SECOND EDITION

WORLD COFFEE RESEARCH

GOOD PRACTICE GUIDE

COFFEE NURSERY MANAGEMENT

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WORLD COFFEE RESEARCH

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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 not only make sure that they are selecting the right variety, but also that the seeds/seedlings that they are planting are all of their chosen variety, and that each one has the best physical/phytosanitary quality to attain its highest production potential.

World Coffee Research (WCR) and a network of collaborators have created three guides: one on the production of coffee seed, one on nursery management, and one the profitable administration of coffee seed and nursery businesses. 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 both 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 sections on traceability, ranging from the purchase of seeds or plants to produce mother plants to the sale or planting of the seeds/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 best practices guide is intended to serve as a useful tool for nursery owners, managers, and technicians, helping them identify ways to improve their practices for best 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 situational 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.

GLOSSARY

Aerobic:
The process in which oxygen is included for development.

Anaerobic:
The process in which oxygen is not included for development.

Seedling:
A term used mainly in Central America that refers to a set of coffee seedlings, to the place where they are produced, and (sometimes) to the individual seedling. Often called “Almácigo” in Spanish.

Coffee Producer:
A producer of coffee beans, coffee seeds, and/or seedlings.

Seed Producer:
A coffee producer that produces fruit to be converted into seed.

Weeding:
Cutting unwanted weeds or grasses in the field.

Cotyledon:
The first leaf (either alone or alongside other leaves) that forms in the embryo of a plant. In Spanish this is commonly known as the “Mariposa” or Butterfly.

Sieve/Screen:
A table or a machine with mesh that has holes of a specific size to classify coffee beans by size after screening.

Shoot Selection:
The process of pruning unwanted shoots from the main coffee stem after the initial pruning process. After pruning, most coffee plants will reproduce too many branches/shoots from the main stem for the plant to support. In Spanish this is commonly referred to as "Deshija."

Water Stress:
When plant demand for water is higher than the amount available during a given period leading to a loss in growth and/or producitivty potential.

Slow/Controlled-Release Fertilizers:
Fertilizers that provide or release nutrients bit by bit after being incorporated into the soil, usually via resin-encapsulated fertilizer technology.

“Match” or “Little Soldier” Stage:
The state of the seedling growth after germination when the stem grows, but the cotyledons are still enclosed in the husk or parchment. Often called “fósforo, grapa, and/or soldadito” in Spanish.

Initial Harvest:
The process of harvesting coffee beans that ripen a few days or weeks before peak harvest. This process is of vital importance to ensure quality, so as not to include beans that are overripe, branch dried, or affected by the coffee borer beatle. Note that the beans from this harvest are usually of lower quality.

Semi-ripe Beans:
The coffee cherries that are not completely ripe during harvest. These beans should be avoided for seed production. Ex: Cherries may be bright red on the top, but yellow/orange on the bottom and therefore not fully ripe.

Seed Lot:
A section of coffee shrubs planted for the purpose of harvesting seeds for future propagation.

Butterfly Stage:
The stage of seeding growth where first leaf (alone or alongside other leaves) forms in the embryo of a plant. In Spanish this is commonly known as the “Mariposa” stage.

Machete:
A long knife primarily used to cut weeds.

NSF (National Sanitation Foundation):
An organization that develops public health standards and certifications to help protect food, water, consumer products, and the environment. As an independent and accredited organization, it assesses, audits and certifies products and systems, as well as providing training and risk management. (More information can be found at http://www.nsf.org).

Breeder:
A person or company that develops/patents plant varieties and accompanying research.

Parafilm:
A sheet of semi-transparent, flexible and waterproof material that is used as a barrier against moisture and the entry of pathogens. It is commonly used to seal grafts, ensure the rootstock and the scion, and prevent the entry of diseases into the tissue.

Rootstock:
In grafting, a rootstock is the base elements provided by the plant, the stem, and the root system. In general, it is ideal to have the rootstock come from a species or variety that is resistant to diseases. Rootstocks are commonly used in the grafting of Coffea canephora (Robusta coffee).

Atypical Plant/Mutation:
A plant that is different from the pre-established variety due to its properties or characteristics. This can come in the form of different sizes, different leaf shape, and/or different leaf color. These mutations vary from the original variety according to genotypic or phenotypic characteristics.

Seedling:
The stage of a plant from germination until transplantation in the field.

Final Harvest Stage:
The process of harvesting the coffee beans that mature after the peak harvest. This process is of vital importance in order to prevent the spread of the coffee berry borer in the soil. Also called “Raspa” or “Repela” in Spanish.

Royalties:
The annual payment for the patent of invention for different varieties’ use and commercialization.

Suspended Solids:
The small solid particles that remain in suspended in water as a colloid or due to the movement of water. It is used as an indicator of water quality.

Substrate:
Material or mixture of materials used to fill plant bags/ containers.

Terraces:
An area left level/flat around a plant to eliminate slope and reduce erosion.

Transplanting:
The process of moving a seedling from one container to another or from the seedbed to the final container.

Plant Tube:
A type of reusable plastic container in the form of a tube that is used to replace the traditional plastic plant bag.

Peat:
An inert, dark brown, and carbon-rich organic material. It is spongy in texture and formed by decomposed vegetable components that can still be seen in the peat. It’s commonly utilized in the germination and growth phases of plants.

Nursery Producer:
A producer of plant seedlings.

World Coffee Research:
A non-profit organization, dedicated growing, protecting, and enhancing supplies of quality coffee while improving the livelihoods of the families who produce it.(More information at https://worldcoffeeresearch.org).

Scion Graft:
The upper fragment of a grafted plant that contributes the genetic material. The scion often overlaps the graft.

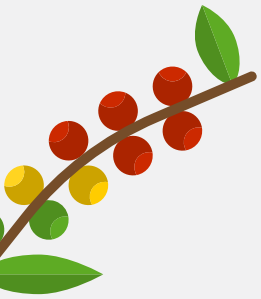
MODULE 1

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 the characteristics of different varieties in detail in order to help 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

Susceptibility

Resistant
Tolerant
Susceptible

Nutritional requirements

Low demand — High demand

VARIETY	QUALITY POTENTIAL SHOWN	YIELD POTENTIAL	YEARS TO FIRST HARVEST	NUTRITIONAL REQUIREMENTS	SUSCEPTIBILITY: COFFEE RUST	SUSCEPTIBILITY: ANTHRACOSIS	SUSCEPTIBILITY: NEMATODES
CATIMOR 129	4	5	2	NPK NPK NPK	Susceptible	Susceptible	Susceptible
GEISHA (PANAMA)	5	2	4	NPK NPK NPK	Tolerant	Susceptible	Susceptible
JAVA	4	2	3	NPK NPK NPK	Tolerant	Tolerant	Susceptible
ANACAFE 14	3	4	2	NPK NPK NPK	Resistant	Susceptible	Susceptible
BATIAN	4	4	2	NPK NPK NPK	Tolerant	Resistant	Susceptible
CENTROAMERICANO (F1 HYBRID)	4	5	2	NPK NPK NPK Very high	Resistant	Tolerant	Susceptible
K7	3	4	3	NPK NPK NPK	Tolerant	Tolerant	Susceptible

VARIETY	QUALITY POTENTIAL SHOWN	YIELD POTENTIAL	YEARS TO FIRST HARVEST	NUTRITIONAL REQUIREMENTS	SUSCEPTIBILITY: COFFEE RUST	SUSCEPTIBILITY: ANTHRACOSIS	SUSCEPTIBILITY: 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 to no profit from the plants.

If the nursery engages in selling seedlings, it must select the varieties with characteristics that are in line with potential customers' needs. In other words, it must take into account criteria such as altitude, the climate/weather conditions, disease prevalence, harvest time, etc.

Included below is a brief guide on coffee varieties and their characteristics. By providing a better understanding about coffee varieties and how they grow, coffee growers' can gain more background in order to better understand the local agronomists'/organizations' variety recommendations.

A. TRADITIONAL VARIETIES

HISTORICAL SUMMARY OF COFFEE VARIETIES

Coffee plants originated in Africa. The two major commerically-farmed species are *Coffea arabica* and *Coffea canephora* (also called Robusta).

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

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

Coffea canephora

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. Brough to African Mainland in 1840.
3. From Africa it was taken to Brazil in 1860 and then spread into Central America.

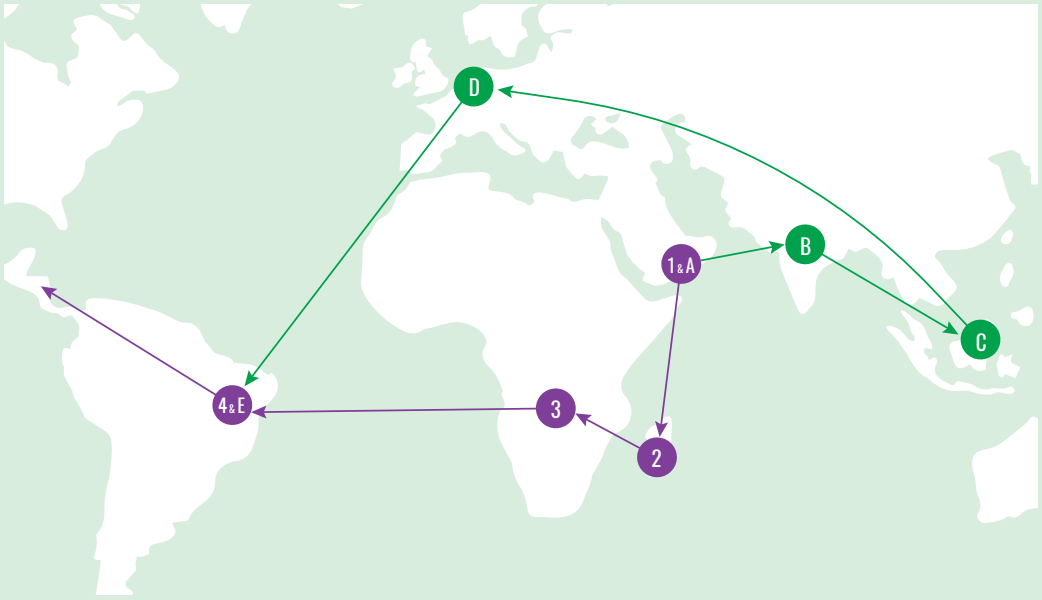
Typica Lineage

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, Martinique, and Brazil. Then to the rest of South America and Central America.



Until the 1940s, most Central American farms consisted of Typica. Since Typica 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, Dominica, Jamaica, and the Dominican Republic.

EVOLUTION OF COMPACT STATURE MATERIALS SELECTION

FIRST STAGE:

During the Green Revolution in the 1950s, researchers created varieties/genetic 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 cup quality, but susceptible to coffee rust.

SECOND STAGE:

With the spread of coffee leaf 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. This resulted 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 was 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 cup quality) and improved introgressed varieties (productive and resistant to coffee rust). They were then 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 cup 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, cup 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 promising 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, so that the resuling offspring have the same characteristics as the mother plant. For more details, please see WCR's *Best 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**

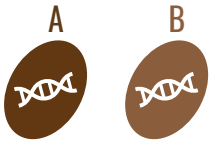
F1 HYBRIDS

WHAT ARE F1 HYBRIDS?

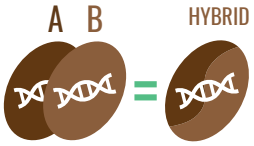
F1 hybrids are a new generation of coffee varieties. An F1 hybrid is created by crossbreeding two genetically different *C. arabica* parents. Many of these relatively new varieties were created to combine the best traits of both parents, including high cup quality, high yield, and disease resistance. 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 a closed flower.
2. Emasculate the flower/receiving plants (mother plants). (Remove flower stamens/staminoides before they open).
3. Collect pollen from donor (father).
4. Maunally pollinate the mother flower.
5. Cover the flower 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

CONTROLLED POLINATION

CV = Commercial Variety (Caturra, Catuaí, Catimor)

S = Wild (Ethiopian)

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**

FIELD EVALUATION OF F1 HYBRIDS

- **Production**
- **Pest and disease resistance**
- **Fruit defects**
- **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

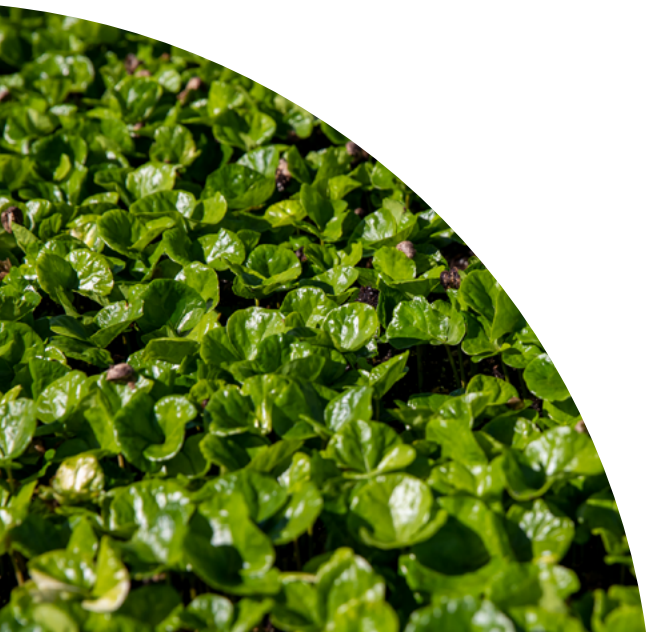
To make sure seeds capable of growing into healthy, strong seedlings with genetic purity are obtained, it is advisable for nurseries to purchase only established, well described varieties (see the WCR Arabica Coffee Varieties catalog for a list). Seed/seedlings should be purchased from certified seed 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 analyzes the method of sexual propagation by seed, with a number of best practices to be followed for nursery operators. 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), fruits normally contain two seeds.

Coffee flower

The success of a 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

On average, it takes thirty-two weeks (224 days) from initial flowering to fruit maturation. 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.

Coffee fruit

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 must be certified to ensure both quality and genetic purity of plants.
2. If a 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 seed propagation

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

PREPARING GERMINATION AREAS

It is critical to determine the specific areas that meet the minimum conditions necessary for coffee seed germination. Likewise, it is very important that the producer plans their germination schedule according the climatic conditions of their region. Germination processes are affected by the weather, so it is recommended to plan the right time so as not to have delays in the process and also so that the seedling is finished in time for the appropriate planting season.

The types of structures required for germination are detailed below. To learn more about the appropriate infrastructure for germination areas, review Module 5.

GERMINATION BEDS

Seeds: Seed bed size should be determined according to available space. Beds should measure no more than 1.25m wide and at least 20cm deep. These size requirements help to ensure an efficient workflow for the nursery operator. Widths greater than 1.25m will make it more difficult for the nursery worker to reach the entire seed bed.

Bed structure: The seed beds should be raised from the ground, 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, and animals.

If the seeds beds are on the ground, a plastic sheet should be placed between the ground and the substrate material in order to reduce the risk of contamination. The plastic should be perforated to allow for proper drainage.

Substrates for germination: A bottom layer of volcanic stone or sand is recommended. To ensure drainage, this layer should be at least 5 cm thick. This is especially important for germination beds sitting directly on the ground in order to avoid contamination.

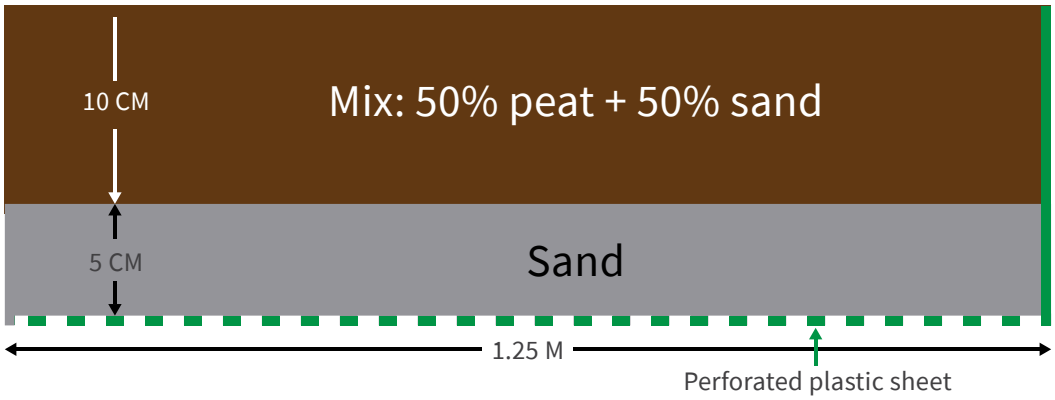
The substrate should preferably be made of peat moss mixed with fine sand. Sand quality is essential. It must not be too fine to avoid compaction, nor too coarse to avoid problems of root development and germination due to lack of moisture.

The sand must be sifted and washed to avoid traces of organic matter. Poorly treated substrates are the main source of microbial contamination in nurseries. Unclean water can also lead to microbial contamination. Sometimes it is advisable to chlorinate the water, especially for large nurseries, to avoid outbreaks of waterborne diseases in the nursery.

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 (grain size 1mm wide) and disinfect with organic or chemical fungicide.
3. The volcanic sand should sit for one day and then be completed the next day 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



In particularly wet conditions, a layer of stone or gravel can be added under the sand to assist with drainage.

Sand selection is critical in order to avoid soil compaction (too fine sand) and/or porosity (too coarse sand). Once the bed is prepared, it should be covered until usage in order to prevent rain from splashing on it and removing the substrate from its place. The material to cover it can be weed-free plant material, plastic wrap, or disinfected jute bags. Plastic sheets can also be used in order to carry out the solarization disinfection process, as mentioned on page 15.

The seedbed or germination bed can be used again for several cycles with the same substrate, as long as there was no problem with any disease during the previous cycles. If there was issues with diseases in the substrate then the mixture must be changed. If the substrate is reused, it should be disinfected again to remove any pathogens and sieved to remove any seed residue that could affect 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 details the inert substrates and handmade mixtures for germination beds, mother plants, transplanting, and maintenance. It is recommended to adjust substrate percentages and provide adequate nutritional management in each phase that the seedling goes through. The process from germination to maintenance is detailed in this Module 2 and in Module 3.

CHARACTERISTICS

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

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

The 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 examined when inspecting substrates (and their raw material) are:

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

GOLD LEVEL: INERT SUBSTRATES

From the germination stage to the maintenance stage of growth, it is advisable to use mixtures previously tested with coffee such as peat, sand, gravel or stone, etc.

However, previously disinfected handmade mixtures can also 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 also 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 effectiveness 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 used in many farms due to lower cost and high availability of raw materials. It is advisable to perform tests at a nursery with varying material percentages in order to determine the mixture best suited for coffee germination. 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 are:

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 organic 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/coir

- 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 seeds, etc.

It is key to carry out chemical analysis of the raw material to be used or to request it from the supplier. At the very least, pH and electrical conductivity should be measured. The pH of the substrate should 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 leaf edge burning.

STORING SUBSTRATES

To store substrates,

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

TRACEABILITY

When using purchased substrate, keep the:

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 the 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 in coffee seedbeds.

Phytosanitary treatment can be biological, chemical or physical, according to the 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 on the right).

BOILING WATER TECHNIQUE

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

SOLARIZATION TECHNIQUE

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

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, put them in water for at least 12 hours in order to rewet the seeds. The rewetting of seeds in water 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. If a bag is used for the imbibition process, it must be made of a material that allows water to enter so that the stimulating action of the water and the seeds soaking in it is effective. If the seeds are not fresh, it is recommended to remove them from the bag for this process and then eliminate all the seeds that float to the top (since they could have lower germination rates).

Soaking seeds

2 On the day of sowing, randomly and hmoogeneously place the seeds in the previously moistened substrate. Then, cover the seeds with a 50%/50% (substrate/sand) mixture. Covering the seed is key: if it is covered with a very thick layer, germination can be delayed and uneven. If it is very thin, the seed can partially dry and not germinate. A layer of substrate 5mm to 7mm thick is recommended to cover the seeds. Space permitting, an excellent way to avoid the transmission of possible diseases is to plant in discontinuous lines, in this way, if any disease outbreak appears, it is easier to correct. The separations can be 5 cm, there can also be physical separations such as plastic pieces.

Acclimatization microtunnel

3 Once this process is completed, 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 methods to water germination beds:

Water appropriately, both in terms of water amount and frequency in order to improve plant development. It is recommended to monitor the soil moisture with a meterto keep moisture around 18%.

GOLD LEVEL

Water misters: 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 should be analyzed to find the nutritional contribution of each mixture inrder 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 the health of seedlings in germinators daily in order 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.

Take into account that one of the main sources of infection are the hands and shoes of the people who enter the nursery, as well as the use of contaminated tools or materials. Strict control of handwashing, shoes and tool disinfection must always be maintained in order to avoid diseases.

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. If fungal diseases are discovered in the germination beds, 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.*

If a fungicide application had been made previously, the procedure must be reviewed and it must be decided whether it is necessary to increase the dose or the frequency. This will depend on the product used.

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 check, remove substrate on the seed at several points. After 30 days, seeds are 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 stages 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. Seed age can also influence germination rates.

TRACEABILITY

Growth must be recorded in each plot to monitor germination including data such as type of substrate used, pH, shade levels, substrate moisture, soil/environmental temperature, and 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 transplanted directly into bags or tubettes for planting in the field at a later date (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

Carefully harvest seedlings 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 during removal.

STEP 2

Discard poor quality seedlings. Staff in charge of harvesting must be able to select material meeting the minimum seedling selection 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. Paper towels are often used to moisten the roots and potassium silicate spray is also recommended to reduce seedling dehydration.

STEP 4

Spray seedlings with water to keep them hydrated when harvesting before transplantation or storage.

STEP 5

Store seedlings 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

Cotyledon seedling fit for transplantation

Seedling fit for transplantation

SEEDLING SELECTION AND DISPOSAL

Seedlings are strictly selected to ensure that they meet the characteristics for optimal growth. They are then sorted by size for uniform production. Although the seedling roots will never be perfectly straight and without curvature, 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

It is best to transplant seedlings on the same day in order to ensure a healthy growth, avoid shrinkage, and diminish morality rates.

1. Discard poor quality seedlings (see Section: *Selection and Disposal*) and count them.
2. Put wet paper towels or newspapers on a tray and pack the germinated seedlings. Seal the tray with plastic and adhesive tape.

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

Packing germinated seedlings

Once the germinated seedlings are packaged, they are moved to the reseeding area. Seedlings can be planted in bags, tubettes, or substrate blocks. The seedling containers must optimize seed germination and growth of transplanted seedlings, in addition to ensuring plant health. Thus, the seedlings must be stored properly to prevent contamination or degradation of quality. In addition, seedlings must undergo quality control upon receipt and during storage.

For further details see Module 3.

CRITICAL POINTS IN RELATION TO GERMINATION OF SEEDS

Complies	Does not comply	Critical Point
		Seeds to sow must be certified to ensure plant quality and genetic purity.
		Different coffee variety seeds should be propagated at separate greenhouses or physically separate areas in order to ensure seed traceability.
		Asexual reproduction infastructure must meet minimum requirements.
		Substrate is disinfected to avoid disease and fungi.
		Meets requirements related to structure and proper management of germination beds.
		Comply with selection criteria for germinated seeds (aka cotyledons) after harvest in order 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.
		Use clean water for irrigation.
		Clean hands and shoes of those who enter the greenhouse area in order to avoid the loss of seeds and seedlings due to microbial diseases.
		Sow seeds in rows.
		Comply with the size of the suggested germination beds or terraces.
		Comply with the recommendations to avoid waterlogging and drainage problems
		Comply with the recommended criteria for the substrate (i.e. free of pests and diseases, without compaction, free of objects such as stones or sticks, etc.)

TRACEABILITY

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

If you want to read more about coffee grafting please refer to page 28 of the manual. This phase is usually carried out between the germination phase and transplantation into the final bag or container.

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. Therefore, 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, all of 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—due 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 to climate change, sustainable agroforestry practices, and overall performance.

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

1. **In vitro reproduction**: 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 mother plant leaf fragments. This technique allows for the 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.

Grafted coffee seedlings

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 identically reproduced
- Increases productivity and pest/disease resistance
- Better adaptation to climate change
- Improved coffee production worldwide through improved productivity
- Accelerates the processes of genetic improvement, which can take many years for coffee naturally
- Some experts believe that asexual reproduction allows the plant to bear fruit earlier in its life cycle

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.

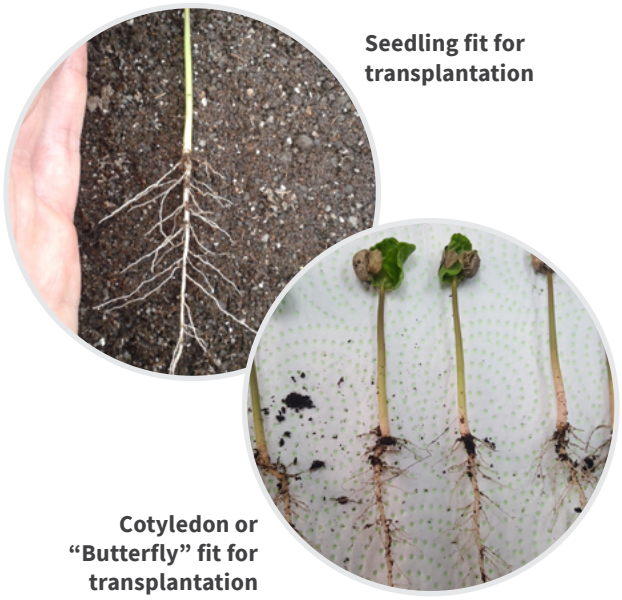
NOTE: This information applies to grafting using rootstock from germinated seedlings. Generally, grafting with germinated seedlings is more practical, economical, generates better performance, and has a high percentage of viability. Also, it is the most common practice in coffee countries that use the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

The rootstock used for grafting may be in the seedling stage (sometimes called “butterfly” stage). Commonly, grafting is done once the seedling has hardened a bit more and its stem diameter matches the diameter of the bud/scion.



Seedling fit for transplantation

Cotyledon or “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 acclimate/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 greenhouses in order 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 and wash hands with soap.

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 scions can be between 2 cm to 2.5 cm in length. 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.

Disinfect scissors (for instance, with iodine 4cc/l) between cuts.

Example of a perfect bud for grafting

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

PACKING

3. 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.
4. Trays with buds are moved to the area where they are prepared for grafting.
5. 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 IN HANDLING MOTHER PLANTS

Complies	Does not comply	Critical Point
		Follow greenhouse entry protocols
		Follow 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 individuals can perform up to 800 grafts per day.

Requirements for grafting personnel include:

1. All operators must wash their hands to the elbows with soap.
2. Dirty fingernails are not tolerated. Use soap and a 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 requirements may proceed 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.

Work tables

2. **Parafilm strips:** This tape is used to attach the scion to the rootstock. Parafilm strips provide physical support for the graft 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 must 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 method:

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 poor quality rootstocks including those with forked roots, short roots, roots impacted by pathogens, etc.
- The operator must disinfect scissors (ex: Iodine - 4cc/l) between cuts. They must cut the rootstocks evenly at 5cm from their necks (+/- 3mm).
- Once rootstocks are prepared, they must be grouped by packets and delivered to the grafting team.
- Rootstocks should be 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 keeping their work area clean.

4

Preparing Parafilm strips

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

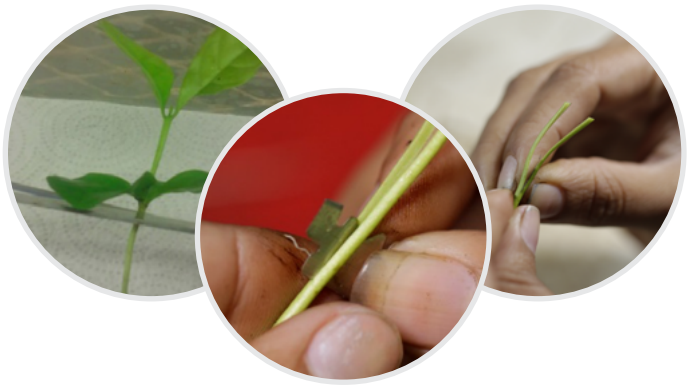
- Preparing homogeneous Parafilm strips for the grafters' team and to keep the grafting area clean. The Parafilm strip is used to preliminary bind rootstock and buds to ensure graft viability.
- The operator is also responsible for continuously delivering rootstocks to individual grafters and keeping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

Scissors

Once everything is prepared, the grafting begins.

5

- First, take a rootstock. Then, 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 on the rootstock.

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

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 the Parafilm holds the plant 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 13 mm in order to avoid strangling the graft.

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

12 Place 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 information for traceability including: variety, grafting date, lot, and the 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 order to resolve any possible future issues with grafts made by one individual. 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. It is recommended to add a general comment at the end of the table describing the main reasons for discarding certain grafts in order to correct bad practices in previous stages that could be causing this situation.

CRITICAL POINTS IN HANDLING GRAFTS

Complies	Does not comply	Critical Point
		Safe facilities and continuous disinfection.
		Follow personnel hygiene protocol.
		Disinfect tools after each cut made between plants.
		Properly rained 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's financial means.

Substrate blocks

[1] IBA = Indolebutyric Acid (IBA), commonly used as a rooting agent.

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, they must take the grafts and immerse their roots in a rooting solution (IBA)[1] for 10 seconds.
- Then, they must make a 5.5 cm-6 cm deep hole in the substrate block.
- 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 in order to prevent roots from bending.
- The seedlings must be taken to the acclimatization area.
- Between 2 and 6 weeks must elapse before making final inventory counts of viable grafts.

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, they must take the grafts and immerse their roots in a rooting solution (IBA)[1] for 10 seconds.
- Then, they must make a 5.5 cm-6 cm deep hole in the substrate block.
- 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 in order 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, they must take the grafts and immerse the roots in a rooting solution (AIB) for 10 seconds.
- Then, they 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 toward the root in order 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 done 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, must be imported.

Trays

TRAYS

Advantages

- Easy handling.
- Makes inventory checks easier.
- Low cost.

Disadvantages

- Damage to root system when seeds are extracted.
- Proper proportions 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 is 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

TRANSFERRING GRAFTS TO ACCLIMATIZATION

Grafts sown in substrate blocks or trays must be moved to the acclimatization area while 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. Both the operator and the cart should go through the foot washing area.

ACCLIMATIZATION TUNNELS

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

To do so, tunnels are recommended. They are built hermetically with a very confined internal environment in order to give grafts the weather conditions they require with a high moisture content. Thin white plastic is used as covering in order to provide greater diffusion of light

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. Then, soak 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 in order 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. Hold it down with clips to make it more airtight.
- Plants can be brought in one day after disinfection. However, it is recommended 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 completed, viable grafts are counted and the plastic sheet is lifted progressively, until it is completely uncovered. At this stage grafts are ready for sale. However, it is best to move them to a hardening area, where they are transplanted to a larger container in order to have a more robust plant for final sale.

Note: Train an operator to monitor relative humidity and temperature within each tunnel. Once the graft has been checked and is confirmed healthy, 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 (but not limited to): a physical space code, variety, and the date/number of plants with their SKUs (Stock Keeping Unit) codes. Also, it is best to maintain an updated master map. See chapter on General traceability system in nurseries in **Module 6.**

Give each plant a SKU code.

CRITICAL POINTS INRELATION TO ACCLIMATIZATION

Complies	Does not comply	Critical Point
		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. The mix can be made with a mixing machine or with shovels in a clean area. It is important to evenly mix in order to homogenize fertilizer.

This substrate can be used in different support structures such as tubettes, substrate blocks, and biodegradable containers for transplantation at a later date.

SILVER LEVEL

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

In addition to the already mentioned characteristics of peat, other inert materials that can be added to the mixture include:

Sand

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

Gravel (stone)

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

Note: The choice of a suitable substrate is critical in the development of a strong root system

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 soil pH making it more alkaline.

Vermicompost

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

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. Perform a substrate nematode analysis.
2. Buy inert substrate or always disinfect substrate before use.
3. Substrate must be free of pebbles and debris and it should not arrive very wet.
4. Store the substrate in sealed bags to reduce the entry of air, pathogens, insects and even rodents. The storage site should not get too hot. There should also be a system of pest traps to prevent contamination.

TRACEABILITY

1. When using purchased substrate keep the 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 covers 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. It is recommended for nurseries to conduct a nutrient analysis of substrates to compensate for nutritional deficiencies through fertilizer formulas, if needed.

Requirements for effective fertilization

- Purchase fertilizer from certified suppliers
- Fertilize plants in line with variety/substrate nutritional requirements
- Apply fertilizer in line with the plant growth stage

Risks from a lack of appropriate nutrition

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

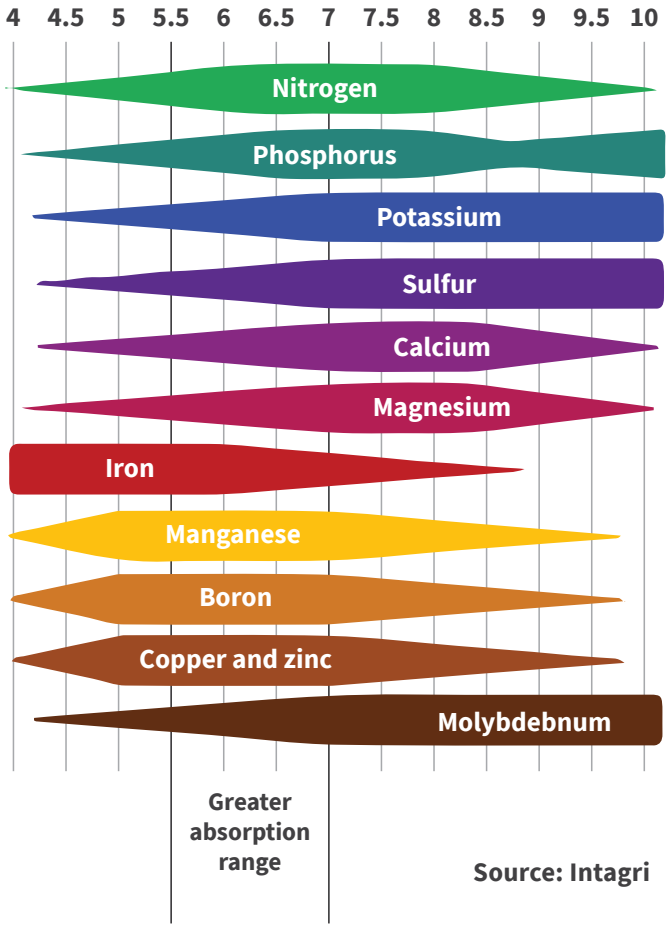
Apart from the importance of proper nutrition, some other factors are also closely related to the proper absorption of nutrients by plants.

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 the chemical reactions of plant nutrient uptake, 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 of the optimum range. Therefore, even if the plant is given all the nutrients it needs, if the pH is out of appropriate range, absorption is nearly impossible.

In a very acidic environment, deficiencies of nitrogen, potassium, calcium and magnesium may occur. In high pH environments (alkaline), the solubility of iron, phosphorus, manganese, zinc and copper may decrease.

The pH range recommended for coffee is **5.4 - 6.8.**



Source: Intagri

PROCEDURES 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 too dry).

Steps to follow:

1. Take several samples from a soil batch, removing the substrate in the whole core of the container, from top to bottom. Take samples uniformly.
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 location, 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 to 3 mS/cm (millisiemens per centimeter) is seen as normal. Low EC facilitates managing fertilization and avoiding phytotoxicity issues in the crop.

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

PROCEDURE TO MEASURING EC

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

Keep in mind that collecting data in the field can be complicated and requires trained and meticulous personnel. If you think that field sampling may be risky, use a laboratory instead.

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

Steps to follow:

1. Take several samples from a soil batch, removing the substrate in the whole core of the container, from top to bottom. Take samples uniformly.
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. Record all the information (date, sampling location, operator, lot, and container).

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

When conducting multiple samples in one day, make sure to rinse the pH and conductivity meters with distilled water between each measurement. Sample at least biweekly or monthly to address issues 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 health 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 nurseries in line with seedling development are offered below.

MICRONUTRIENTS

Micronutrients that play 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, but only small 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. **An excess of one of these nutrients can cause lack of another.**

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

NUTRITIONAL DEFICIENCIES

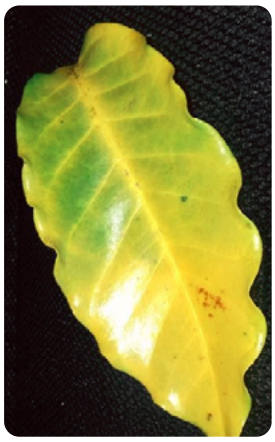
Coffee requires several nutrients to reach maximum production potential. Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) are considered macronutrients for coffee plants.

Please note that the symptoms mentioned below may also be related to poisoning, pests or diseases. Therefore, it's important to check for the external issues before taking remedial fertilization 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 ensure proper pH and EC levels.

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 uptake. 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 recommended to stop fertilizing the soil for some time until the plant recovers.

SOIL CONDITIONERS

Soil conditioners are generally applied when using substrate primarily containing topsoil or handmade mixtures in order to reduce mixture acidity and control some pathogens. They are added prior to using the substrate, after disinfection.

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. Note that there are many methods for germination fertilization. Thus, it is best to consult an agronomist and continuously assess the nursery plan, adapt, 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 4-8 weeks, depending on climate conditions and seedling management.

Nutritional and phytosanitary recommendations are made below.Please note that there are many methods for graft acclimitization. Thus, it is best to consult an agronomist and continuously assess the nursery plan, adapt, 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

[1]Sample formulas of controlled released fertilizers: 15-9-12, 14-14-14. Formulas vary per country. Similar formulas can be used as well.

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

MAINTENANCE OF SEEDLINGS

After germination, seedlings 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 the proper conditions needed to grow quickly with good health.

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

Broadcast scattering of fertilizer is not recommended as it can result in unequal fertilizer 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: These formulas must be applied based on substrate analysis and the individual variety requirements.

Phytosanitary control relies on the daily inspection of nurseries in order to detect problems in time and 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
		Check seedbeds daily for phitosanitary issues and potential toxicity

B. DISEASE AND PEST MANAGEMENT IN NURSERIES

An Integrated Pest Management (IPM) plan is a strategy that contains several control measures that are used together in order to combat a crop pest or disease.

Existing forms of pest and disease control include:

- Cultural practices: Agronomic practices that the producer can carry out to avoid the contagion or dissemination of a pest or disease on coffee plants and the plants that surround them. For example, a cultural practice to reduce the incidence of Coffee Berry Borer (CBB) is the harvesting of all coffee beans, even those on the ground.
- Physical control: The use of direct physical removal means such as traps or physical barriers such as anti-aphid mesh.
- Biological control: The use of additional biological organisms that are natural enemies of the pest to be controlled (predators, pathogens or parasites). For example, the use of entomopathogenic fungi to control insects such as the coffee berry borer.
- Phytogenetic control- The use of materials that are genetically resistant or tolerant to certain diseases or pests. For example, the planting of coffee varieties that tolerate the presence of rust or nematodes in the soil.
- Chemical control- The use of pesticides that affect pests or diseases. It is not recommended to use only this type of approach since, although it could be effective for a specific moment, it does not by itself solve the problems of contagion or incidence over time. Additionally, the sustained use of the same chemical molecules on a pest can encourage it to generate resistance to the applied product, making it more difficult to control in the future.

By collectively using all of the above types of measures, the negative impact that pests may have on crop yield over time is reduced.

The economic threshold : it is often said that a pest or disease must be controlled once it crosses the economic threshold. This is defined when the population or incidence affects the crop negatively to the point that the losses caused by them are greater than the cost of controlling the pest or disease. Sampling of pest populations or incidence of diseases provides the necessary information to know when this threshold has been crossed and, therefore, the moment in which control of that organism is necessary.

Pests are populations of organisms that negatively affect a crop and reduce its yield. They can affect different parts of the plant, such as fruits, foliage or roots. Sometimes we lose sight of the fact that pests and other phytopathogens are living organisms that, in their essential role to stay active and reproduce, unfortunately affect coffee plantations. It is important to take into account that, as they are living organisms, having a detailed knowledge of their behavior, habitat, and reproductive cycle allows for the more targeted development of a control plan that is effective in reducing pest populations and the incidence of diseases (or even avoiding contagion from the start). Integrated Pest Management (IPM) plans must also be constantly updated, as pest and disease populations are living organisms and are constantly affected by factors such as temperature, relative humidity, precipitation, and wind speed.

When designing an IPM plan, it is important to take into account the entry method of the pathogen into the the plant, in addition to the biology of the pathogen. Infection can occur through the incorporation of contaminated planting material, or through the use of tools (for example, those used to prune or remove weeds) that are not properly disinfected. New coffee plants or surplus trees planted on the plantation should always be inspected to be free of pests or diseases such as nematodes or Myrothecium. Likewise, tools such as shovels, saws, saws, machetes and others must be disinfected regularly to avoid the spread of diseases such as Fusarium or Rhizoctonia.

Constant sampling is a basic tool for the implementation of an IPM plan since it helps to evaluate the incidence of the negative effects of pests and diseases and also the performance of the measures used for their control. Field sampling and observation can be supported by laboratory analysis if necessary.

INSECTS

The next page provides information on the main pests that affect coffee seedlings in their nursery stage. It also provides background on proper pest management to control issues arising for insect infestations.

CITRUS MEALYBUG *(Planococcus citri)*

There are several species of citrus mealybug, some are aerial (harm foliage) while others harm the plant's roots. In general, the mealybug is 3 to 5 mm long, with an oval body and a yellow cuticle, which is actually a glandular secretion. It is covered with a floury white shell.

Main Symptoms

- Plant yellowing.
- The production of "sugary" secretions, where the fungi, *Capnodium sp.* and *Meliola sp.* (Sooty mold) form a black film on the leaves, which interferes with the photosynthesis of the plant. Ants feed on these secretions, thus forming a symbiosis. The ants are in charge of directing the mealybugs to different plants and spreading the contagion.

Preventative Management

- Eliminate weeds around and inside the nursery. Take precautions when bringing in materials from other nurseries that may be contaminated.

Cultural Control

- Eliminate plants that are heavily infested with the pest.
- Nitrogen fertilizers can help promote the appearance of mealybugs, therefore it's best to carry out constant samplings in addition to creating a balanced plant nutrition plan.

Citrus Mealybug

Biological Control

- Natural predators such as Green Lacewings (*Chrysoperla sp.*) can help control mealybug populations.

Chemical Control

- Insecticides should be mixed with a mineral oil for agricultural use, since the mealybug's shell makes it difficult for insecticides to enter the insect. However, the mineral oil helps to perforate this barrier and makes them susceptible to the insecticide.
- Insecticide applications should be alternated between systemic and contact products.
- Applications should be directed at ants as well as mealybugs.
- Only use insecticides that are allowed in your country and follow the guidelines of the safety data sheet of each product, also called MSDS (Material Safety Data Sheet).
- Applications aimed at root-borne mealybugs must be done in a "drench" system so that the product penetrates and covers the root system.

APHIDS *(Aphis coffeae)*

Aphids are small insects (2mm long) that range from yellow to light green or even black. They reproduce quickly, forming large colonies in a short time. They like the tender buds of the leaves from which they suck the sap.

Preventative Management

- Eliminate weeds around and inside the nursery. Take precautions when bringing in materials from other nurseries that may be contaminated.

Cultural Control

- Eliminate plants that are heavily infested with the pest.
- Nitrogen fertilizers can help promote the appearance of mealybugs, therefore it's best to carry out constant samplings in addition to creating a balanced plant nutrition plan.

Aphids

Biological Control

- Among the predatory insects that regulate aphid populations are: ladybugs, green lacewings and hoverflies.

Chemical Control

- Insecticide applications should be alternated between systemic and contact products.
- Only use insecticides that are allowed in your country and follow the guidelines of the safety data sheet of each product, also called MSDS (Material Safety Data Sheet).
- It is recommended to delimit and mark foci, in order to only treat the impacted coffee plants, and thus not affect beneficial organisms.

COFFEE LEAF MINER *(Leucoptera coffeella)*

The coffee leaf miner is a micro lepidoptera. The female lays eggs which can take six to 10 days to hatch. Then, the larvae penetrate the leaf tissue to feed, where irregular spots of dead tissue called “mines” are formed. The insect goes through four larval stages, which last between 16 to 26 days. After the fourth instar stage, the larva pupates on the leaves, building a white cocoon with silken threads on the underside of the leaf, during which it is not vulnerable to insecticides. This state lasts about 14 days. Strong coffee leaf miner infestations can cause defoliation in plants.

Preventative Management

- Eliminate weeds around and inside the nursery. Take precautions when bringing in materials from other nurseries that may be contaminated.

Cultural Control

- Provide consistent irrigation since drought or dryness benefits the development of larvae.

Biological Control

- Some biological control wasps such as *Polistes spp. & Polybia spp*. feed on the insect. Fungi such as *Beauveria bassiana* and *Metarhizium anisopliae* can also be used.

Chemical Control

- Use of cultural and biological control is encouraged first, as insecticides have a detrimental effect on populations of beneficial insects. However, if the damage is widespread, insecticides can be applied.
- Insecticide applications should be alternated between systemic and contact products.

If you want to know more about coffee pests and different forms of pest management, you can visit:

Principales plagas del café y su control

Manejo Integrado de Plagas del Café

Coffee leaf miner

NEMATODES *(Meloydogyne spp y Pratylenchus spp)*

There are two main genera of nematodes that harm coffee plants. They can be present from the nursery stage to adult plants. Nematodes are living beings, similar to earthworms, but they cannot be seen with the naked eye. They attack the root system of plants, causing severe injuries and deformation. In addition, they reduce the absorption capacity of the plant, leading to chlorosis, defoliation, and overall loss of vigor, which directly affects seed production.

The species *Meloydogyne spp* can cause serious root deformation, creating the appearance of lesions or small balls on the roots.

Preventative Management

- Carry out a laboratory analysis of the substrate material in order to verify if there are nematodes present.
- In areas with high nematode incidences, plant coffee plants that are grafted onto *Coffea canephora* rootstocks, especially the Nemaya variety.

Chemical Control

- If the incidence of nematodes is high, the application of nematicides should be the last resort. It is necessary to leave it as a last resort since they are excessively toxic products.
- Only use insecticides that are allowed in your country and follow the guidelines of the safety data sheet of each product, also called MSDS (Material Safety Data Sheet).

FUNGI

This section will focus on the fungi that mainly affect seedlings in their nursery stage. If you want more information about coffee fungi such as: Coffee Leaf Rust, Anthracnose and American Leaf Spot, you can review *Guide 1, Module 2. Seed Production Field Maintenance. Guide to Good Seed Practices. Point E. Pest and disease control.*

ROOT ROT *(Rhizoctonia solani Kuhn, Phytium spp. Fusarium spp.)*

Root rot often leads to black or yellow leaves and/or dead seedlings. Symptoms include dark spots on the roots and cankers at the base of the stems. The stems typically bend and then die. In some cases, black spores can be seen in the dark lesions on the stems. These injuries hinder the translocation of water and minerals, leading to the death of the seedlings. Seedlings are most vulnerable to root rot in the seedbed stage and after the transplantation.

The fungi that cause root rot are soil dwellers and survive on infected plant material or by forming specialized structures (sclerotia or chlamydospores). They can appear alone or with each other. They are spread by contaminated soil particles via wind, splashing raindrops, tools, or other activities in the infected area.

Preventative Management

- Change substrate materials prior to new germinations and graft transplantation. Substrate should always be disinfected prior. For more details on substrate disinfection, see Module 2, Section C of this guide.
- Material used to cover the planted area or plastic tunnels must be completely clean (new, never having touched the ground or having been disinfected thoroughly).
- Disinfect tools, hands, boots, and any other materials used in the nursery.
- Use uncontaminated water sources.

Cultural Control

- Promote aeration between seedlings by planting them at the recommended density.
- Pull out diseased or dead seedlings to prevent spread.
- Avoid excess water/pooling of water.
- Use well-draining substrate materials.
- Avoid substrates with acidic pH levels.

Biological Control

- There are different forms of beneficial fungi or mycorrhizae that can help fight and/or compete for space with harmful fungi, such as *Trichoderma sp.* These can be applied to substrates after disinfection for inoculation.

Chemical Control

- If the fungus appears, you can apply contact fungicides such as strobilurins, carbamates and cuprics. It's best to avoid triazoles since they tend to poison seedlings.
- There are specific fungicides for *Rhizoctonia*. If you determine that stem disease is caused exclusively by this fungus, use these specific fungicides.
- Only use insecticides that are allowed in your country and follow the guidelines of the safety data sheet of each product, also called MSDS (Material Safety Data Sheet).
- In very humid areas, fungicides can be applied to the seedbeds as a preventive measure.

MYROTHECIUM LEAF SPOT *(Myrothecium roridum)*

This fungus leads to many issues with coffee leaves and stems. The first symptoms on the leaves are dark circular spots with a ligh center. These spots increase in size over time and develop concentric rings. They then reproduce with dark black spots.

On the stems, infected plants begin to show signs of deformations or lesions at the bottom sometimes accompanied by taproot rot. As the stem thickens, conducting tissues become blocked. This, in turn, induces the formation of adventitious roots on the portions of the stem below the canker or at the base of the pivot root. When the severity of the infection is high, the young plants die. In some cases, the plants may survive, but then die when they are transplanted to the field.

Preventative Management

- Treat the substrate with a preventative fungicide before establishing seed beds or nursery.
- Only transplant healthy seedlings.
- Only transplant in sanitary conditions.

Cultural Control

- Promote aeration between seedlings by planting them at the recommended density.
- Pull out diseased or dead seedlings to prevent spread.
- Maintain strict humidity control.
- Elimine las plantas que hayan muerto.
- Monitor the nursery closely for plants with damaged or chlorotic leaves. Separate these plants and examine them for cankers and/or the presence of adventitious roots. Destroy diseased plants.

There is no effective chemical control for *Myrothecium roridum*, to date. Currently, best practices dictate the removal of diseased plants and the complete elimination of plants in a greenhouse if the spread becomes serious. Facilities should be thoroughly sanitized after an outbreak of the disease.

CERCOSPORA LEAF SPOT *(Cercospora coffeicola)*

This fungal infection of the leaves begins when the stomata form circular lesions with a dark edge, a light center, and (in some cases) a chlorotic halo. The lesions measure between 3 and 10 mm in diameter. They are initially small, but can increase in size, eventually causing premature leaf drop.

The disease occurs under stress conditions, which can be caused by environmental factors such as drastic changes in humidity and temperature. In the nursery it is most commonly caused by a poor nutritional program.

Preventative Management

- Provide a good nutritional balance to young coffee plants in the nursery
- Only plant with healthy, vigorous seedlings.
- Avoid sudden disruptions during the final stages of plant acclimatization (when plastic cover is removed).

Chemical Control

- If the disease progresses, apply contact fungicides such as strobilurins, carbamates and cuprics. It is best to avoid using triazoles since they tend to poison the seedlings.
- Only use insecticides that are allowed in your country and follow the guidelines of the safety data sheet of each product, also called MSDS (Material Safety Data Sheet).

SOOTY MOLDS *(Capnodium spp. y Meliola spp.)*

These fungi do not invade the tissues of the coffee leaves, but instead they interfere with photosynthetic processes and the plant development due to the prevention of light from reaching the leaves. As mentioned previously, it is usually associated with insect pests such as the mealybug, although it can also appear when aphids are present.

Preventative Measures

- Remove any anthills near the nursery space.
- Use the practices mentioned previously in the insect pests section in order to prevent sooty mold outbreaks.

Chemical Control

- Foliar fungicide sprays can be used on the upper and lower sides of the leaves.

BACTERIAS

Xylella fastidiosa

The *Xylella fastidiosa* bacteria proliferate in the internal ducts (Xylem) of the roots, stems and leaves. The ducts of infected plants become blocked due to the bacterial infection. This bacterium is transmitted by leafhopper insects, commonly known as "leafhoppers", "grasshoppers", or "crickets". If one of these insects bites an infected plant, it multiplies in the vector insect and after several days infected, it is capable of transmitting the disease to healthy plants.

Main Symptoms of *Xylella fastidiosa*

- The formation of slime or foam on the plants.
- Loss of leaf turgor on the upper part of the plant.
- The progressive exhaustion of the plant with symptoms of chlorosis and defoliation.
- Malformation of the leaves, especially seen by the presence of narrow, small and elongated leaves with wavy edges and a yellowish green to reddish coloration.
- Short internodes and the proliferation of shoots.

Cultural Control

- Remove dead plants.
- Keep an eye out for plants with damaged leaves with the characteristic slime of the bacteria. Separate these coffee plants and examine them for a few days.
- Keep the nursery weed-free to avoid grasshopper hosts.
- Use barriers around the nursery to reduce vector dispersal.

Recommended Sanitary Control

- Eliminate diseased plants in the case of a serious outbreak of the bacteria.
- Spray copper-based fungicides.
- Reduce relative humidity through drainage.
- Reduce excess shade.
- Reduce nitrogen fertilization and increase potassium and/or silicon applications.

***Xylella* vector**

! It is very important to control vector insects in coffee seedlings. If they are not controlled, the disease will continue to spread even if bactericide applications are made.

Black Bacteria (Pseudomonas syringae)

Symptoms of *Pseudomonas syringae* begin with brown to black necrotic spots with yellow halos around them. In extreme cases, it can cause leaf drop. The spots caused by *Pseudomonas syringae* often have an oily texture.

Cultural Control

- Remove bags with dead plants.
- Keep an eye out for plants with damaged leaves with the characteristic slime of the bacteria. Separate these coffee plants and examine them for a few days.
- Protect the nursery from strong winds.
- Lower relative humidity, create drainage systems to avoid waterlogging.
- Reduce excessive shade.

Recommended Sanitary Controls

- Remove diseased plants.
- Spray copper-based fungicides.

Photo Credit:
CafeiCultura Magazine

Sudden temperature changes increase the risk of bacterial attacks. Be careful when changing nursery plastic coverings (some allow in more light/heat than others) and make sure acclimatize seedlings before sale or transportation.

For more information about diseases that affect coffee visit:
Coffee diseases.

WHAT TO CHECK BEFORE SELLING PLANTS

There are many quality control checks that must be performed prior to selling coffee plants. Some of these include:

- Plants maintain genetic conformity.
- Plants are free of diseases and pests.
- Plants present good vegetative and root development.
- Plants do not have nutritional difficiencies.
- Plants have proper root system/stem/leaf ratios.

In some cases, external problems in the quality issues above can be confused with symptoms of pest or disease attacks. Some of these alternative conditions are follows:

PLANT MOISTURE

Seedlings dehydrate quickly, so they must be sold at 100% moisture capacity in order to withstand the journey to the field for transplantation.

An example of extreme wilting from dehydration

Action: Set aside wilting plants and water past the point of wilting. Do not sell plants before seven days of observation in order to detect issues like leaf burn.

ATYPICAL OR MUTATED SEEDLINGS

Mutated or atypical plants differ from their mother plant in terms of different phenotypic characteristics.

Variegated plants with a genetic deficiency

It is important to check plants for mutations well before giving a diagnosis or even sending them to the laboratory for analysis, since these mutations can be confused with nutritional deficiencies or intoxications.

Action: These plants should be discarded if identified in the nursery.

Angustifolia plant, has much narrower leaves than normal

If these plants are identified, they should be discarded from the nursery.

PLANTS WITH NUTRITIONAL DEFICIENCIES

If the plants have nutritional deficiencies, they should not be sold.

Action: Plants should be removed from the lot and nurtured. They can be sold or planted in the field if the deficiency is corrected.

Plants with nitrogen deficiencies

SYMPTOMS OF LEAF BURN

Leaf/plant burns can occur for various reasons. Some examples are: intoxication with fertilizers or agrochemicals, excessive sun exposure, mechanical damage, and/or strong winds.

Action: Eliminate the plants and note the plant origins and quantity of plants removed.

Place of leaf burn

EXAMPLES OF HEALTHY PLANTS

Plants with good development in bags

Plant with good development in tubette

Plant with good development in a substrate block

PEST MANAGEMENT CRITICAL POINTS

Complies	Does Not Comply	Critical Point
		Daily monitoring to verify problems with pests, diseases, burns, toxicities, etc.
		Separate plants with pests or diseases and treat them (if there are few), if the problem is in the entire lot, treat the entire lot.
		If the nursery is outdoors, in times of high sun, the seedlings can be covered with plastic or some vegetative cover in order to prevent sunburn. A shade net can also be used.
		Avoid excess shade with plastic or other materials.
		Provide good nutritional balance to seedlings
		Eliminate weeds around and inside the nursery
		Take precautions when bringing in materials from other nurseries
		Change the substrate before starting a new germination or graft transplant process.
		Properly disinfect the substrate
		Use a well-draining substrate to fill final containers in order to prevent water from pooling
		The material to cover the planted area or the plastic tunnel must be clean (new material that has not touched the ground or washed with disinfectant)
		Disinfect tools, boots, hands, and any other materials used in the nursery.
		Use uncontaminated water sources
		Promote aeration between seedlings by planting them at the recommended density.
		Maintain strict humidity controls.
		Remove bags with dead plants.

C. IRRIGATION

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

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

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

Nursery owners must respect their country's water regulations, both related to source use and 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 or at small nurseries or with many lots at 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's best to use a spray nozzle in order to avoid harming the plants with a flood of water directly from the hose.

AUTOMATIC IRRIGATION

Automated irrigation is common in countries where access to technology is cheap and easy while labor is expensive. It's mainly used by 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 many systems of water sprayers and micro sprinklers systems. These systems are chosen according to water flow/pressure available.

Some major irrigation issues to consider include:

1. When using sprinkler or spray irrigation, conduct routine maintenance of sprinkler and pipes in order to ensure even, constant watering.
2. Ensure constant pressure at every point in the system.
3. Avoid drip irrigation at the germination stage since some spots may not receive enough water.
4. Short, constant irrigation is recommended. For example, it's best to water 2-3 times per day, depending on climate. Do not overwater or drown the plants.

CRITICAL POINTS INRELATION TO IRRIGATION

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

MODULE 5

RECOMMENDATIONS FOR INFRASTRUCTURE FROM GERMINATION TO MAINTENANCE

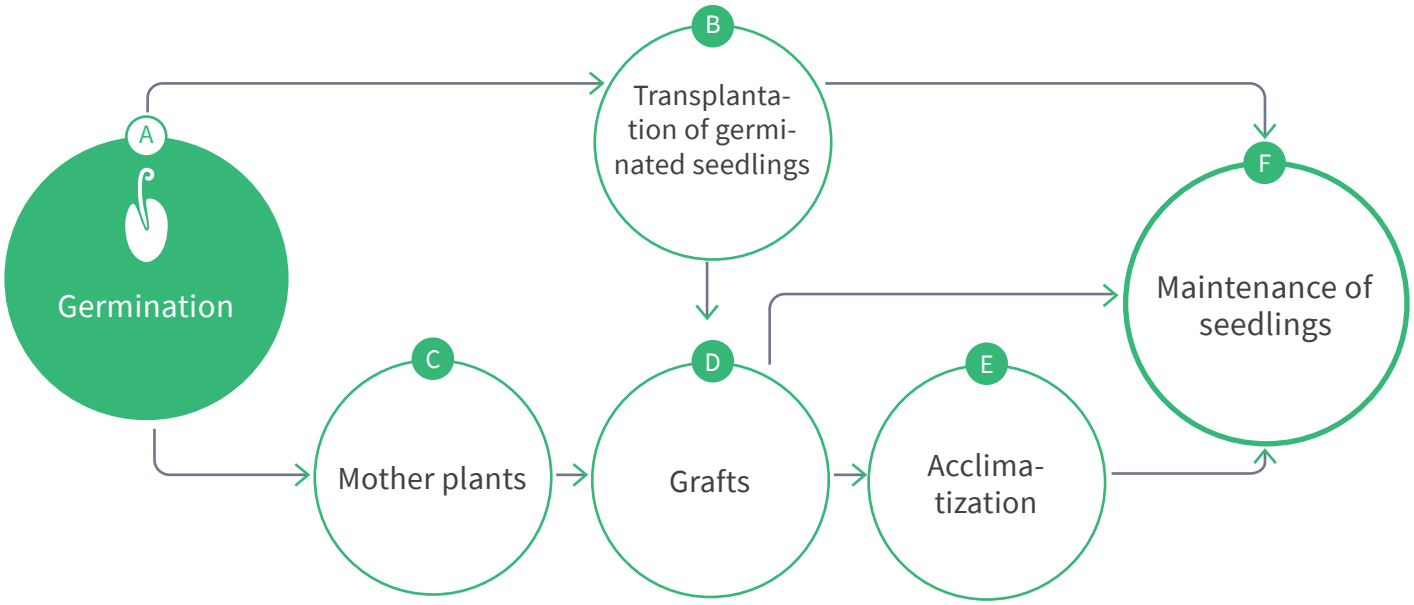
MODULE 5 - CONTENTS

Module 5 describes different types of structures recommended according to the stage of seeds/seedling growth.

Plants have different needs at each stage of growth, from germination to grafting to acclimation to maintenance. Therefore, appropriate infrastructure is needed at each stage of plant development.

STAGES OF NURSERY DEVELOPEMENT

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



A. STRUCTURE REQUIRED FOR GERMINATION

Germination can take place using different types of structures, depending on the growers' means. However, growers must meet a number of minimum requirements for coffee seed germination. Minimum requirements are listed below, in addition to examples of structures used at this stage of the plant production process.

Minimum requirements for germination infrastructure:

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

Risks from inappropriate infrastructure

- Improper seedling development.
- Higher seedling mortality.
- Uneven germination rates in the same lot or longer than usual germination.
- Higher risk that seeds will not germinate due to harmful fungi, bacteria, insects or rotting.

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

GOLD LEVEL: GREENHOUSE

Requirements:

- Plastic walls to protect seedbeds against wind.
- Moderate sun exposure from 20 to 40%.
- 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 made of metal (galvanized iron) or wood.
- Moderate sun exposure from 20% to 40%.
- Roofs at least 2.5 meter high.

Example of germination beds

BRONZE LEVEL: CANVAS, STRAW OR VEGETATIVE COVER

Requirements:

Rustic, variable structures according to producer means. Minimum requirements include:

- Controlled ventilation in an area protected against strong wind
- Moderate sun exposure from 20% to 40%.
- Roofs at least 2.5 meter 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. STRUCTURES REQUIRED FOR HARDENING SEEDLINGS

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 transplanting grafts to substrate blocks, tubettes or bags.

GOLD LEVEL: GREENHOUSE

- Plastic walls to protect against wind.
- Moderate sun exposure from 20% to 40%.
- Roofs at least 2.5 meter high.
- Strict hygiene conditions implemented at entrance.
- 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 constructed with metal structure (galvanized iron) or wood.
- Moderate sun exposure from 20% to 40%.
- Roofs at least 2.5 meter 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 sun exposure from 20% to 40%.
- Roofs at least 2.5 meter high.No cross shade from trees or buildings.
- Disinfected substrates.
- Ground or sand floor.

Transplanted seedlings | **Filling bags for transplanting** | **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: Includes 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. STRUCTURES REQUIRED FOR MOTHER PLANT MAINTENANCE

Some guidelines about the structures 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 between 7,000 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 a lobby are in order 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 between 7,000 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 hose in a directed manner.

Mother plants greenhouse

D. STRUCTURES REQUIRED FOR GRAFTING

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

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 a lobby first in order to wash hands and put on apron.

SILVER LEVEL

Roof, sides, and floor

- Semi-enclosed area, made of wood or shade netting.
- 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

Sinks at grafting area

BRONZE LEVEL

Roof, sides, and floor

- Semi-enclosed area made of wood or shade netting.
- Minimum height between floor and ceiling is 2.5m to avoid high thermal amplitude.
- Dirt 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 that fall on the floor.

E. STRUCTURES REQUIRED FOR ACCLIMATIZATION

ACCLIMATIZATION TUNNELS

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

Infrastructure

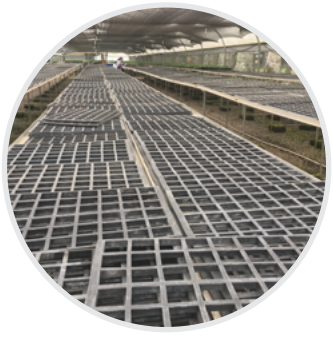
- **Acclimatization macrotunnel**

Various models of acclimitization tunnels are available on 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 is essentially the greenhouse protecting the microtunnels and the first protection filter for seedlings.

- **Tables**

The dimensions of the tables where microtunnels are installed must be in line with operational and management needs, mainly for the personnel working in the tunnels. They must allow workers to place trays and carry out other tasks with ease. For example, a 3m wide and 15m long tunnel can accommodate 2 microtunnels 1.20m wide x 14.5m long x 0.8m high. Tables are not always needed. Microtunnels can also be placed on the floor as long as the floor is made of concrete or a geotextile material is used to cover the floor in order 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 should be hermetically sealed, with thin white plastic sheets for the greater diffusion of light, in order to create a very confined internal environment and thus give grafts the high-humidity climate that they require.

On 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 preferred in order to maintain the desired climate (high relative humidity and controlled temperatures between 22-28°C). Watering can also be done manually with shower hoses, 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 that allows for 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. STRUCTURES 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' resources.

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

GOLD LEVEL

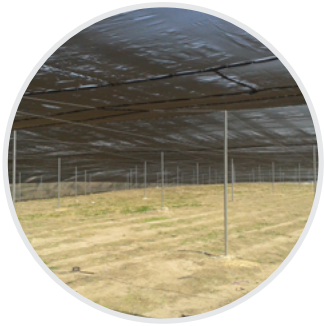
Roof and sides

- 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 the 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 a roof for the 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 the 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 shade 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 until 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 20% and 40% sun exposure.
		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 or pooling of water. 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 offices in addition export agencies in each country.

A. GENERAL TRACEABILITY SYSTEM AT NURSERIES

GENERAL TRACEABILITY SYSTEMS

It is key for nurseries to track coffee seedlings from seed to sale. This allows for monitoring in order to ensure **plant health and genetic purity** which helps optimize production potential. In addition, detailed, up-to-date traceability helps uncover the **source of problems** (e.g., disease or contaminated substrate) and helps growers take remedial actions 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 the map updated with the number of seedlings, variety and origin of materials (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 in order 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 specifications for each variety. This is done in order to guarantee the identification of seeds according to agronomic and genotypic criteria, and to make sure that they are in line with customer needs. Once seeds are received, a log like the one on the right should be 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 completed, it is important to monitor germination in order to detect problems. After 20 days, the first radicles of the seeds should emerge. Gently remove substrate at several different points to check for growth. 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 on variety and moisture percentage.

KEEP A MONTHLY RECORD OF SEEDLINGS

To control inventory, a card can be used to keep track of a variety, entry and removal, and stocks of the 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 in order to continuously maintain its integrity. This code is also useful to track the SKU of the seed lot and the place where it was previously stored.

KEEP A RECORD OF SEEDLING GRAFTING

Table 7. Sample logbook to maintain 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 recommended to record substrate type, as well as the type of container used for each seedling.

MAINTENANCE STAGE

KEEP SEEDLING TRACEABILITY AT THE MAINTENANCE STAGE

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

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

This growth record helps to identify growth issues and take appropriate, timely remedial actions in order 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 only produce and commercialize 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 that 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 seedling inventory
		Updated seedling sales or shipment cards

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