bud/scion.



Seedling fit for transplantation

"Butterfly" fit for transplantation

UNDESIRABLE CHARACTERISTICS:

Double (forked) root

Small root

Triangle bean

Cut root

C. HANDLING MOTHER PLANTS TO OBTAIN BUDS/SCIONS

There are different options for handling mother plants, depending on what phases of vegetative propagation are managed at each nursery. Some nurseries acquire mother plants from cotyledonary somatic embryos and perform acclimate and grow them. Some have their own vegetative reproduction or somatic embryogenesis labs. In this guide, we will focus on nurseries that purchase mother plants developed in trays, and keep them in growth greenhouses to extract the buds to graft onto rootstocks. For more details on greenhouse infrastructure see Module 5 of this guide.

STAFF REQUIREMENTS

GREENHOUSE ADMISSION PROTOCOL

1. Sanitize shoes at the entrance of greenhouses or work areas. Immerse shoe soles in a tray with a disinfectant solution.
2. Wash hands up to the elbows and apply alcohol gel.
3. Wear aprons or lab coats available at each tunnel. In the workshop area, operators are required to wear closed, clean shoes. Workers wearing dirty rubber boots are not allowed.

PERSONAL HYGIENE PROTOCOL

1. Shower daily.
2. Wear clean clothes to mother plant and grafting nurseries.
3. Always wash hands thoroughly upon arrival to workplace, after going to the bathroom, eating, or any other activity.
4. Wear work apron/lab coat.
5. Use disposable gloves.
6. Trim nails wash with soap and brush.

WORK MATERIALS

1. **Sprayer bottle with disinfectant and blade:** Operators must disinfect blades and hands before each cut to prevent the spread of disease.
2. **Sprayer bottle with water:** Operators must keep buds hydrated by spraying them with water.
3. **Trays:** Trays are used to place buds to graft.

BUD CUTTING - SPECIFICATIONS

1. Bud size may vary; however, it must have at least 3 cm of tissue so that when cutting it can be done between 2 cm to 2.5 cm. The longer the contact surface, the greater the likelihood of graft viability.
2. Operators must wear disposable latex gloves and change them for every new tunnel.
3. Disinfect scissors (for instance, with iodine 4cc/l) between cuts.

Example of perfect bud for grafting

Example of poor bud for grafting, with extra set of lateral leaves

PACKING

1. Once cut, buds are placed in a thermos bottle or plastic container. They will be sprayed with water and protected from the sun with a piece of cloth, canvas or plastic to avoid dehydration.
2. Trays with buds are moved to the area where they are prepared for grafting.
3. If trays will not be used immediately, they should be stored at a temperature between 18°C and 20°C with high relative humidity (90%) inside the container. Buds should not be stored for more than one day.

Maximum storage time for buds: 1 day

Storing temperature: 18°C - 20°C

CRITICAL POINTS INHANDLING MOTHER PLANTS

Complies	Does not comply	Critical Point
		Following greenhouse entry protocols
		Following staff hygiene protocol
		Disinfect tools each time a new cut is made
		Follow packing specifications to ensure viability
		Keep bud temperature between 18°C and 20°C with minimum 90% moisture. Buds must not be stored more than one day
		Ensure enough irrigation and nutritional/phytosanitary protection plan for mother plants

D. GRAFTING

Grafting is a thorough, careful process. Personnel involved in grafting must undergo training to reduce seedling mortality and increase production.

STAFF REQUIREMENTS

Since grafting involves critical work, staff must be trained in advance. Beginner grafters can perform between 50 and 100 grafts per day. After two to four weeks they can reach about 250 to 400 grafts per day. Experienced people can perform up to 800 grafts per day.

Requirements for grafting personnel include,

1. All operators must wash hands to the elbows with soap at the sink.
2. Dirty fingernails are not tolerated. Use soap and brush to clean nails.
3. All operators are required to wear aprons and closed, clean shoes at the workshop. Operators wearing dirty shoes or boots are not allowed.

Workers complying with the above may go to their work areas.

WORK MATERIALS

1. **Work Tables:** stainless steel tables are preferable because they are easier to clean, more innocuous and do not shelter bacteria or disease. Nonetheless, tables can be made of wood, glass or plastic. Tables should be disinfected twice a day with a disinfectant solution.
2. **Parafilm strips:** They are used to attach the scion to the rootstock. They provide physical support for the graft

Work tables

to hold and adhere properly.

3. **Spray bottle or tray with disinfectant:** Grafters must disinfect hands and blades before preparing each new graft

4. **Sprayer bottle with water:** Grafters must keep grafts hydrated, so they have to constantly spray mother plants and grafts with water.
5. **Blade:** Grafters must have a blade/scissors to cut the rootstock and the plant.

GRAFTING PROCESS

Even though there are different ways to graft, this guide focuses only on one procedure:

1 **Receiving buds**

Buds are received cut and selected from the mother plants' greenhouse.

2 **Receiving rootstocks**

Previously selected rootstocks with good root development and bare roots are received.

3 **Preparing rootstock roots**

It is advisable to have an operator in charge of this task. Operator's responsibilities:

- Reject rootstocks with poor quality, including those with forked roots, short roots, affected by pathogens, etc.
- He/she must disinfect scissors (for example, with Iodine - 4cc / l) between cuts made. Cut rootstocks evenly 5cm from their necks (+/- 3mm).
- Once rootstocks are prepared, they must be grouped by packets and delivered to the grafting team.
- Rootstocks are sprayed with water and protected with adhesive plastic mainly to limit root dehydration.
- The operator is responsible for continuously delivering rootstocks to individual grafters and leaving his/her work area clean.

4 **Preparing Parafilm strips**

It is advisable to have an operator in charge of this task. Operator's responsibilities:

- Preparing homogeneous Parafilm strips for the grafters' team and to keep the grafting area clean. The Parafilm strip is used to preliminary bind rootstock and buds to ensure graft viability.
- The operator is also responsible for continuously delivering rootstocks to individual grafters and leaving his/her work area clean, not only at the end of the day. In addition, once this activity is over, he/she must leave the grafting workshop clean.

Scissors

Once everything is ready, grafting begins.

5

- First, take a rootstock. Take a blade and disinfect it.
- Cut the upper part of the rootstock (leaves and buds), then make a longitudinal incision at least 2.5 cm long. Leave it on a clean stand.

Rootstock cut and longitudinal incision

6 Take a good bud or germinated seedling.

7 Take a blade and disinfect it thoroughly.

8 Make a longitudinal incision along the bud stem, the same length as the one made in the rootstock.

9 Join rootstock and bud as quickly as possible without touching the bare tissues with hands.

10 Tie with Parafilm from bottom to top, making sure it is not loose. To do so, it must be stretched. It is important to go above the cut so that Parafilm ties tissues properly. There is no specific length for the Parafilm strip, the most important thing is that it is easy to handle. Strip width must not exceed 1.3 cm to avoid strangling the graft.

11 The completed graft is placed in the plastic container and sprayed.

12 Plant grafted plants in substrate blocks or beds (see section E).

13 Clean the glass table with cotton and alcohol; restart the process.

14 Each tray of grafted plants is labeled with its information for traceability. (Variety, grafting date, week, lot, grafter name or code). In addition, a color code can also be used to distinguish varieties.

TRACEABILITY

- It is important to keep a record of the people involved in the grafting process, in case of later observations and to be able to look for a possible source of the problem. It is recommendable to assign a number to each grafter related to the team: the one cutting buds, the one cutting Parafilm and the carrier.
- Precise identification of rootstock and bud must be maintained during the entire process.

Sample traceability and grafting table

Date:											
									Catching (counting)		
# of grafters	Container	Lot	Code	Variety	Origin	Destina-tion	Number of grafts	Disposal of rootstocks	Date	Stock	Disposal

For further detail on traceability see Module 6.

CRITICAL POINTS INHANDLING GRAFTS

Complies	Does not comply	Critical Point
		Safe facilities and continuous disinfection.
		Follow personnel hygiene protocol.
		Disinfect tools after each cut made between plants.
		Train grafters.
		Keep grafts at 20-25°C with 70-90% moisture. Plant them as soon as possible in substrate blocks, trays, or directly on beds.

E. PLANTING GRAFTS

There are three ways to plant grafted seedlings, depending on nursery owner financial means.

Substrate blocks

GOLD LEVEL: PLANTING IN INERT SUBSTRATE AND SUBSTRATE BLOCKS

- This work is very delicate and must be carried out by qualified, responsible personnel.
- Operators must disinfect their hands with quaternary ammonium.
- Next, he/she must take the grafts and immerse their roots in a rooting solution (AIB) for 10 seconds.
- Then, he/she must make a hole in the substrate block, 5.5 cm to 6 cm deep.
- The root must remain straight, without bending at the base of the hole.
- The substrate must be pushed toward the root to prevent air from remaining in the hole. The substrate must not be squeezed vertically to prevent roots from bending.
- The seedlings must be taken to the acclimatization area, and between 2 and 6 weeks must elapse before making sticking counts.

SILVER LEVEL: PLANTING GRAFTS IN DISINFECTED SUBSTRATE IN TRAYS

- Previously disinfected substrate must be used.
- Trays are prepared without compacting substrate too much.
- Operator disinfects hands with quaternary ammonium.
- Next, he/she must take the grafts and immerse the roots in a rooting solution (AIB) for 10 seconds.
- Then, he/she must make a hole in the tray 5.5-6 cm deep.
- The root must remain straight, without bending at the base of the hole.
- The substrate must be pushed on the sides and toward the root, to prevent air from remaining in the hole. The substrate must not be compacted vertically (to prevent roots from bending).
- Take seedlings to the acclimatization area. Wait between 2 and 6 weeks before assessing mortality (e.g., counting seedlings).

Although this is a cheaper method, its mortality rate is much higher than that for Gold and Silver levels.

BRONZE LEVEL: BEDS

- Previously disinfected substrate must be used.
- Beds are prepared using disinfected substrate.
- Employee disinfects hands with quaternary ammonium.
- Next, he/she must take the grafts and immerse the roots in a rooting solution (AIB) for 10 seconds.
- Then, he/she must make a hole in the tray 5.5-6 cm deep. The distance between grafts is 5 cm X 5 cm.
- The root must remain straight, without bending at the base of the hole.
- The substrate must be pushed on the sides and toward the root, to prevent air from remaining in the hole. The substrate must not be compacted vertically to prevent roots from bending.
- Place grafts in acclimatization tunnels and cover them with plastic sheet. Wait 2 to 6 weeks before assessing mortality (e.g., counting seedlings).
- After acclimatization, functional grafts are transplanted from beds to bags/tubettes.

ADVANTAGES AND DISADVANTAGES OF DIFFERENT WAYS TO PLANT GRAFTS

SUBSTRATE BLOCKS

Advantages

- Ease of handling (per unit).
- No root damage when the plant is moved.
- Facilitates carrying inventories.
- Different sizes available in the market.
- Filling can be made by machines, according to block size. Lower need for labor.
- Some blocks are biodegradables and avoid the need to return plastic.

Disadvantages

- High investment (machine).
- Little availability in Latin American countries. Available abroad (must be imported).

Trays

TRAYS

Advantages

- Easy handling.
- Facilitate carrying inventory.
- Low cost.

Disadvantages

- Damage to root system when seeds are extracted.
- Good relationship between density/ depth/volume is hard to achieve.

BEDS

Beds

Advantages

- Low cost.
- Customized construction using local resources.

Disadvantages

- Does not facilitate carrying inventory.
- Makes sowing difficult.
- Dead plants pollute the rest (inoculum remains).
- Naked root resulting in stress and reducing success rates.
- No individual selection possible.

CRITICAL POINTS INRELATION TO GRAFT PLANTING

Complies	Does not comply	Critical Point
		Use inert, previously disinfected substrate
		Follow staff hygiene protocol
		Hole deep enough for root not to bend (it must remain straight)
		Press substrate from the sides to prevent air from remaining at the root. Do not press downwards as main root may bend
		Place grafts in acclimatization tunnels

F. ACCLIMATIZATION

TRANSFERING GRAFTS TO ACCLIMATIZATION

Grafts sown in substrate blocks or trays must be moved to the acclimatization area avoiding contact with the outside environment (wind, pests, and diseases)

- Transfer grafts in a previously disinfected cart if possible.
- When a tray is complete, record all the information and place the tray on a cart. Once the cart is full, take it to the tunnel area.
- Before entering the tunnels, disinfect hands and both the operator and the cart must go through the footbath.

ACCLIMATIZATION TUNNELS

Acclimatization is the process to provide grafts with the temperature and humidity they need to enhance their viability.

To do so, tunnels in beds of transplanted plants are recommended. They are built hermetically, using a thin white plastic for greater diffusion of light, for a very confined internal environment in order to give grafts the weather conditions they require with a high moisture content.

INFRASTRUCTURE

See Module 5 on for further detail on acclimatization tunnels.

IRRIGATION

An irrigation system is installed with nebulizers that are located inside the tunnel (above the microtunnels) to maintain high relative humidity (> 90%) and to lower temperature (26°C < 30°C).

Trays **Grafts ready to acclimatize**

CLEANING THE TUNNELS

- Once acclimatized trays are taken out, all the remaining material must be collected, including clips and labels.
- Remove weeds and waste from the tunnel.
- Remove sprinklers. Disassemble them all and place them in a detergent solution with a brush, then dip them in 12% chlorine for one day, and rinse with water.
- Use a broom to wash the entire inner surface of the tunnel with water and detergent.

REVIEW

- Check the plastic of the tunnel for holes. Repair if there are any to avoid moisture loss.
- Check tables and repair if needed.

PREPARING AND DISINFECTING

- First, wash the tunnel with water and detergent and let it dry completely. The following day, apply a solution of fungicide and bactericide, close the tunnel and wait for one day.
- Next, install the sprinklers and trays previously washed and disinfected.
- Place white plastic on top of each microtunnel. Press it with clips to make it more airtight.
- Plants can be brought in one day after disinfection; however, it is recommendable to leave the tunnel empty for at least 3-4 days.
- When the grafts are brought in, they are placed in plastic tunnels to be confined. Through an irrigation system (by nebulization), the desired temperatures of 25-30°C, and relative humidity of 90-100% are maintained.
- Relative humidity (RH) is the most important factor for the survival of plants during the acclimatization stage.

Acclimatization takes between 4 and 8 weeks, depending on climate, moisture conditions, and management.

After the process of acclimatization is over, viable grafts are counted and plastic sheet is lifted progressively, until it is completely uncovered. At this stage grafts are ready for sale. However, it is recommendable to move them to a hardening area, where they are transplanted to a larger container to have a stronger plant for final sale.

Note: Train an operator to monitor relative humidity and temperature within each tunnel. Once the graft has been checked and seen to have stuck, the plastic is removed progressively until it is completely uncovered. Later it is transferred to the hardening area, where it is transplanted to a larger container.

TRACEABILITY

To ensure traceability of individual grafts, the data of sowing and transfer to acclimatization area are recorded, including at least physical space code, variety, date and number of plants with their SKUs (Stock Keeping Unit) codes. Also, keep the master map always updated. See chapter on General traceability system in nurseries in **Module 6.**

Give each plant a SKU code.

CRITICAL POINTS INRELATION TO ACCLIMATIZATION

		Thoroughly clean tunnels
		Disinfect tunnels completely before introducing new grafts for acclimatization
		Have a nebulization system in the tunnels
		Maintain a 25°C -30°C temperature and monitor every 30 min
		Maintain humidity between 90% -100% and monitor every 30 min
		Perform daily inspections for pest and disease control, apply pesticide if needed
		Staff working at the acclimatization zone is properly trained to do so
		Perform preventive cleaning of affected plants
		Implement a phytosanitary applications plan

G. SUBSTRATES

Three different substrate levels can be used, in line with individual nursery owners' possibilities.

GOLD LEVEL

Peat

- There are different peat suppliers, each with different formulas.
- Generally peat has high water retention, good porosity and it is inert (free of pests and diseases). It does not require disinfection the first time it is used.
- Peat's caliber will differ depending on its formula. Fractions of 5-6mm +/- 2mm must be used.
- Peat is a standardized product, with constant characteristics.

Use 100% of peat and add a controlled-release fertilizer, for instance, 15-9-12. There are many to be considered in the market. Mix can be made with a mixing machine or with shovels in a clean area. It is important to mix evenly to homogenize fertilizer.

This substrate can be used with different support structures such as tubettes, substrate blocks y biodegradable containers for transplantation later on.

SILVER LEVEL

Inert, proven mixtures are recommended such as peat, sand, gravel (stone), etc.

Sand

- Sand is very helpful in substrates, as it helps keep the mixture loose and ventilated.
- Sand with grains 1 mm in diameter is recommended. It requires sifting prior to using.
- Some sand types must be washed before use to eliminate impurities. Thus, clean, disinfected sand is recommended.

Gravel (stone)

- Gravel keeps soil drained and ventilated.
- Quartz and pumice stone are very popular.

BRONZE LEVEL

Compost

- Results from aerobic and anaerobic biological decomposition of organic waste under controlled conditions.
- Improves the physical properties of the soil, provides moisture, nutrients and helps drain the soil.

Coal

- Improves soil porosity.
- Levels soils´ pH making them more alkaline.

Vermicompost

- An organic fertilizer obtained from earthworms by digesting vegetable waste, among other materials.
- Provides nutrients such as nitrogen, calcium, magnesium, phosphorus, potassium, and essential micronutrients.
- It improves the physical conditions of soils including porosity, infiltration, and aeration, among others.

Bokashi

- Fermented, semi-decomposed organic fertilizer.
- Provides nutrients, moisture, and porosity.
- Made from low-cost raw material.

Coconut fiber

- Can retain a water volume up to 3-4 times its own weight.
- Slightly acidic pH and good porosity.
- Must be washed prior to use in order to remove salt.

Other usable materials include rice husks and macadamia seed, among others.

See Module 2 in this guide for details on substrate disinfection.

Substrate must be made of quality raw material and must be properly stored to prevent contamination or degradation of quality. If purchased, it must be submitted to rigorous quality control at the time it is received; if made onsite, raw material quality must be checked. There must be quality control during storage as well.

KEY ACTIVITIES TO CONTROL SUBSTRATE QUALITY

1. Require or perform nematode analysis to substrate.
2. Buy inert substrate or always disinfect substrate before use.
3. Substrate must be free of pebbles and debris and it should not come very wet.
4. Store in sealed bags to reduce entry of air, pathogens, insects and even rodents. The place must be fresh and must have a trap system as well as preventive control of pests and diseases.

TRACEABILITY

1. When using purchased substrate, keep purchase order, lot number, supplier, and quantity received, as well as substrate specifications to ensure traceability and substrate quality.
2. If the substrate is made onsite, keep a list of raw materials, quantities, and origin.

CRITICAL POINTS INRELATION TO SUBSTRATES

Complies	Does not comply	Critical Point
		Substrate should be able to retain moisture but must drain excess water
		Substrate must be disinfected or inert
		It must be permeable and not compacted
		Perform measurements of pH and conductivity of substrate both before and during use

MODULE 4

NURSERY MANAGEMENT

MODULE 4 - CONTENTS

This module deals in general with seedling fertilization from the acclimation stage to maintenance for final sale, as well as main toxicities, diseases, pests and recommendations for irrigation.

A. FERTILIZATION

HOW SHOULD APPROPRIATE FERTILIZATION BE CARRIED OUT?

To obtain quality seedlings, good nutrition adapted to plant needs at each stage is essential. For nurseries it is recommendable to make a nutrient analysis of substrates to compensate nutritional deficiencies through a formula, if needed.

Requirements for effective fertilization

- Purchase fertilizer from certified suppliers
- Fertilization in line with variety/substrate nutritional requirements
- Apply in line with growth stage

Risk from inappropriate nutrition

- Improper development of the coffee seedling
- Higher risk of disease due to nutritional deficiencies
- Productivity problems and greater susceptibility to pests in adult plants
- Toxicity that could lead to plant death

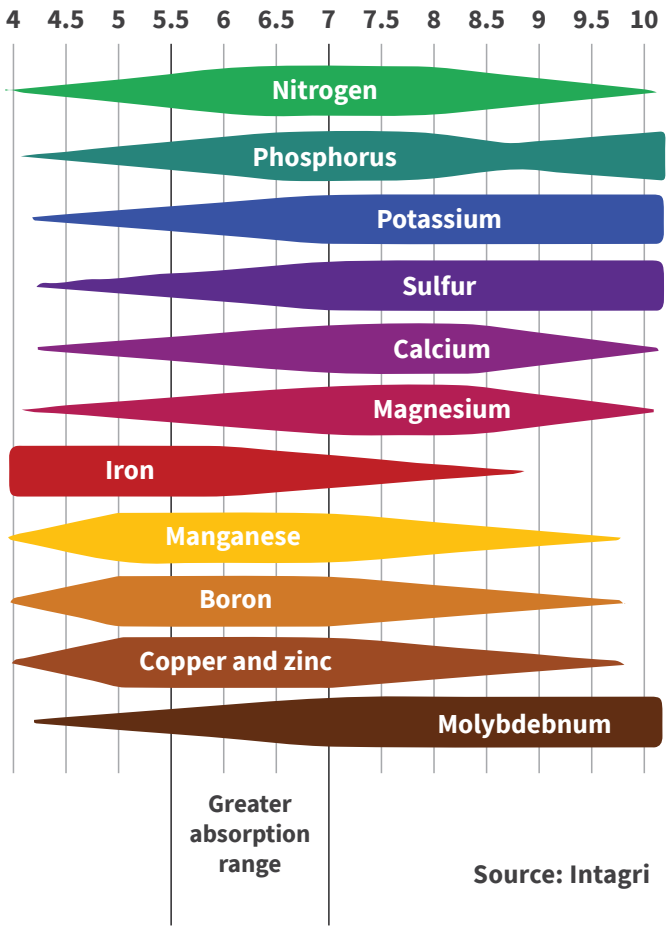
Apart from the importance of proper nutrition, some factors are closely related to correct absorption of nutrients by plants.

WHAT IS PH AND HOW DOES IT IMPACT NUTRIENT AVAILABILITY?

The potential of hydrogen, pH, measures acidity (low pH = acid) or alkalinity (high pH = basic or alkaline) of a medium. pH controls chemical reactions determining if nutrients are or are not available (soluble or insoluble) for absorption. For this reason, the most common nutritional problems occur in crops when the pH is outside its optimum range. Therefore, even if the plant is given all the nutrients it needs, if the pH is out of appropriate range, absorption is impossible.

In a very acidic environment, deficiencies of nitrogen, potassium, calcium and magnesium may occur; while with high pH the solubility of iron, phosphorus, manganese, zinc and copper may decrease.

The pH range recommended for coffee is 5.4 - 6.8.



Source: Intagri

PROCEDURE TO MEASURE PH

Prior to measuring, make sure that the pH meter is well calibrated.

Measurements are made based on a substrate at field capacity (not too wet or dry).

Steps to follow:

1. Take several samples from a batch in a homogeneous way, removing the substrate in the whole section of the container, from top to bottom.
2. Stir the samples uniformly in a container.
3. Take the sample before fertilizing or remove all fertilizer grains from the mixture.
4. Weigh 20 g of substrate in a beaker.
5. Add 50 ml of distilled water.
6. Mix well and let stand 30 minutes.
7. Mix again and measure with the pH meter directly the beaker solution.
8. Record all the information (date, sampling place, operator, lot, and container).

ELECTRICAL CONDUCTIVITY (EC): WHAT IT IS AND HOW IT AFFECTS PLANT NUTRITION

Electrical conductivity measures the concentration of soluble salts in substrate. This means that the more electrical conductivity, the higher the concentration of salts. Ideally, EC in substrates is low, preferably less than 0.5 mS. For coffee 0.5 mS/cm up to 3 mS cm (millisiemens per meter) is seen as normal. Low EC facilitates managing fertilization and avoiding phytotoxicity issues in the crop.

EC allows to determine substrate salinity, that is, the higher the CE, the more elements in the solution.

PROCEDURE TO MEASURE EC

Prior to measuring, make sure that the conductivity meter is well calibrated.

Measurements are made based on a substrate at field capacity (not too wet or dry).

Steps to follow:

1. Take several samples from a batch in a homogeneous way, removing the substrate in the whole section of the container, from top to bottom.
2. Stir the samples uniformly in a container.
3. Take the sample before fertilizing or remove all fertilizer grains from the mixture.
4. Measure 100 ml of substrate in a beaker.
5. Add 150 ml of distilled water.
6. Mix for 30 minutes.
7. Filter the solution with a cone equipped with a coffee filter.
8. Measure the filtered solution with the conductivity meter directly on the beaker.
9. Carry all the information in a record (date, place of sampling, operator, lot, and container).

Note: Generally, samples with high conductivity have low pH.

In case different samples are taken, rinse the pH meter and the conductivity meter between each measurement with distilled water. Sample every two weeks or monthly at most to fix problems on time.

MACRO AND MICRO ELEMENTS

MACRONUTRIENTS

Coffee requires several nutrients to reach its maximum production potential from a nutrition point of view. Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) are considered macronutrients for coffee plants.

N

Nitrogen is the key element for coffee, especially for vegetative development, growth of new shoots, and green color.

P

Phosphorus helps develop good roots thus providing plants with greater support.

K

Potassium plays a key role in hardening tissues.

Ca

Calcium plays a major role in the development of roots and cell walls.

Mg

Magnesium plays a major role in photosynthesis and plant development.

S

Sulfur is essential to produce chlorophyll.

Example of management plans to maintain nursery plantations in line with seedling development are offered below.

MICRONUTRIENTS

Micronutrients playing a key role in coffee are Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), Boron (B), Chlorine (Cl), and Molybdenum (Mo).

Many coffee formulas include micronutrients, also, only little amounts of these are needed.

For optimal plant growth nutrients must be absorbed and then distributed in adequate proportions. Maintaining this nutritional balance can create or expand synergism and antagonism between nutrients in the soil. **The excess of one of them can cause lack of another.**

This infographic shows where nutritional deficiencies in juvenile stage of coffee seedlings appear.

NUTRITIONAL DEFICIENCIES

Coffee requires several nutrients to reach maximum production potential from a nutrition point of view. Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) are considered macronutrients for coffee plants.

Notice that the symptoms mentioned below may also be related to poisoning, pests or diseases. Please check well before taking remedial action.

DEFICIENCY OF NITROGEN

Symptoms of deficiency:

- Chlorosis or general yellow color of mature leaves
- Lower vegetative growth
- Possible defoliation
- Decrease in chlorophyll content

Source: ECOM

LEAVES

DEFICIENCY OF PHOSPHORUS

Symptoms of deficiency:

- Slow plant growth
- Poor root system
- Small leaves

Source: ECOM

LEAVES

ROOTS

DEFICIENCY OF MAGNESIUM

Symptoms of deficiency:

- Decreased vegetative growth
- Yellow spots seen against the light between leaf veins

Source: ECOM

LEAVES

DEFICIENCY OF CALCIUM

Symptoms of deficiency:

- Marginal chlorosis at the edges of young leaves
- Corrugated leaves
- Necrosis and deformation of tips
- Generalized pale green color

Source: ECOM

LEAVES

ROOTS

DEFICIENCY OF BORON

Symptoms of deficiency:

- Deformation
- Reduced size
- Elongation
- Yellowing of central and side veins

LEAVES

DEFICIENCY OF ZINC

Symptoms of deficiency:

- Chlorosis of new leaves (except veins)
- Reduced leaf size
- Reduction of distance between knots
- Leaves crinkle inwards
- Small, narrow, pale leaves
- Rough leaf texture, wrinkling

Source: ECOM

LEAVES

TOXICITY

MAJOR TOXICITY PROBLEMS

Toxicity can occur at nurseries during the entire production process. Therefore, it is key to manage fertilization carefully and to ensure good pH and EC pattern.

Seedlings are highly sensitive to fertilizer toxicity. Very high levels can even cause death to seedlings.

Even if toxicity does not cause death, it still can halt plant growth and cause yellow leaves and leaf-drop in certain cases. Typically, this is due to low pH or increased EC, preventing nutrient assimilation. In this case, wash the substrate with water to drain excess nutrients and/or use lime to increase pH. Applying molasses in a soil drench application (irrigation to roots) or foliar amino acids can help plants recover. It is recommendable to stop fertilizing the soil for some time until the plant recovers.

SOIL CONDITIONERS

Soil conditioners are generally applied when using substrate based on topsoil or handmade mixtures to reduce mixture acidity and control some pathogens. They are added after disinfecting substrates and prior to using them.

Liquid soil conditioners can also be added in drench applications (liquid irrigation to roots), reducing labor costs.

FERTILIZER

There is a broad line of fertilizers in the market that can be classified as edaphic, water soluble, and foliar.

- **Edaphic** fertilizers come with physical formulas (less efficient) or chemical formulas (direct release or slow release). Slow release fertilizers allow greater use of nutrients by plants, avoid leaching and reduce soil acidification.
- **Water-soluble** fertilizers are either liquid or soluble powder. Most water-soluble fertilizers have an acid reaction (except for calcium nitrate, for instance), so they must be used with appropriate doses.
- **Foliar** fertilizers can be transferred through salts and oxides, synthetic chelates or amino acids. The latter is more efficient for absorption by plants.

GERMINATION STAGE

At this stage, germinated seedlings for buds or rootstock are obtained. Germination takes place within 40 - 60 days for viable plants. Nutritional and phytosanitary recommendations are made below. Notice that many ways to handle exist. Thus, it is best to ask an agronomist for a plan for the nursery and continuously assess it, adapt it and make changes for seedling welfare.

GOLD - GERMINATION TRAYS

	Fertilization	Time
Edaphic fertilization	No (CE < 1mS)	None
Nutritional foliar plan	(NPK+ME), starting with the butterfly stage	Once per week
Phytosanitary foliar plan	Apply fungicide starting with germination stage	Once per week

SILVER - GERMINATION BEDS WITH INERT SUBSTRATE

	Fertilization	Time
Edaphic fertilization	No CE < 0.5mS	None
Nutritional foliar plan	(NPK+ME), starting with the butterfly stage	(NPK+ME), starting with the butterfly stage
Phytosanitary foliar plan	Fungicides between germination and seedling stage	2 times per week

BRONZE - SAND BED

	Fertilization	Time
Edaphic fertilization	No CE < 0.3mS	None
Nutritional foliar plan	None	None
Phytosanitary foliar plan	Fungicide in seedling stage	Only one time

GRAFT ACCLIMATIZATION STAGE

Acclimatization usually lasts between 4 and 8 weeks, depending on climate conditions and management of seedling.

Nutritional and phytosanitary recommendations are made below. Note that there are many ways to manage seedlings. Thus, it is best to ask an agronomist for a plan for the nursery and continuously assess it, adapt it and make changes for seedling welfare.

GOLD - SUBSTRATE BLOCK

	Fertilization	Time
Edaphic fertilization	Controlled released fertilizer[1] (3 - 5g/l) + Water soluble fertilizers NPK+ME (1.4-2.0 mS)	Use fertilizer only once, when mixing + water soluble fertilizers. Once per week between weeks 5 and 8
Nutritional foliar plan	Nutritional fertilization (NPK+ME)	Twice per week
Phytosanitary foliar plan	Fungicide/ bactericide	Twice per week

SILVER - TRAYS

	Fertilization	Time
Edaphic fertilization	Controlled released fertilizer to the substrate (3 to 5g/l)	Use fertilizer only once, when mixing
Edaphic fertilization	Nutritional fertilization (NPK+ME)	Once per week
Edaphic fertilization	Fungicide/ bactericide	Once per week

BRONZE - BED

	Fertilization	Time
Edaphic fertilization	Water soluble fertilizers NPK+ME (1.4-2.0 mS)	Water soluble fertilizers once per week between weeks 5 and 8
Nutritional foliar plan	Nutritional fertilization (NPK+ME)	Every two weeks
Phytosanitary foliar plan	Fungicide/ bactericide	Every two weeks

[1]Sample formulas of controlled released fertilizers: 15-9-12, 14-14-14. Formulas vary per country. Something similar may be looked for.

MAINTENANCE OF SEEDLINGS

To maintain seedlings, first they are transplanted from beds, trays or substrate blocks to tubettes or bags where they will grow for later transplantion to the field. At this stage seedlings should be given proper conditions needed to grow quickly with good health.

The time they spend at the maintenance stage depends on plant demand and size requirements of customers. Nutritional and phytosanitary recommendations are made below. Note that there are many ways to manage plants. Thus, it is best to ask an agronomist for a plan for the nursery and continuously assess it, adapt it and make changes for seedling welfare.

Broadcast scattering of fertilizer is not recommended as it can result in unequal application leading to toxicity for some plants and deficiency for others.

SILVER - SUBSTRATE + SOIL BAG

	Fertilization	Time
Edaphic fertilization	Controlled released fertilizer (3 - 5g / plant + add lime to substrate + granulated fertilizer 18-46-0 diluted	All three are combined with substrate only one time
Nutritional application plan (leaves)	Nutritional fertilization (NPK+ME)	Every two weeks
Phytosanitary application plan	Fungicide/ bactericide	Every two weeks

GOLD - SUBSTRATE + TUBETTE

	Fertilization	Time
Edaphic fertilization	Controlled released fertilizer included in the mixture (3 - 5g/l) + water soluble NPK+ME (1.6-2.5 mS)	Fertilizer used only once when mixing + water soluble fertilizers every 10-15 days after 3-4 weeks after transplanting
Nutritional foliar plan	Nutritional fertilization (NPK+ME)	Once per week
Phytosanitary foliar plan	Fungicide/ bactericide	Once per week

BRONZE - SOIL BAG

	Fertilization	Time
Edaphic fertilization	Edaphic fertilizer applied after planting (3-5g/plant) + Granulated fertilizer 18- 46-0, dilute	Both are mixed with substrate only once
Nutritional foliar plan	Nutritional fertilization (NPK+ME)	Every two weeks
Phytosanitary foliar plan	1 fungicide/ bactericide	Every thirty days

Notice: the formula must be applied based on substrate analysis and individual variety requirements.

An important point about phytosanitary control is the daily inspection of nurseries to detect problems in time and try to control the problem in a localized way.

CRITICAL POINTS IN RELATION TO FERTILIZATION

Complies	Does not comply	Critical Point
		To ensure nutrient absorption, apply fertilizers in the recommended pH range for coffee (5.4 and 6.8)
		Keep electrical conductivity between 0.5 mS/cm and 3 mS/cm (millisiemens per meter)
		Conduct chemical analyses of substrates to adjust for fertilization
		Use fertilizer from certified suppliers
		Fertilize in line with individual varieties nutritional requirements
		Apply fertilizer according to seedlings growth stage
		Check seedlings daily for toxicity
		Daily check seedbeds for phitosanitary issues and potential toxicity

B. DISEASE AND PEST MANAGEMENT IN NURSERIES

INSECTS

Information about major pests affecting coffee seedlings in nurseries and their management follows.

When only a small number of seedlings have been harmed by insects, to separate those plants and treat them as appropriate. For advanced infestation throughout the nursery, take measures throughout the entire lot.

MEALYBUG (*Planococcus citri*)

Mealybugs measure 3 to 5 mm long, with oval bodies and yellow cuticles. They are covered with a floury white carapace.

Major symptoms

- Yellow plants.
- Mealybugs produce sugary secretions, where the fungus *Capnodium sp* (Fumagina) develops forming a black film on the leaves which interferes with photosynthesis. Ants feed on these secretions, and therefore a symbiosis is created. Ants will transport the mealybugs to different plants.

Preventive management

- Eliminate weeds within and around the nursery. Be careful when bringing materials from other nurseries.

Cultural control

- Eliminate plants heavily infested with the pest.
- Avoid highly nitrogenized fertilization.

Biological control

- Natural predators like *Chrysoperla sp* can be used.

Chemical control

- To apply insecticide, mix it with agricultural mineral oil because mealybug shell protects it against insecticides. Oil penetrates this barrier and makes them vulnerable.

APHIDS *(Aphis coffeae)*

They are small insects (2 mm long), yellow, light green or black. They reproduce quickly creating large colonies in a short time. They like the tender shoots of leaves because they suck their sap.

Preventive management

- Eliminate weeds within and around the nursery. Be careful when bringing materials from other nurseries.

Cultural control

- Eliminate plants heavily infested with the pest.
- Avoid highly nitrogenized fertilization.

Biological control

- Predator insects regulating aphid populations include coccinellids, chrysopidae, and syrphids.

Chemical control

- Use only insecticides allowed in the country and follow the guidelines in the safety sheet of each product, also called MSDS (Material Safety Data Sheet). It is advisable to delimit and mark sites to treat only the shrubs under attack. This way beneficial organisms will not be impacted.

COFFEE LEAF MINER *(Leucoptera coffeella)*

Micro lepidopteran whose female lays eggs taking 6 to 10 days to hatch. The larvae penetrate the leaf tissue and go through four larval stages lasting between 16 and 26 days. After the fourth stage, the larva builds a white cocoon with silk threads on the underside of the leaf. At this stage, it is not vulnerable to insecticides. This stage lasts about 14 days.

Preventive management

- Eliminate weeds within and around the nursery. Be careful when bringing materials from other nurseries.

Biological control

- Biological control wasps can be found in the market including *Polistes spp*. and *Polybia spp*. Fungi like *Beauveria bassiana* and *Metarhizium anisopliaean* can also be used.

Chemical control

- Nursery owners are urged to use first both cultural and biological control, since insecticides have a detrimental effect on the populations of beneficial insects. However, if the damage is very large, insecticides can be applied.

Coffee leaf miner

FUNGI

Fungi harming mainly nursery seedlings will be dealt with here. For more information about coffee fungi such as coffee rust, anthracnose and American leafspot see the *Good Practices Guide: Coffee Seed Production,* Module 2, Section E: Pest and disease control.

DAMPING OFF *(Rhizoctonia solani)*

Damping off shows in sites where there are seedlings with black or yellow leaves, or dead seedlings. Symptoms include dark spots on the roots and cankers at the base of stems. These impede translocation of water and minerals, resulting in death. Damping off is caused by fungi in the soil and in infected plant material or those found in specialized structures (sclerotia or chlamydospores). They spread by contaminated soil particles carried by the wind, through sprinkle from raindrops, tools, and other means in the area.

Preventive management

- Change substrate every time a new germination or graft transplantation process is to be started. In addition, this substrate must be previously disinfected. For more detail on how to disinfect substrates see Module 2, section C of this guide.
- The material to cover the planted area or the plastic tunnel must be clean (new, one that has not touched the floor, or washed with disinfectant).
- Disinfect tools, materials used in the nursery, and workers' hands.
- Use non-polluted water sources.

Cultural control

- Facilitate aeration between plants by planting them following density recommendations.
- Discard sick/dead seedlings to avoid propagation.
- Avoid excess water/waterlogging.
- Use drained substrates.
- Avoid highly acidic pH.

Biological control

- Different fungi or mycorrhizae can help fight/compete for space, such as *Trichoderma sp.*

Chemical control

- In case of fungi, apply allowed contact fungicides such as strobilurins, carbamates and cupric fungicides. (It is better to avoid triazoles as they tend to intoxicate the seedlings).

CANKER *(Myrothecium roridum)*

Infected coffee shows symptoms of canker in the lower portions of stems and/or rotting of main root. This results in adventitious roots in the portions of the stem located under the canker or at the base of the main root. Young plants die in cases of very severe infection; in other cases plants can survive but they die when grown and transplanted to the field.

Halos (round necrotic spots) with sporulation on the underside of the leaves appear.

Preventive management

- Treat substrate with preventive fungicide before establishing seedbeds or nurseries.
- Transplant only healthy seedlings.
- Carry out transplantation activities under strict hygiene measures.

Cultural control

- Facilitate aeration between plants by leaving a space between each pair of plant rows and provide height to the shade mesh.
- Keep a strict moisture control.
- Eliminate dead plants.
- Constantly monitor the nursery for damaged and chlorotic leaves and plants. Separate these shrubs and look for cankers and/or adventitious roots and destroy diseased plants.

No effective chemical control exists for canker. Separate and destroy diseased plants. In case of severe attack, consider removing everything and conducting deep disinfection of structures.

CERCOSPORA LEAF SPOT *(Cercospora coffeicola)*

Leaf infection begins through stomata creating circular lesions with dark-brick colored edge, clear center and in some cases a chlorotic halo. Initially they are small, but they can increase, eventually causing premature fall of leaves.

Preventive management

- Provide good nutritional balance to young coffee shrubs in the nursery.
- Use healthy, strong plants to start planting.

Chemical control

- In case the disease progresses, apply allowed contact fungicides, such as strobilurins, carbamates and cupric fungicides. (It is better to avoid triazoles as they tend to poison seedlings).

BACTERIA

Xylella fastidiosa

Xylella fastidiosa (Coffee Leaf Scorch) proliferates in the internal ducts (xilema) of roots, stems and leaves. Ducts in infected plants are blocked due to the bacteria and gums of the infection. The vectors for this bacterium are insects known as “leafhoppers”, “grasshoppers” or “toritos” (homoptera of the Cicadidae family). When insects bite infected plants, the bacterium multiplies inside the vector. After several days, the vector is able to pass the disease to healthy plants.

Vector de la Xylella

Major symptoms of *Xylella fastidiosa*

- Loss of turgor of leaves on the upper part of plants.
- Progressive exhaustion of plants with symptoms of chlorosis and defoliation.
- Malformation of leaves, especially due to the presence of narrow, small and elongated leaves with wavy edges and a yellowish green to red coloration.
- Short internodes, proliferation of buds.

Strong temperature changes increase the chances for attack by bacteria. Pay attention to shade net change (to dull or give more light to seedlings) and acclimatization before selling/shipping.

Vector control is extremely important in coffee nurseries.

Cultural control

- Discard dead plants.
- Constantly check nursery for damaged leaves and the viscosity that characterizes the bacteria. Separate these shrubs and check them for several days.
- Keep the nursery free of weeds.

Recommended sanitary control

- Discard sick plant in case of strong attack.
- Apply copper-based treatment.
- Drain to reduce relative moisture.
- Control excess shade.
- Reduce nitrogen fertilization and increase potassium applications.

Pseudomonas syringae

Symptoms start with brown to black necrotic spots surrounded by yellow halos. Extreme cases involve falling leaves.

Source: CafeiCultura Magazine

Cultural control

- Discard bags of dead plants
- Constantly check nursery for damaged leaves and those showing the viscosity typical of the bacteria. Separate those shrubs and check them for several days
- Protect the nursery against strong wind

Recommended sanitary control

- Discard sick plant in case of strong attack
- Apply copper-based treatment
- Drain to reduce relative moisture
- Control excess shade

Strong temperature changes increase the chances for attack by bacteria. Pay attention to shade net change (to dull or give more light to seedlings) and acclimatization before selling/ shipping.

THINGS TO CHECK BEFORE SELLING OR FINAL PLANTING IN THE FIELD

Items to check before sale to growers include,

- Genetic conformity
- Pest/disease free
- Good vegetative/radicular development
- No nutritional deficiencies
- Equitable root system/air system ratio

PLANT MOISTURE

Seedlings dehydrate quickly so they must be fully hydrated to survive the journey.

Extreme withering

Step to take: Separate and water until withering is overcome. Do not send before 7 days to check for problems (burning).

ATYPICAL/MUTANT PLANTS

Mutant plants are those showing differences with their variety from their seedling stage.

Variegated plant showing genetic deficiency

It is key to check plants well before diagnosing or even send them to the laboratory to analyze since these mutations can be confused with nutritional deficiencies or poisoning.

Step to take: Discard these plants when identified at nursery.

Narrow leaved plants. Leaves are much narrower than normal

Discard these plants at nursery.

PLANTS WITH NUTRITIONAL DEFICIENCIES

Defective plants must not be shipped.

Step to take: Separate and nourish plants. They can be sold later on or planted in the field.

Plants with nitrogen deficiencies

NECROSIS SYMPTOMS

There are several reasons for foliar necrosis including agrochemical and fertilizer toxicity and other external sources like sunlight.

Step to take: Discard the plant and report origin and amount.

EXAMPLES OF HEALTHY PLANTS

Plant with good development level in a soil bag

Plant with good development level in a tubette

Plant with good development level in a substrate block

CRITICAL POINTS IN RELATION TO PEST MANAGEMENT

Complies	Does not comply	Critical Point
		Daily monitoring to check problems with pests, diseases, burns, and toxicity, among others
		Separate plants with pests/diseases and treat them (if they are few). If the disease/pest is impacting the entire lot, treat the whole lot
		In times of plenty of sunlight, cover the seedlings with shade net or some vegetable cover to avoid sunburn; sunscreen can also be applied
		Provide good nutritional balance to seedlings
		Remove weeds around and inside the nursery
		Be careful when bringing materials from other nurseries
		Change substrate each time a new germination or graft transplant process is about to start. Substrate must be previously disinfected.
		The material to cover the planted area or the plastic tunnel must be clean (new, one that has not touched the floor, or washed with disinfectant)
		Disinfect tools and materials used in the nursery
		Use non-polluted water sources
		Facilitate aeration between plants by leaving a space between each pair of plant rows and provide enough height to the shade mesh
		Keep a strict moisture control
		Eliminate bags were plants died

C. IRRIGATION

Irrigation is an important factor in plant development. Nursery owners need to ensure enough quality water throughout the production process of plants.

Before using water, conduct physical/chemical sampling in a laboratory to check for quality and identify remedial needed, if necessary.

Irrigation must be controlled and adjusted to the phenological status of plants, environmental conditions and substrate used.

Nursery owners must respect water regulations of their country, both related to source use and related to nursery wastewater.

There are several irrigation systems available in the market.

MANUAL IRRIGATION

Manual irrigation is generally used in countries where labor is cheap and material costs are high, at small nurseries or with many lots with different phenological stages. It is also used in highly-technified nurseries to irrigate edges or specific dry plants. Irrigation staff can use continuous flow hoses or showers (a more artisan system). With hoses, it is preferable to use irrigation stake with nozzle to make sure water will not hit the plant or extract/splash substrate.

AUTOMATIC IRRIGATION

Automated irrigation is common in countries where access to technology is cheap and easy and labor is expensive. They are mainly large nurseries with single, uniform sowing. It is also a common in arid places, since automated irrigation tends to be more efficient than manual irrigation in terms of water consumption.

There are common systems of water guns and micro sprinklers systems. They are chosen according to water flow/ pressure available.

Some major issues to consider in relation to irrigation include:

1. When using sprinkler or spray irrigation, give continuous maintenance to sprinkler nozzles to ensure even, constant watering.
2. Ensure constant pressure at every point in the system.
3. Avoid drip irrigation at germination stage as some spots may not receive enough water.
4. Short, constant irrigation is recommended, for instance, 2 or 3 times per day, depending on climate. Do not flood plants.

CRITICAL POINTS INRELATION TO IRRIGATION

Complies	Does not comply	Critical Point
		Water plants preferably daily, even several times per day, for short periods of time
		Water must come free from pollutants
		Irrigation must be even and abundant

MODULE 5

RECOMMENDATION FOR INFRASTRUCTURES FROM GERMINATION TO MAINTENANCE

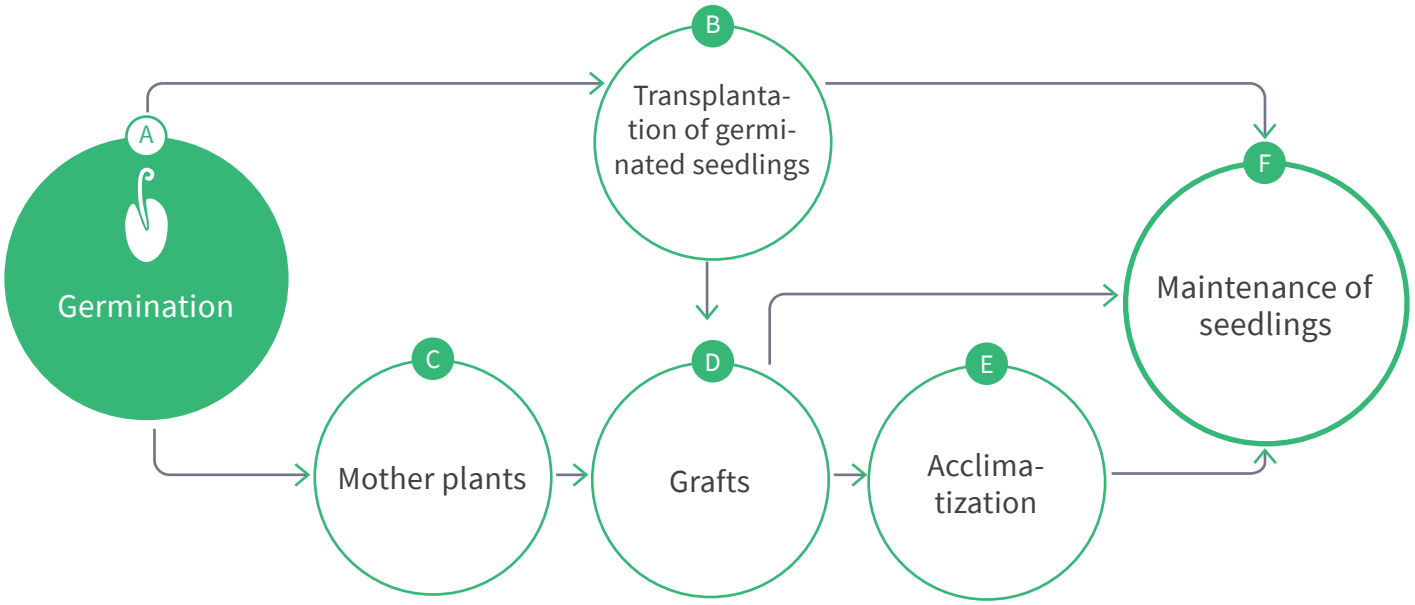
MODULE 5 - CONTENTS

Module 5 describes different types of infrastructure recommended according to the stage of growth of seeds/ seedlings.

Plants have different needs at each stage of growth, from germination to grafting to acclimation to maintenance. Therefore, appropriate infrastructures are built to meet their needs at each stage.

STAGES OF NURSERY DEVELOPEMENT

Seed selection is intended to guarantee its viability to obtain high quality plants ensuring success for future plantations.



A. STRUCTURE REQUIRED FOR GERMINATION

Germination can take place on different types of structures, depending on growers' means. However, growers must meet a number of minimum requirements for coffee seed germination. Minimum requirements are listed below, as well as examples of structures useful at this stage.

Minimum requirements for germination infrastructure:

- Controlled ventilation, protection against strong wind.
- Allow brightness between 40% and 20%.
- Roofs at least 2.5 meters high.
- No cross shade from trees or buildings.
- Located in a warm zone (minimum temperature 18°C, maximum 35°C, average 22°C -26°C).
- The structure must protect seedlings against heavy rain.

Risks of having inappropriate infrastructure

- Improper seedling development.
- Higher seedling mortality.
- Uneven germination in the same lot or it takes longer than normal germination.
- Higher risk that seeds will not germinate due to attack by fungi, bacteria, insects or rotting.

Classification of the external structure required for proper germination, by levels.

GOLD LEVEL: GREENHOUSE

Requirements:

- Plastic walls to protect seedbeds against wind.
- Moderate brightness: 40 to 20%.
- Roofs at least 2.5 meters high.
- Fertilization and irrigation can be controlled automatically.

Greenhouse

SILVER LEVEL: SHADE NET STRUCTURE

Requirements:

- Enclosed shade net structure with live barriers close by, if possible, to protect seedbeds against gusts of wind
- Preferably metal structure (galvanized iron) or else wooden.
- Graduate brightness from 40% to 20%.
- Roofs at least 2.5 meter high.

Example of germination beds

BRONZE LEVEL: CANVAS, STRAW OR O VEGETAL COVER

Requirements:

Rustic, variable structure according to producer means. Minimum requirements include,

- Controlled ventilation in an area protected against strong wind
- Moderate brightness: 40 to 20%.
- Roofs at least 2.5 meters high.
- No cross shade from trees or buildings.

Improved traditional germinator

Seedbed with canvas

Traditional germinator

SEEDLING CONDITIONS AND CYCLE IN THE GERMINATION STAGE

STAGE	SHADE	TEMPERATURE	LENGTH	PHENOLOGICAL STATUS
Germination	The entire cycle	Temperature min 18°C, max 35°C (Avg 22-26°C)	40-60 days	Until turning into germinated seedlings or "butterflies"

B. STRUCTURE REQUIRED FOR HARDENING GERMANINATED SEEDS/GRAFTS

Some guidelines about the structure required at the area where germinated seedlings are transplanted to substrate blocks, tubettes or bags are given below. These also apply to transplant of grafts to substrate blocks, tubettes or bags.

GOLD LEVEL: GREENHOUSE

- Plastic walls to protect against wind.
- Graduate brightness from 40% to 20%.
- Roofs at least 2.5 meters high.
- Strict hygiene conditions implemented at door.
- Inert substrates
- Concrete floor

SILVER LEVEL: SHADE NET STRUCTURE

- Enclosed shade net structure with live barriers close by, if possible, to protect against gusts of wind.
- Preferably metal structure (galvanized iron) or else wooden.
- Graduate brightness from 40% to 20%.
- Roofs at least 2.5 meters high.
- Inert substrates.
- Ground or sand floor covered with geotextile or geomembrane.

BRONZE LEVEL: CANVAS, STRAW OR VEGETAL COVER

- Controlled ventilation in an area protected against strong wind.
- Moderate brightness between 40% and 20%.
- Roofs at least 2.5 meters high.
- No cross shade from trees or buildings.
- Disinfected substrates.
- Ground or sand floor.

Transplanted seedlings | **Filling bags for transplant** | **Transplantation in full sunlight (Not recommended)**

Inert substrates: Previously sterilized substrates such as peat, sand, and stone or previously disinfected handmade substrates like compost, bokashi, rice husks, sawdust, etc. For further information see Module 2, section C of this guide.

Strict hygiene conditions: They include washing hands with antibacterial soap, clean shoes, washing boots/shoes with disinfectant solution, and clean clothes. For further information see Module 3, section C of this guide.

C. STRUCTURE TO MAINTAIN MOTHER PLANTS

Some guidelines about the structure required in the area where mother plants are maintained, either in substrate blocks, tubettes or bags. These also apply to the maintenance of graft seedlings transplanted to substrate blocks, tubettes or bags.

GOLD LEVEL

Roof

- Enclosed area with transparent thick greenhouse plastic roof.
- Luminosity can range between7,000 and 20,000 lux. Depending on climate zone, shade nets may be used to mitigate luminosity.
- Minimum height between floor and ceiling is 2.5m to avoid high thermal amplitude.

Support

- Trays with mother plants are placed on tables to avoid contact with the floor and proliferation of fungi and disease.
- Tables must be made of strong materials able to resist humidity.
- Table size depends on work capacity. A suitable size can be 1m high and 1.2m wide.

Entering

- Enter wearing lab coats/area-specific aprons.
- Use foot baths (to wash boots or shoes)
- Enter lobby type SAS to wash hands and put on apron.

Irrigation

- Fertilization-irrigation by sprinkling or dripping.

Mother plants greenhouse

SILVER LEVEL

Roof

- Preferably enclosed with plastic/shade net roof (40% - 60% shade)
- Luminosity can range between7,000 and 20,000 lux.
- Minimum height between floor and ceiling is 2.5m.

Support

- Trays with mother plants are placed on tables to avoid contact with the floor and proliferation of fungi and disease.
- Tables must be made of strong materials able to resist humidity.
- Table size depends on work capacity. A suitable size can be 1m high and 1.2m wide.

Irrigation

- Sprinkler irrigation is recommended, but it can also be done with a shower in a directed manner.

Mother plants greenhouse

D. STRUCTURE REQUIRED FOR GRAFTING

A hygienic space is needed to graft in order to ensure greater viability of seedlings, minimizing contamination by pathogens and mortality.

GOLD LEVEL

Roof, sides, and floor

- Enclosed area, like a concrete warehouse or similar material.
- Minimum height between floor and ceiling: 2.5m to avoid high thermal amplitude.
- Concrete floor or similar.
- Sufficient natural or artificial light is required to perform the grafting process.

Work tables

- The tables must be made of stainless steel and grafters must sit to do the work.
- Table size depends on work capacity. A suitable size can be 1m high and 1.2m wide.

Entering

- Enter wearing lab coats/area-specific aprons.
- Wash hands properly with soap up to the elbows before entering, after eating, going to the bathroom or changing activities.
- Use foot baths (to wash boots or shoes).
- Enter lobby type SAS to wash hands and put on apron.

SILVER LEVEL

Roof, sides, and floor

- Semi-enclosed area, made of wood or sheets.
- Minimum height between floor and ceiling: 2.5m to avoid high thermal amplitude.
- Clean canvas or grit floor.
- Enough natural or artificial light is required to perform the grafting process.

Work tables

- The tables can be made of plastic or wood and grafters must sit to do the work.
- Table size depends on work capacity. A suitable size can be 1m high and 1.2m wide.

Entering

- Enter wearing lab coats/area-specific aprons.
- Wash hands properly up to the elbows before entering, after eating, going to the bathroom or changing activities.
- Use foot baths (to wash boots or shoes).

Grafting area

Sink at grafting area

BRONZE LEVEL

Roof, sides, and floor

- Semi-enclosed area made of wood or sheets
- Minimum height between floor and ceiling is 2.5m to avoid high thermal amplitude.
- Ground floor.
- Enough natural or artificial light is required to perform the grafting process.

Work tables

- The tables can be made of plastic or wood and grafters must sit to do the work.
- Table size depends on work capacity. A suitable size can be 1m high and 1.2m wide.

Entering

- Wash hands properly up to the elbows before entering, after eating, going to the bathroom or changing activities.

Discard vegetative materials falling on the floor.

E. STRUCTURE REQUIRED FOR ACCLIMATIZATION

ACCLIMATIZATION TUNNELS

Acclimatization is the process through which the required temperature and moisture are provided to the grafts to ensure maximum viability.

Infrastructure

- **Acclimatization macrotunnel**

Various models are available in the market. The larger the volume, the less thermal amplitudes it will have inside. A building with stainless steel materials, wind resistance, and plastic manufactured for this use (with ultraviolet treatment) should be considered. The macrotunnel can be said to be the greenhouse protecting the microtunnels and the first protection filter for seedlings.

- **Tables**

The dimensions of the tables to place micros tunnels must be in line with operational and management needs, mainly for the personnel in charge of the maneuvers. They must allow placing the trays and carry out with ease other activities in the general management program. For example, a 3m wide and 15m long tunnel can accommodate 2 microtunnels 1.20m wide by 14.5m long by 0.8m high. Tables are not always needed. Microtunnels can also be placed on the floor as long as it is made of concrete or a geotextile material is used to cover the floor to minimize the risk of pathogens.

Sample macrotunnel

Tables to install at microtunnel

Microtunnel on the floor

Acclimatization microtunnels

To acclimatize, it is recommended to build a tunnel in each of the beds where transplanted plants are placed. They are hermetic, with thin white plastic sheets for greater diffusion of light, in order to create a very confined internal environment and thus give grafts the highly-humid climate they require.

At some farms microtunnels are used in germination beds to increase temperature and control humidity, which results in faster seed germination.

Example of microtunnel

Floor covered by geotextile material

Clips for acclimatization tunnels

Irrigation

Irrigation by micro nebulization or high pressure in the macrotunnel is most appropriate to maintain the desired climate, high relative humidity and controlled temperature, 22-28°C. Watering can also be done manually with showers, but the tunnel must be covered immediately after watering.

Acclimatization tunnel. Nebulized water is intended to increase moisture in the environment

Roof and floor

The roof can be made of plastic sheet or any other material allowing the passage of sunlight.

The floor must preferably be made of gravel or stone to prevent proliferation of pathogens.

SEEDLING CONDITIONS AND CYCLE IN THE ACCLIMATIZATION STAGE

STAGE

Acclimatization

SHADE

Entire cycle

TEMPERATURE

Relative moisture >90% and controlled temperature (22-28°C)

LENGTH

6-8 weeks

PHENOLOGICAL STATUS

2 pairs of leaves (5-10 cm)

F. STRUCTURE REQUIRED FOR SUCCESSFUL NURSERY MAINTENANCE

After acclimatization or transplantation, plants are transferred to the maintenance area. At this stage, they must be given conditions similar to those in the field. Different types of structures can be used in line with growers' possibilities.

For the first 4-8 weeks of acclimatization, it is advisable to place plants under shade net, canvas, or palm roofs.

GOLD LEVEL

Roof and sides

- Galvanized iron structure for sides and ceiling where shade net is placed. Shade net can be pulled aside according to seedlings age and need for brightness.
- The minimum height between floor and ceiling is 2.5 m to avoid high thermal amplitude.
- Leveled ground floor covered with sand.

Irrigation

- Irrigation by spraying or dripping.

Shade net roof for the first maintenance stages

Roof for the first stages of seedling life

SILVER LEVEL

Roof and sides

- Galvanized iron structure or wooden materials for sides and roof for sides and ceiling where shade net is placed. Shade net can be pulled aside according to seedlings age and need for brightness.
- The minimum height between floor and ceiling is 2.5 m to avoid high thermal amplitude.
- Leveled ground floor.

Example of shade net infrastructure or the first stages of seedling maintenance

Irrigation

- Manual/sprinkler irrigation.

BRONZE LEVEL

Roof and sides

- Wood or living trees structure; roof with wooden strips or tree trunks covered with dried leaves, palm leaves, banana leaves or another organic element. The shade is eliminated when plants do not need it and can be re-placed in times of excessive sunlight.
- Ground floor.

Example of shadow roof with plant material for the first maintenance stages

Irrigation

- Manual/sprinkler irrigation.

Examples of recommended maintenance when plant is transfered to open field:

Maintenance at final stages

Maintenance in tubettes

SEEDLING CONDITIONS AND CYCLE AT THE MAINTENANCE STAGE

STAGE	SHADE	TEMPERATURE	LENGTH	PHENOLOGICAL STATUS
Maintenance	From transplantation on	Temperature: min: 18°C max: 35°C (avg: 22-26°C)	2-3 months	3-4 pairs of leaves (18- 20 cm)
	Progressive change in full sunlight	Temperature: min: 18°C max: 35°C	2-3 months to delivery to grower	4-6 pairs of leaves (20- 30cm)

ACTIVITIES NOT RECOMMENDED FOR SEEDLINGS AT NURSERIES

Seedlings in early stage with no shade

Seedlings under natural shade (Not the best practice as some portions may be more exposed to sunlight than others)

TRACEABILITY

Nurseries must maintain seedling traceability from seed to sale.

Among other tools, they must create a Master Map to locate areas under production on a variety-by-variety basis, with seed germination, acclimatization and/or maintenance areas. Each area is assigned a unique code and maps are kept updated as groups of plants in the different areas are transplanted or moved, depending on the availability of physical space. For more details, see Module 6, Traceability.

CRITICAL POINTS INRELATION TO INFRASTRUCTURE

Complies	Does not comply	Critical Point
		Controlled ventilation; protection against strong winds.
		Moderate luminosity, between 40% and 20%.
		Ceilings at least 2.5 meters high.
		No cross shade from trees or buildings.
		Located in a warm area (minimum temperature 18° C, maximum temperature 35° C, average 22° C -26°C).
		Strong structures able to withstand heavy rain and winds.
		No waterlogging. Consider humidity conditions mentioned above.

MODULE 6

TRACEABILITY AND MARKETING

MODULE 6 - CONTENTS

Module 6 provides a guide to maintaining traceability and a general description of the seed sale process.

In the previous modules, the importance of traceability and records at nurseries was succinctly mentioned and specific recommendations were made. Although this is a key issue, it is often disregarded by nursery owners. For this reason, an entire chapter is devoted to this topic in this guide.

In most countries, seed sales are governed by particular laws, which may differ if seeds are being imported vs. exported. To better understand the requirements in a particular country, it is highly recommended to visit the Ministry of Agriculture as well as export promoting agencies in each country.

A. GENERAL TRACEABILITY SYSTEM AT NURSERIES

GENERAL TRACEABILITY SYSTEMS

It is key for nurseries to keep traceability of coffee seedlings from seed to sale. This allows monitoring to ensure **plant health and genetic purity** to optimize production potential. In addition, detailed, up-to-date traceability helps uncover the **source of problems** (e.g., disease or contaminated substrate) and take remedial action quickly and appropriately.

This chapter describes the major elements in such a system.

A reliable traceability system at nurseries is a key guarantee of quality seedlings to buyers.

Two tools must be designed and kept updated at nurseries:

A **Master Map** is needed to accurately locate germination, acclimatization, and maintenance areas. Areas are segmented by variety under production and each one is assigned a unique code. Keep map updated with number of seedlings, variety and origin of material (in case there are plants of the same variety but with different origin). Update the map as groups of seedlings are transplanted or moved to another area.

Each sector in the field must have permanent signage documented in the Master Map to facilitate instructions to workers.

Design a **Sowing Master Timeline** directly related to the area Master Map. Keep it continuously updated.

Table 1. Sample Sowing Master Timeline for a seed variety:

Area code	Variety	Sowing week number	Availability week number	Amount (kg)	Number of seedlings	Lot	Bed

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RECEIVING AND STORING SEEDS

SAMPLE LOG WHEN SEEDS ARE RECEIVED

First, a purchase order must be issued indicating the quantities of each variety, with a percentage of variation, and with its own specification. This is done in order to guarantee the identification of seeds according to agronomic and genotypic criteria, and to make sure they are in line with customer needs. Once seeds are received, a log like the one below is kept.

Table 2. Sample booklog when seeds are received

Record of date of receipt	
Purchase order number	
Shipment references	
Supplier	
Variety specifications	
Number of supplier lot	
Amount shipped	
Amount lost in transportation	
Net amount received	
Add certification if applicable (Rain Forest Alliance, Organic, Bird Friendly, DNA analysis, and certification of origin, if applicable, and so on)	

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Once a month, seed estimates in kilograms are checked and recorded. Adjustments are made to reduce the variation when needed. Usually, weight is adjusted down due to moisture loss.

A single seed lot number - SKU (Stock Keeping Unit) * is always assigned and used. This number is linked to the information received about each seed lot from a specific supplier and written down in a logbook.

Sample SKU **1903-02**

Year Lot Entry into storage

GERMINATION STAGE

MAINTAIN TRACEABILITY OF SOWING

At the germination stage, an updated booklog per area and variety is kept to inform about amount of seed.

Table 3. Sample booklog when seeds are received

Area code	
Specific site code (bed)	
Variety	
Date seed was sown	
Number of seeds planted. Include SKU*	
Name of person in charge of sowing	
Stage to which it is transferred (i.e., transplantation, acclimatization place, nursery)	
Date of collection	
Amount	
Area code/site where transferred	
Name of person in charge of collection	

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KEEP AN ACTIVITY AND APPLICATION RECORD FOR EACH AREA

Table 4. Sample booklog to record disease and pest management activities during germination

Area code	
Specific site code (bed)	
Variety	
Date	
Type of pest/disease to control	
Type of application/activity	
Product applied	
Dose	
Name of person in charge	

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KEEP A MONTHLY RECORD OF SEED GROWTH

Once sowing is done it is important to monitor germination to detect problems. After 20 days, the first radicles of the seeds should emerge. Gently remove substrate at several different points to check. After 30 days seeds turn into germinated seedlings.

Table 5. Sample monthly record of seed growth

Variety	
Lot	
Bed	
Kilograms sown per square meter	
Percentage germination	

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These stages can be affected by several factors responsible for non-germination or delay in germinating of the seeds, such as very low moisture of seeds (little viability), poorly controlled moisture of substrate, seed rotting due to pathogens, and unsuitable climate conditions.

One kilogram of seed usually contains 3,000 seeds. However, this amount may vary depending mainly on variety and percentage of moisture.

KEEP A MONTHLY RECORD OF SEEDLINGS

To control inventory, a card can be used to keep control of a variety, entry and removal, and to keep track of stocks of this product at the nursery.

Table 6. Sample booklog to control general inventory

INVENTORY CONTROL							
NAME OF PRODUCT:	Caturra						
DATE	**DESCRIPTION**	**ENTRY**	**REMOVAL**				**TOTAL STOCK**
			SALE	**TRANSFER**	**REPLACEMENT**	**DISCARDED**	
May-16-19	Initial inventory						**16970**
May-24-19	Sowing	5670					**22640**

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TRASPLANTATION STAGE

When transplanting, each seedling is given a code. Each package, tray or individual pot is properly marked with an ID label or bar code to maintain its integrity continuously. This code is also useful to track the SKU of the seed lot and the place it was previously stored.

KEEP A RECORD OF SEEDLING GRAFTING

Table 7. Sample logbook to keep traceability of grafts made per day

Variety	Variety of	Date	Requested Amount	Actual Amount	Difference
H1	Robusta	2-12-19	1200	1250	50

KEEP A RECORD FOR TRANSPLANTATION OF SEEDLINGS TO BAGS/TUBETTES

Table 8. Sample log to record bag/tubette filling activities

Mix and filling of bags or tubettes					Transplantation				
Date	Bed number	Operators names	Mising ratio	Types of bags/ tubettes	Date	Variety	Container	Quantity	Operator's name

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It is also recommendable to record substrate type, as well as package used for each seedling.

MAINTENANCE STAGE

KEEP SEEDLING TRACEABILITY AT THE MAINTENANCE STAGE

At the maintenance stage, make sure number of seedlings with individual codes, per variety, and in each area are kept up to date.

Table 9. Sample logbook for the Maintenance stage

Area code	
Specific location	
Variety	
Number of seedlings to grow	
List of codes for growing seedlings	
Date of arrival	
Individual responsible for entering them	
Stage to which seedlings are moved (i.e., nursery, waste, sale)	
Date moved	
Number of seedlings moved	
Codes of seedlings moved	
Individual responsible for moving them	

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For each area:

KEEP AN ACTIVITY AND APPLICATION RECORD

Just like at the germination stage, a logbook is kept to record the fertilization and pest and disease management activities. For more information, see a sample activity log and application in this Module, at the Germination stage, sub-chapter B.

KEEP A MONTHLY RECORD OF SEEDLING GROWTH

The growth record helps identify growth issues and take appropriate, timely remedial action to maximize growth and minimize mortality rates.

KEEP A MONTHLY INVENTORY OF SEEDLINGS

To know the number of seedling of a given variety in a specific area, as well as their precise code identification, a logbook system can be used.

In addition, to ensure full traceability:

- Each seedling is located by code at the bed map.
- Bed data are linked to customers' purchase-order data.

Always keep different varieties in different beds.

Table 10. Sample logbook for the Maintenance stage

Area code	
Specific location	
Variety	
Percentage of replanting (percentage of seedlings dying two weeks after transplanting)	
Mortality rate (percentage of seedlings dying after replanting)	
Percentage not complying with shipment characteristics	

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Table 11. Sample monthly plant inventory

Area code	
Variety	
Location	
Number of seedlings at the beginning of the month	
Codes assigned to each seedling	
Number of seedlings moved and from what location (that is, another bed, waste, sale, and so on)	
Seedling code	
Number of seedlings at month end	
Name of person in charge	

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B. MARKETING OF SEEDLINGS

Each nursery must comply with local commercial and phytosanitary regulations. Some countries require that nurseries be registered with the health institutions, and that they produce and commercialize only varieties registered in the country's catalog of varieties. **Please contact the phytosanitary authorities of each country to check requirements.**

In case of exporting, requirements and import permits granted by the country of destination must be met. Tests are commonly performed to demonstrate products are free from pests and diseases. Once the documentation process is over, a phytosanitary certificate is issued to allow exports.

In both cases a seedling sale card must be completed with the complete information (lot, date, variety, customer, address, product, etc.)

Table 12. Sample monthly plant inventory

Name of farm seedlings come from	
Buyer name	
Date seedlings were purchased	
Seedling lot code	
Variety	
Driver name and surname	
Type of vehicle	
License plate #	
Number of seedlings shipped	
Signature of sender	
Name of person in charge of making the entry of the lot to the storage facility	
Comments	

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CRITICAL POINTS IN RELATION TO TRACEABILITY IN NURSERIES

Complies	Does not comply	Critical Point
		Updated master map of germination, acclimatization, and maintenance.
		Updated sowing master schedule
		Updated logbook for the reception of seeds and seedlings.
		Updated germination record.
		Updated record of activities and applications per area
		Updated monthly seedling growth record
		Updated seedling graft record
		Updated monthly seedling inventory (Kardex)
		Updated transplantation record
		Updated monthly inventory of seedlings
		Updated seedling sales or shipment cards

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