coffee & climate
enabling effective response

GOOD AGRICULTURAL PRACTICES FOR ROBUSTA COFFEE PRODUCTION



Hanns R. Neumann Stiftung

ACKNOWLEDGEMENT

Within the framework of the Global Initiative for coffee&climate, the manual "**Good Agricultural Practices for Robusta Coffee Production"** has been redesigned. The current edition comes with a different layout, new recommendations on rational water use, exclusion of agro-chemicals which were banned in the timeframe between the first and current edition of this book and a chapter on climate change.

The first edition was published in 2009 and was given official recognition by the Ministry of Agriculture and Rural Development in Vietnam and was financed by the following organizations:

- Nestlé / Nescafé
- Kraft
- Sara Lee
- Douwe Egberts Foundation
- International Coffee Partners
- Ministry of Agriculture, Nature and Food Quality (LNV)
- Solidaridad

All editions of this manual have received valuable feedback from the following organizations and individuals:

- Vietnam Coffee and Cocoa Association (VICOFA)
- Western Highlands Agriculture & Forestry Science Institute and branches in Gia Lai and Lam Dong
- Department of Agriculture and Rural Development of Dak Lak, Gia Lai and Lam Dong
- Provincial Extension Center in Dak Lak, Gia Lai and Lam Dong.
- District People's Committee of Krong Pak (Dak Lak), Chu Se (Gia Lai) and Di Linh (Lam Dong) districts
- District Agricultural Office of Di Linh and Chu Se
- District Agricultural Extension Station of Krong Pak, Chu Se and Di Linh districts
- Central Highland Soil, Fertilizer and Environment Research Center
- Café Control in Dak Lak, Gia Lai and Lam Dong
- Rural Development Project in Dak Lak - GiZ
- Farmers in Dak Lak, Gia Lai and Lam Dong
- Agro Services Department at Nestle Vietnam
- Yara Vietnam

FOREWORD

Coffee is one of the most important export products of Vietnam, creating jobs and income for millions of people, mostly ethnic minorities in the Central Highlands and some other mountainous areas. While coffee production has gained some major achievements, the sector still remains potentially unsustainable which affects productivity, quality and production efficiency. This may in turn affect Vietnam's prestige and its position in the global market. One of the main reasons for the above situation is the coffee producers' limited knowledge about technical practices.

Therefore, enhancement of technical knowledge for the producers on sustainable coffee cultivation is a decisive factor in the coffee sector. Based on scientific research findings and practical experience in coffee production in Vietnam over many years, together with experts, researchers, extension officers and national and international individuals and organizations, the National Agricultural Extension Center (Ministry of Agriculture and Rural Development) in cooperation with the foundation Hanns R. Neumann Stiftung Asia Pacific has composed and published the manual **"Good Agricultural Practices for Robusta Coffee Production".** We hope this material will be useful for extension officers and Robusta coffee farmers. Due to the limitation of time and experience, few shortcomings are definitely unavoidable in this book. We look forward to receiving attention and valuable comments from the readers to improve future editions.

Dr. Phan Huy Thong
Director of the National Agricultural Extension Center
Ministry of Agriculture and Rural Development

About the Initiative for coffee&climate

In 2010, key players from the private, the development and the research sector joined forces to address challenges posed by changing climatic conditions to the entire coffee value chain. They founded the initiative for coffee&climate (c&c) as a development partnership with the vision to enable all coffee-farming families worldwide to effectively respond to climate change. The c&c approach is currently implemented in pilot projects in Brazil, Tanzania, Trifinio (Guatemala, Honduras, El Salvador) and Vietnam. These regions have been chosen mainly because of their strategic relevance as key coffee producing areas, representing Arabica and Robusta production, intensive and diverse growing system as well as wet and dry processing. The initiative envisions to enable all coffee farmers worldwide to effectively respond to changing climatic conditions by:

- combining state of the art climate change science and proven farming methods
- offering suitable hands-on tools
- forming a network of all relevant stakeholders in the field
- applying a 360° precompetitive approach including the entire value chain

c&c is open and invites further dedicated partners and stakeholders in the coffee sector to join in.

More information can be found on:

www.coffeeandclimate.org

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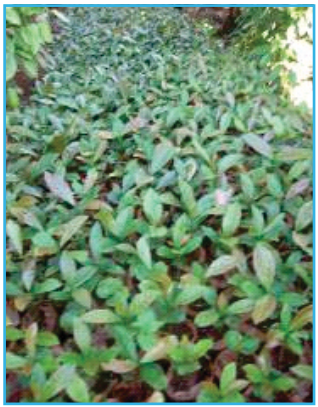


➢ Propagation by seeds

Advantages:

- Simple and low cost technique
- Easy for farmers to select seeds for propagation
- Possible to carry out at a large scale
- Low transport costs

Disadvantages:

- Non-uniform coffee quality and productivity (e.g. small beans)
- Coffee trees are prone to leaf rust infection
- Trees generally have a low productivity
- The maturation time to full productivity takes longer

Remarks:

- *This method is recommended for rootstock only*
- *Seeds for seedling production should be taken from plants with big and uniform ripe cherries (95 - 100 beans / 100 gr)*

1.1 ROBUSTA COFFEE PROPAGATION TECHNIQUES

➢ Vegetative propagation

Method 1: Cuttings

- It is not recommended because the seedlings generally have a low drought-resistance
- Since cuttings can only be taken from upright branches the scalability is low
- The root system of seedlings propagated through cuttings is often weak

Cuttings

Method 2: Grafting

Advantages:

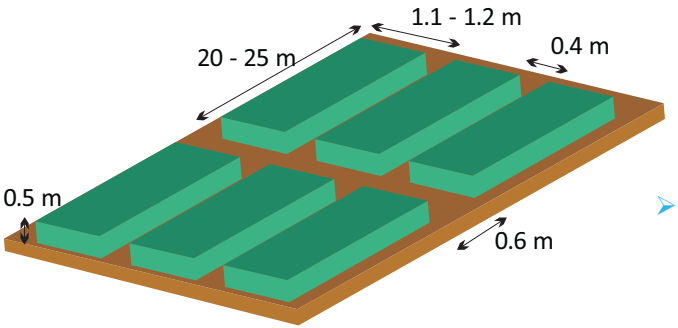
- The good characteristics of the mother tree are copied in the scion
- Plants grow well
- High uniformity in terms of productivity and quality
- Plants are drought and pest resistant (e.g. leaf rust)
- The maturation time to full productivity is shorter
- High productivity and quality (e.g. big bean size)

Disadvantages:

- Complex technique which requires highly skilled practitioners

Grafting

1.2 NURSERY DESIGN



➢ Location requirements

- Near water resources
- Convenient for transport
- Near the location of the coffee plantation
- On well-drained soils with slope < 3 %
- The soil must be free of nematodes

➢ Preparation

- Clear the site and uproot all plant species on the spot
- Plough the soil at a depth of 10 - 15 cm
- Determine the positions of the framework stakes and planting beds
- The size of the planting beds is 1.1 - 1.2 m wide; 20 - 25 m long and 15 cm high
- Do not place the stakes on the walking spaces
- The walking space between two beds is about 0.35 - 0.40 m
- Keep a walking space of 0.5 - 0.6 m at the beginning of the beds
- Place the stakes (iron or wood), trellis & roof work
- Use locally available materials like bamboo, wood, sugarcane leaves, etc.
- Ensure a shade cover of 70 - 80 %

1.2 NURSERY DESIGN

➢ Specifications for seedling bags

- Use poly-ethylene (PE) bags with dimensions of 14 by 25 cm
- Punch 6 small holes in the lower part of the bag; the lowest hole about 2 cm above the bottom

➢ Soil structure

- Use well-aerated soil with high humus content (> 3 %)
- Mix the soil with fine and soft compost, free of indigenous plant roots, stones and gravel
- The ratio soil / compost = 4/1
- Add 5 - 6 kg fused Calcium Magnesium Phosphate fertilizer per m^3 of soil mixture
- Add 1 - 3 kg of lime per m^3 of soil mixture if the soil is acid

➢ Fill the PE bags with the soil mixture

- Make sure the soil in the bags is compact and does not fall apart in different parts
- Place the bags closely to each other in straight lines
- Bury the PE bags to a depth of about 1/3 -1/4 of the bags' height

1.3 PROPAGATION BY SEEDS

➢ Seed germination

- Seeds for propagation of rootstock must be provided by authorized agencies (such as WASI or Provincial Variety Centers)
- The ideal temperature for seed germination is 40 - 42^{0}C under well-aerated conditions (sufficient oxygen supply)

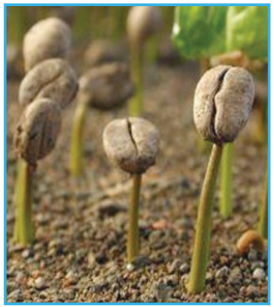
➢ Method 1: Removing the parchment husks

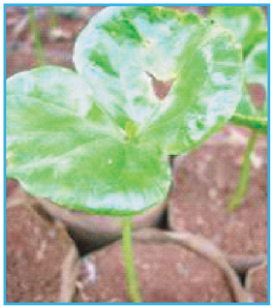
- Dry the parchment in light sunlight (before 10 am) for the parchment husks to loosen and to be easily removed manually
- Soak the seeds in clean and warm water of circa 40 - 50^{0}C for 14 - 16 hours
- Subsequently sieve the silverskin
- Place the seeds into a clean jute bag and store them in a well-covered basket to keep the heath
- Daily check the seeds and remove the silverskin and rotten or mouldy seeds
- Seeds will germinate in 5 - 7 days
- Immediately sow the seeds after germination (the size of the sprout should not be longer than 1 mm)

1.3 PROPAGATION BY SEEDS

➢ Method 2: Without removing the parchment husks

- Pulp fresh cherries with a hand pulper
- Dissolve lime in water at a ratio of 1/50 to avoid acidification of the water when removing the mucilage
- Let the excess lime precipitate and remove precipitated lime; use only clean water
- Heat the lime solution to 55 - 60^{0}C
- Subsequently soak the seeds for 18 hours in the lime solution to remove the remaining mucilage (pulp); i.e. fermentation
- If the average day temperature is 23 - 25^{0}C and the average night temperature not lower than 18^{0}C spread the seeds (parchment) in a 3 - 4 cm thick layer on the growing beds
- Put a sand layer of 1 - 2 cm on top of the seeds
- Subsequently cover the sand layer with rice straw or jute
- The seeds will germinate after 10 to 15 days
- Immediately sow after germination (the size of the sprout should not be longer than 1 mm)
- Do not sow seeds that have germinated for longer than 3 weeks





1.4 SOWING TECHNIQUES

➢ Method 1: Sowing directly in PE bags

- Irrigate the PE bags 1 - 2 days before, to assure homogeneous moisture distribution throughout the soil
- Put 1 seed in the centre of each bag, the sprout pointing downwards
- Cover the seed with a soil layer of 3 - 4 mm (do not sow too deep as it will delay seedling development)

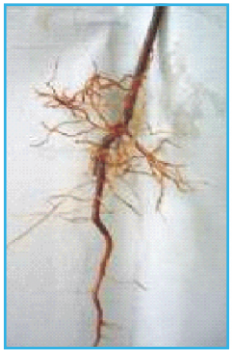
➢ Method 2: Sowing on seedling beds

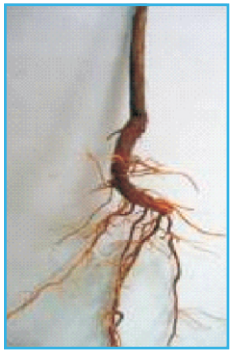
- Prepare the seedling beds (cf. nursery design)
- The soil mixture is identical to the soil mixture in the seedling bags
- Spread the germinated seeds evenly on the beds, 3 - 4 cm apart in a row, the rows spaced 10 cm apart, the sprouts pointing downwards (1 kg / m^2)
- Cover the seeds with a soil layer of 3 - 4 mm
- Cover subsequently with a layer of sawdust or rice husks
- Keep the soil sufficiently moist
- This labor intensive method allows for quick growth and easy checking for a straight taproot before transplanting in PE bags

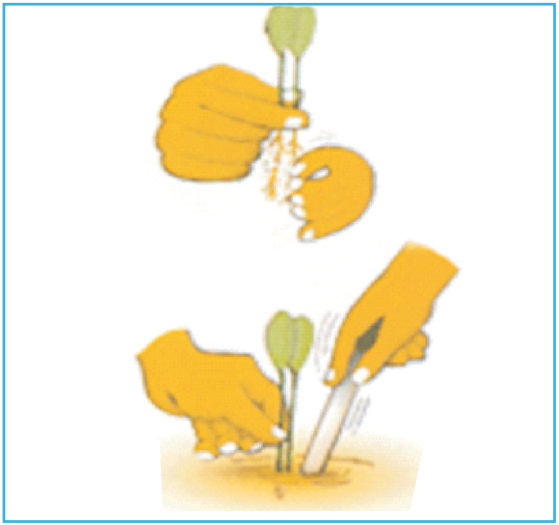
1.5 TRANSPLANTING SEEDLINGS INTO BAGS

➢ Transplanting saplings into seedling bags

- Plant the saplings in the seedling bags once they are 3 - 4 cm tall or once the first pair of leaves is fully developed
- Use a 1 cm diameter stick to drill a hole of 10 - 12 cm depth in the seedling bags
- Place the saplings straight into the hole and backfill
- Irrigate the seedling bags and keep them in a cool place during the first days (e.g. under shade)
- Remove sapling of which the taproot is curled, damaged or shorter than 4 cm
- Shorten the taproot if it is longer than 10 cm
- If there are two straight taproots, remove one







1.6 NURSERY MANAGEMENT


Irrigation


Fertilization

➢ Irrigation

- Apply a small volume of water in high recurrence for young seedlings
- Reduce the irrigation frequency when the seedlings get older
- Adjust the irrigation frequency and volume depending on the weather condition and the plants' growth rate
- Do not irrigate excessively and irrigate only during sunset or sundown

➢ Fertilization

- Fertigate the seedlings when they have 1 - 2 pairs of leaves: Urea and KCl (N, K) in a ratio 2:1 with a concentration of 0.10 - 0.15 %
- Fertigate with a concentration of 0.2 - 0.3 % when the seedlings have more than 3 pairs of leaves
- Depending on the development of the seedlings, apply a fertilizer solution consisting of manure or oil-cake soaked one month before with fused Calcium Magnesium Phosphate; the fertilizer solution has a ratio of 1/5 - 1/3

1.6 NURSERY MANAGEMENT

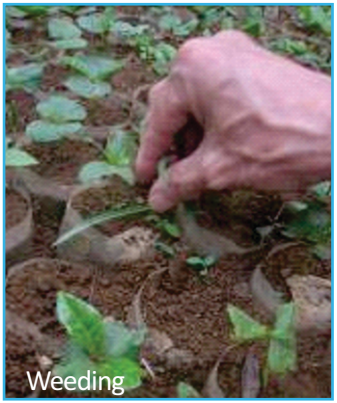
➢ Fertilization

- A nursery of 1000 m^2 requires 2 - 3 tons of manure or 0.1 - 0.2 ton of oil-cake and 100 kg fused Calcium Magnesium Phosphate
- Rinse the leaves of the seedlings with fresh water after each fertilizer application

➢ Light adjustment

- Seedlings with less than 1 pair of leaves require 20 - 30 % of sunlight
- When the seedlings have 3 - 4 pairs of leaves, 40 - 60 % light is required
- 80 - 100 % light is required for seedlings with more than 4 pairs of leaves

1.6 NURSERY MANAGEMENT


Weeding


Turning over soil surface


Spraying chemicals to prevent pest and diseases

➢ Soil management and weeding

- Regularly weed the walking spaces in the nursery
- Regularly remove weeds from the seedling bags to minimize pest and disease infestation and to reduce competition for nutrients
- Regularly turn over the soil surface in the seedling bags to assure good soil aeration

➢ Pest and disease management

- Fully compost organic fertilizers prior to application in the nursery
- Do not use soil contaminated with diseases; dry the soil before use in the nursery
- Do not over-irrigate
- Temporary stop irrigation when diseases are detected
- Check the nursery regularly and remove seedlings infected with diseases
- Spray cuprous chemicals 2 - 3 times at a 10 - 15 day interval

1.7 SCION GARDEN DESIGN

➢ Location requirements

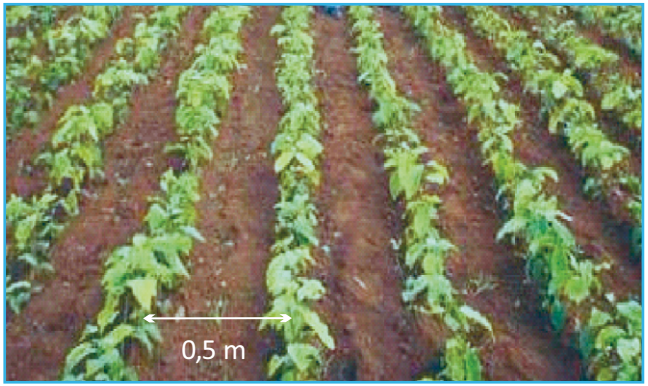
- Near a water source
- Near the location of the coffee plantation
- Easily accessible by road
- Best located on well drained soils with slopes < 3 %
- Best on well-drained soils with a high humus content

➢ Variety source

- Acknowledged and provided by authorized agencies (such as WASI or Provincial Variety Centers)

➢ Design

- Planting density: 8 - 12 trees / m^2
- Distance between rows: 0.4 - 0.5 m
- Width of the walking space: 0.8 - 1.0 m
- Distance between trees in a row: 0.20 - 0.25 m
- Width of the planting trench: 0.20 - 0.25 m
- Depth of planting trench: 0.20 - 0.25 m
- Planting depth: 0.05 - 0.1 m



Rows in a scion garden

Scion garden

1.8 SCION GARDEN MANAGEMENT

➢ Irrigation

- Irrigate every 7 - 10 days in the dry season to a soil depth of at least 20 cm

➢ Fertilization

- Planting rows of 100 m long need 1 m^3 of manure & 20 kg fused Calcium Magnesium Phosphate as a first application
- Subsequently apply 0.8 - 1.0 ton of manure; 5 kg fused Calcium Magnesium Phosphate; 2 kg Urea; 1 kg KCl for a row of 100 m split over three applications
- Combine fertilization and irrigation in the dry season
- March - April: Urea + KCl
- May - June: Urea + KCl
- November - December: after the main pruning, dig a ditch (5 - 10 cm deep) between two rows to apply inorganic and organic fertilizers

Scion garden

➢ Management

- Regularly de-sucker the stem
- Start basic pruning in November - December
- Remove weak branches on a regular basis and keep 4 - 5 strong stems per tree
- Regularly weed and control for pests and diseases (scales, leaf skeletonizer, etc.)

1.9 ROOTSTOCK STANDARDS

➢ Rootstock

- Seedling should have 5 - 6 pairs of leaves
- Seedlings should be 20 - 25 cm tall
- Seedlings should be hardened against direct sunlight for minimum 20 days
- Internodes should be spaced 3 cm apart
- The stem should be straight
- The leaves should not be deformed
- The seedling should be disease free
- Stump diameter > 4 mm
- Do not apply additional fertilizer to the rootstock seedlings 10 days before grafting

➢ Scion

- Scions are taken from the scion multiplication garden with an authorized known variety

1.10 PROPAGATION BY GRAFTING

➢ Scion harvesting

- Harvest scions before 10 am in the morning
- Choose young twigs with at least 4 internodes (1)
- Use a sharp knife or pruning scissors to cut the upper part of a twig including 2 - 3 internodes (2)
- Leave at least one internode on the tree to assure growth of new suckers (scions)
- Use the top part of the twig (scion) only, having 2 internodes, one pair of fully developed leaves and one pair of young leaves on top (2)
- Use a pair of scissors to cut 2/3 of each leaf (3, 4)

Remark: *Scions should only be harvested 7 - 10 days after fertilizer application*

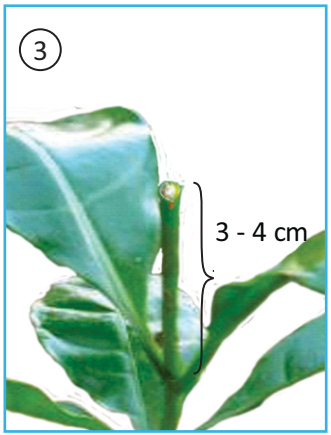
1.10 PROPAGATION BY GRAFTING

➢ Grafting period

- Grafting can be done all year round in the nursery
- The best time is from March to June

➢ Grafting method (rootstock part)

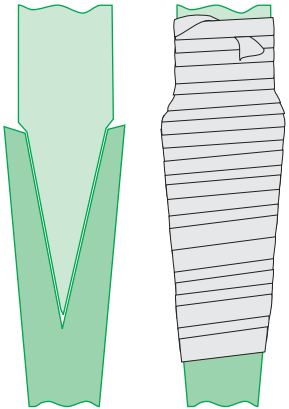
- Apply top cleft grafting
- Use a sharp knife to cut the stem of a rootstock seedling 3 - 4 cm above the top axil (1,2,3)
- Split the stem of the rootstock seedling on top in a V shape (4)
- Do not use old scions



1.10 PROPAGATION BY GRAFTING

➢ Grafting method (scion part)

- Use a sharp knife to cut a wedge (V) shaped scion (1, 2)
- Insert the scion into the cleft of the rootstock (3)
- Make sure the both scion and rootstock fit tightly together
- Use a plastic string to hold the scion and rootstock tightly together (4)
- Ensure that the plastic string covers the grafted area completely and the last wrapping roll is at the top



Remarks:

In case of a difference in size between scion and rootstock, one-side connection needs to be ensured, which means the skin of rootstock and scion must connect to each other.

1.10 PROPAGATION BY GRAFTING

➢ Taking care of the grafted seedlings

- Use a PE bag (without holes) to cover the grafted scion
- Close the lower part of the PE bag tightly to prevent air evaporation
- Remove the PE bag after 10 - 15 days
- Cover the seedlings in the nursery with a synthetic plastic or nylon net of 60 cm high to avoid direct sunlight
- Remove the plastic string after 20 - 25 days
- Regularly remove suckers below the grafted position
- Manage the nursery as presented in Module 1.6
- The seedlings are ready for transplanting after 45 - 60 days

1.10 PROPAGATION BY GRAFTING

➢ Rootstock standards

- The scion has developed at least 1 more pair of leaves
- The contact point between scion and stem of rootstock grows well without observed callus
- The grafted seedlings have been hardened against direct sunlight by removing the shadow cover 1 week before transplanting
- The grafted seedling is free of diseases and deformations

1.11 QUESTIONS AND EXERCISES

1. What are advantages and disadvantages of propagation by seeds and asexual propagation?
2. How to design a nursery?
3. What are the differences between 2 seed germination methods?
4. What are the standards for scion and rootstock?
5. Explain each step in grafting.
6. What are the standards for grafted seedlings?
7. How to manage a nursery in terms of light, water, nutrition and pests & diseases?
8. Visit a nursery of a group member and
    - evaluate its strengths
    - evaluate its weaknesses
    - recommend specific solutions to improve it
9. Each group member grafts 3 scions a rootstock.

MODULE 2. SOIL MANAGEMENT

2.1 SOIL PROPERTIES

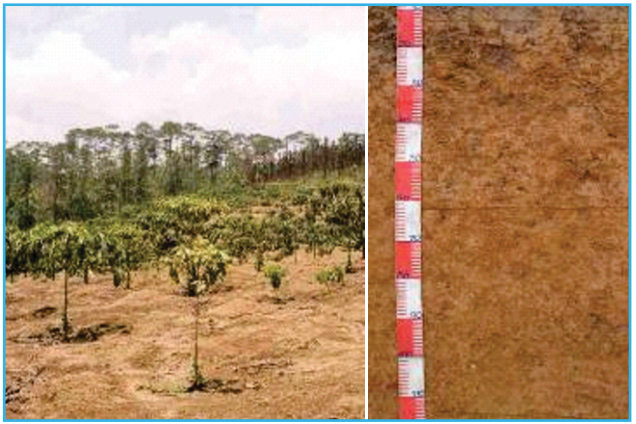
➢ Good soils

- Depth: over 0.7 m
- Porous and well-structured to assure quick water infiltration
- Well-aerated to allow good root penetration
- Good water holding capacity
- Red basaltic soils
- Stable soils to minimize erosion on steep slopes

Organic matter	> 2 %
Nitrogen content	0.08 - 0.10 %
P_2O_5	0.15 - 0.20 %
P available	> 5 mg / 100 g of soil
K_2O	0.10 - 0.15 %
K available	> 10 mg / 100 g of soil

Soi depth	> 0.7 m
Porosity	55 - 60 %
Groundwater level	> 2 m below surface
Water availability	> 100 mm / m soil depth
Drainage	Good

2.1 SOIL PROPERTIES



➢ Sub-optimal soils

- Depth: over 0.7 m
- Soils with a clay increase in the subsoil are prone to erosion; cultivation on these soils is best done on flat land (slope < 3 %)
- Well-aerated to allow good rooting capability
- Good water holding capacity
- Grey yellowish soils which often develop on metamorphic rock

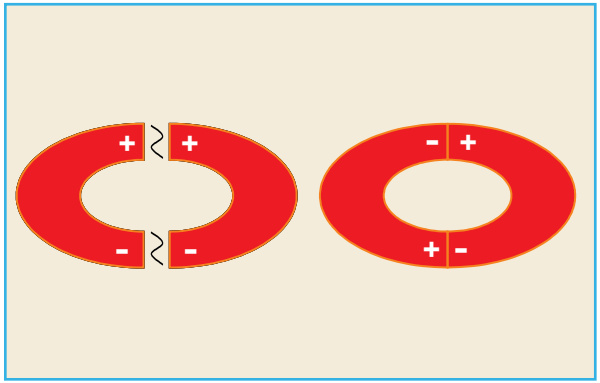
➢ Bad soils

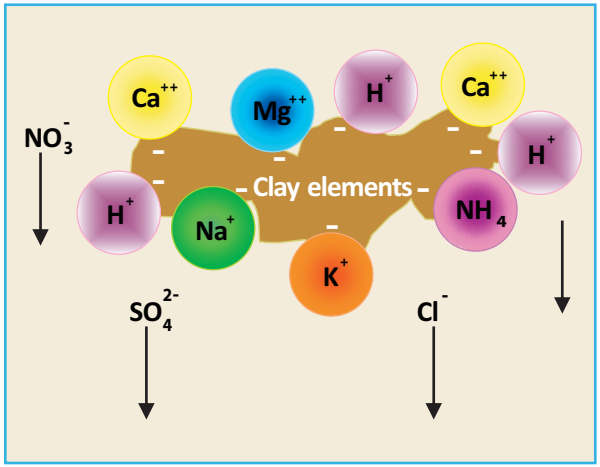
- Soils with a high clay content, which often have a compact structure which makes it difficult for the roots to penetrate
- Soils with a shallow groundwater level (< 1 m), which are often poorly drained; roots cannot respire under these conditions and coffee trees die after 2 - 3 years after planting
- Bad soils for coffee cultivation are usually found in valleys near rivers

2.2 SOIL ACIDITY

➢ Causes of soil acidification

- Coffee trees mainly take up positively charged cations:
  - + Calcium (Ca^{++}), potassium (K^{+}), ammonium (NH_4^{+}), magnesium (Mg^{++}), etc.
- Cations stick to negatively charged sides of organic matter and clay
- When organic matter decomposes through microbiological activity it releases carbon dioxide:
  - + CO_2 gas is released
  - + $CO_2 + H_2O$ = acid (H^{+})
- Hydrogen cations (H^{+}) occupy negatively charged sides in the soil and acidify the soil
- Over-application of chemical acidifying fertilizers such as ammonium sulfate (SA) or superphosphate





2.2 SOIL ACIDITY


Granite hill in Lak district, Daklak province


Climate


Soil erosion

➢ Causes of soil acidification

- **Parent rock**
  - + Soils formed on acid parent rock (granite, granodiorite, etc.) are generally more acid than soils developed on basic parent rock (basalt)
- **Climate**
  - + More rainfall causes increased cation leaching
  - + This causes imbalanced charges on the clay particles
  - + Acid hydrogen cations (H^+) replace other cations on the clay particles, leading to increased acidification of the soils
- **Erosion and nutrient leaching**
  - + Soil acidity is generally higher on sloping land

2.3 LAND RECLAMATION

- ☒ **Do not reclaim any land that is not officially destined for agriculture or agro-forestry by law**
- ☒ **Do not illegally deforest new land**

➢ **In case new land with natural vegetation (e.g. forest) is legally reclaimed for agriculture**

- Do not clear all the natural vegetation
- Integrate native vegetation with coffee farming in a bio-diverse agro-forestry system
- Selectively remove only species which cannot be used as natural shade, natural wind-break or for other purpose

➢ **Remove all on-farm crop residues**

- Reduce risks of pest and disease infection
- Prevent fungi development
- Use on-farm organic residues to make compost

➢ **Careful land reclamation**

- Soils will keep a higher porosity and water retention capacity
- Soil drainage characteristics remain better
- Soil structure remains better allowing better root penetration

➢ **On existing land**

- Focus on productivity increase instead of reclaiming new land area
- Rejuvenate the plantation in case of productivity decline; consider new high yielding varieties

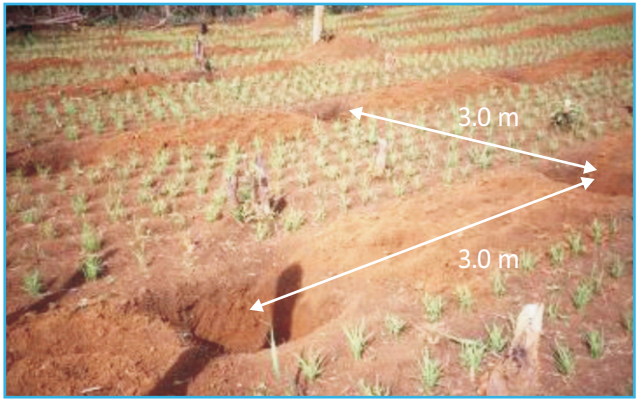
2.4 PLANTATION DESIGN

- **Plough the soil before planting**
- **Identify the main wind and slope direction to determine**
  - The orientation of planting rows
  - The orientation of wind-break trees
- **Importance of good planting density**
  - Minimize competition for light and maximize aeration
  - Minimize competition for water and nutrients
  - Easier to take care of the coffee trees and to harvest
  - Improved economic efficiency
  - Reduced management cost
- **Planting density depends on**
  - Soil quality and slope
  - The choice for mono cropping (only coffee) or intercropping (coffee with other crops or forest tree species)

2.4 PLANTATION DESIGN

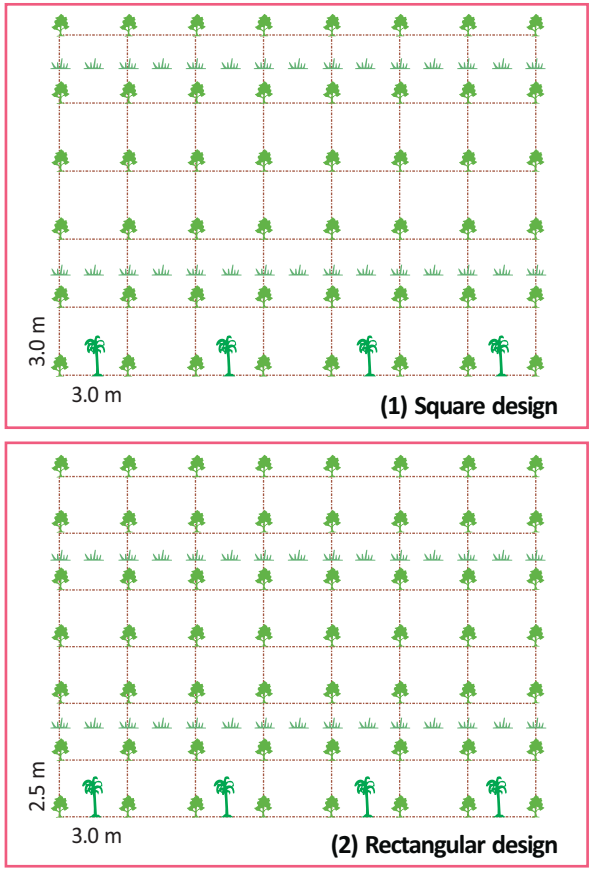
➢ Planting density by soil types

GOOD SOIL ON FLAT LAND	
1 tree / planting hole	2 trees / planting hole
3.0 m x 3.0 m	3.0 m x 3.0 m
1,111 trees / ha	2,222 trees / ha
2 stems per tree	Distance between trees: 20 – 25 cm



SUBOPTIMAL SOIL ON SLOPING LAND	
1 tree / planting hole	2 trees / planting hole
3.0 m x 2.5 m	3.0 m x 2.5 m
1,333 trees / ha	2,666 trees / ha
2 stems per tree	Distance between trees in one planting hole: 20 - 25 cm

2.4 PLANTATION DESIGN



➢ Square design (1)

- Plant spacing for coffee: 3.0 m x 3.0 m
- Simple
- Recommended on flat land

➢ Rectangular design (2)

- Distance between coffee trees in a row: 3.0 m
- Distance between rows: 2.5 m
- Rows are perpendicular to the slope direction

Note:

Shade tree

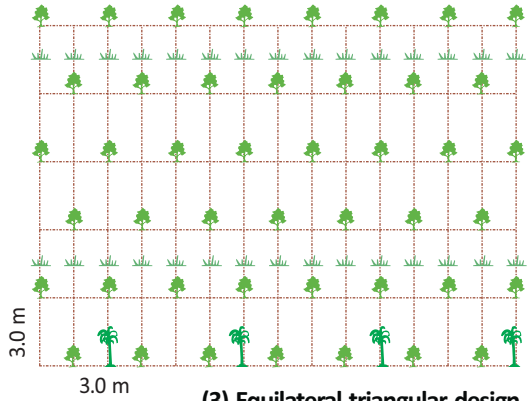
Coffee tree

Wind-break tree

2.4 PLANTATION DESIGN

➢ Equilateral triangular design (3)

- Plant spacing: 3.0 m x 3.0 m
- On sloping land
- This design helps to reduce erosion



(3) Equilateral triangular design

Slope and wind direction

➢ Planting design for shade and wind-break trees

- Cassia Siamea: 12 m x 12 m (70 trees / ha)
- Leucena Leucocephala: 9 m x 12 m (100 trees / ha)
- Avocado, Durian, etc. : 12 m x 12 m
- Pepper: 9 m x 9 m (100 - 200 trees / ha) grown on tree species such as Cassia Siamea, Leucena Leucocephala, etc.

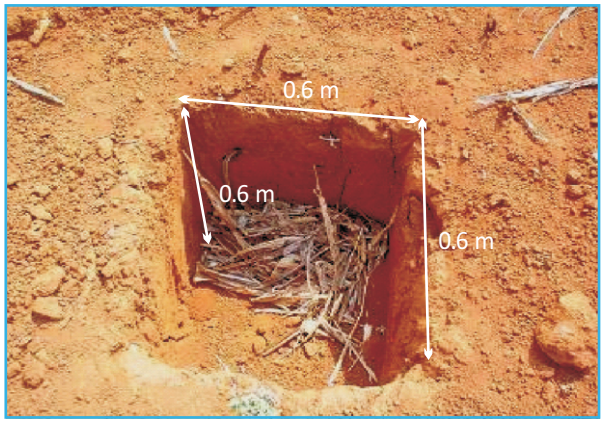
Note:

Shade tree

Coffee tree

Wind-break tree

2.5 INITIAL LAND PREPARATION



➢ Time

- April or May; before the onset of the rainy season
- 1 - 2 months before transplanting so that organic matter will be decomposed and the soil structure will be better

➢ Digging planting holes

- Dig planting holes manually or by machine
- Digging manually
  - Cheap for small plantations (1 - 1.2 ha)
  - Easy to carry out in remote areas
  - Easy to do on steep slopes

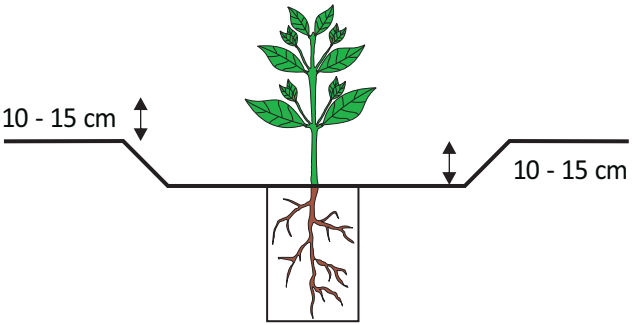
➢ Soil treatment

- Keep the topsoil separately beside each planting hole
- Mix the topsoil with organic fertilizers and phosphate
  - Compost: 5 - 10 kg
  - Fused Calcium Magnesium Phosphate: 0.3 - 0.5 kg
- Add the soil mixture to the bottom of the planting hole

2.5 INITIAL LAND PREPARATION

➢ Widening the planting holes (basins)

- Use a hoe to widen the planting basins
- Move the more fertile topsoil to the bottom of the planting basin

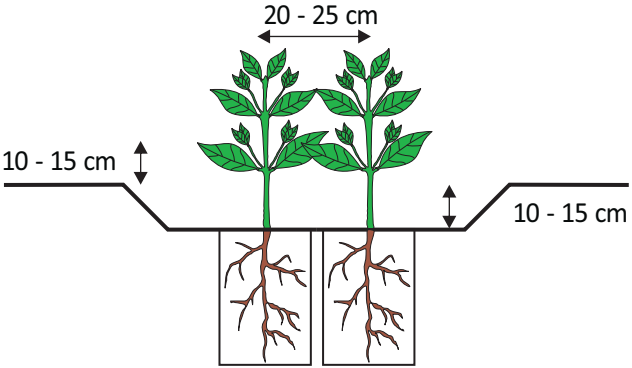


➢ Sub-surface planting technique

- The bottom of the planting hole should be 10 - 15 cm lower than ground level

➢ If no animal dung is available

- Apply organic household waste
- Apply green manure *(Cassia splendida vogel, Fallopia japonica, Chromolacna odorata, Tithonia diversifolia, etc.)*



➢ Compost organic manure before integrating into the soil in situ 2 months before planting

➢ Prevent young seedlings from being attacked by ants and termites

2.6 POST-TRANSPLANTING CARE

➢ 2 – 3 months after planting

- Widen the planting basins to 100 - 120 cm
- Depth of the planting basin: 20 - 30 cm

➢ By the end of rainy season (October)

- Cover the bottom of the planting basins with mulch to reduce evaporation

➢ In the dry season

- Irrigate the seedlings
- Water volume: 100 - 200 liters / tree / irrigation round
- Irrigation interval: 20 - 25 days (if no rain occurs in between)

2.7 EROSION CONTROL

➢ **On bare soils (not covered with vegetation)**

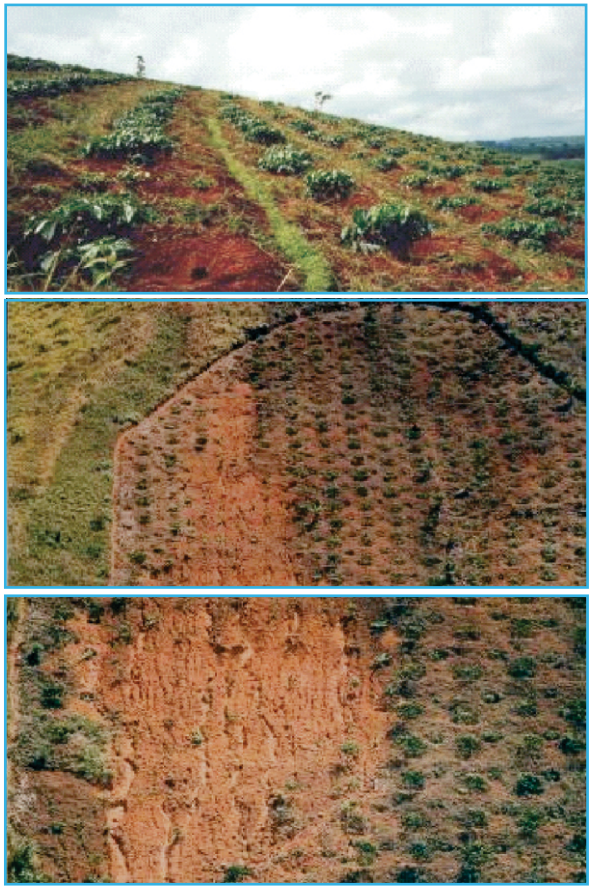
➢ **Slope > 3 - 5%**

➢ **Immature stage**

- One erosion prone soils
- Canopy has not yet fully developed
- Win-break and shade trees are not yet fully developed
- Planting basins are not yet fully excavated

➢ **Soil erosion**

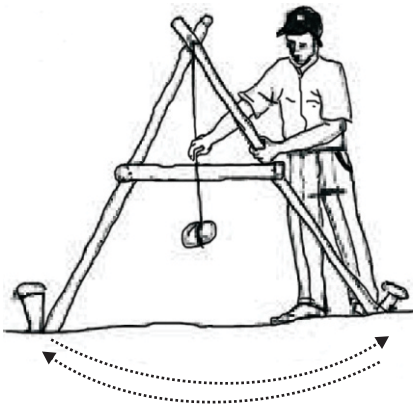
- Soil erosion negatively affects soil nutrition and plant growth
- The risk of erosion in mature coffee gardens and because the canopy fully covers the land



2.7 EROSION CONTROL

1

2



➢ Planting along contour lines

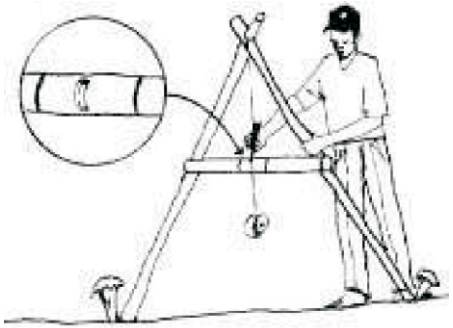
- Contour lines connect points of the same altitude in the landscape
- The purpose of this method is to plant the trees in the same row (on a contour line) at equal altitude above sea level
- Use an A-shaped wooden equilateral triangle with plumb line and horizontal bar (1)
- The spacing between the wooden triangle's legs is equal to the distance between the trees in a row
- Calibrate the wooden triangle on a horizontal surface so that the plumb line crosses the horizontal bar exactly in the middle (2)

2.7 EROSION CONTROL

➢ Planting along contour lines

- Make a mark on the horizontal bar where the plumb line crosses it (e.g. by cutting a notch in the wood)
- Fix one foot of the wooden triangle to locate the starting point (3)
- Move the other leg along the contour line until the plumb line falls in the notch, i.e. ½ of the distance between trees in a row
- Mark that point (4)
- Put one foot of the triangle at the point that has just been marked
- Locate the second point by moving the second foot of the triangle again until the plumb line meets the marker point at the horizontal bar
- Repeat the above steps until the end of each row

3



4

2.7 EROSION CONTROL

➢ Intercropping

- During the immature stage (year 1 - 4), when the canopy of the coffee trees is not fully covering the land
- Intercrop with leguminous food crops
- Intercrops protect and improve the soil quality
- Intercrops produce food and generate additional income

➢ After harvesting use the plant remains from leguminous crops

- Leave plant remains from the intercrops in the field
- Compost the plant remains and mix with the soil in the planting basins

2.7 EROSION CONTROL

➢ Intercropping

- Intercrop with leguminous crop species (such as Catjang cowpeas, Phaseolus angularis Wight, etc.)
- Plant intercrops far from coffee plants
- Regularly remove vines from the intercrops that grow over the coffee trees

➢ Do not intercrop with conrn, cassava, rice, etc.

- These crops have a high nutrient demand
- Therefore there is competition for nutrients and in some cases for light
- Coffee plants become stunted and seedlings may die

➢ Intercrop leguminous crops along contour lines

- Reduction of soil erosion by 48 %

2.7 EROSION CONTROL

Macuna sp.

➢ Intercropping with leguminous crop

- Recommended species are Cassia splendida Vogel, Tephrosia candida, Cajanus cajan, etc.
- Reduced wind speed and sunlight
- Pruning remains of the intercrops are a good source of organic matter and can enrich the soil with nutrients
- Improvement of chemical and physical soil conditions
- On sloping land, it is recommended to plant one row of Fallopia japonica or Cassia splendida Vogel between every 3 - 5 rows of coffee trees

2.7 EROSION CONTROL

➢ Application of planting basins

Advantages

- It is the most effective erosion prevention technique
- It facilitates application of water and fertilizer directly to the individual plants
- This technique reduces runoff of water and agrochemicals

Year 1

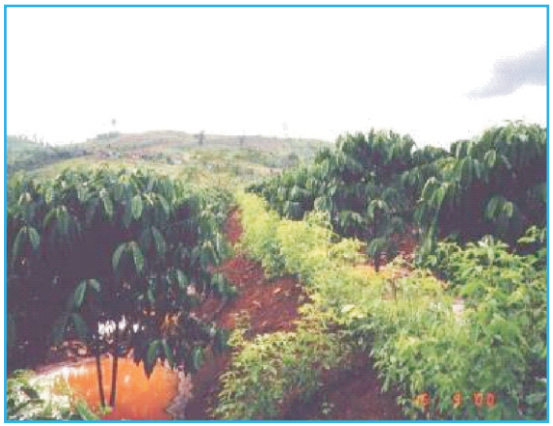
- 2 - 3 months after planting (August - September); after harvesting the intercrops
- Enlarge the basins to a diameter of 0.8 - 1.0 m
- Depth of the planting basins: 0.15 - 0.20 m
- The planting basins can be square or circular
- Apply organic matter in furrows along the basins or spread out on the basin's surface

Year 2 and 3

- Enlarge the planting basins annually before the rainy season
- Enlarge the basins in line with the size of the canopy cover
- The final diameter of the planting basins is 1.8 - 2.0 m

From year 4 onwards

- Maintain the basins regularly



2.7 EROSION CONTROL

➢ Mulching

Advantages:

- Reduced loss of water through evaporation
- Improved soil water retention capacity
- Improved soil nutrient retention capacity
- Improved weed control
- Prevention of soil surface compaction
- Improved erosion prevention
- Reduced nutrient leaching; improved soil fertility
- More stable soil temperature

➢ Mulch types

- Plant remains (e.g. leaves, pruning remains, etc.)
- Organic matter such as coffee pulp, husks, maize stubbles, banana leaves, etc.
- Cover the basin's surface with mulch or integrate into the soil at a depth of 5 cm

2.8 SHADE TREES

➢ Shade trees

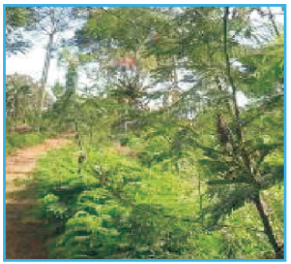
- Plant 50 - 70 shade trees / ha
- Recommended shade trees are Cassia siamea, Leucena spp., Wrightia laevis Hook, Dalbergia cochinchinensis, Dalbergia tonkinensis, Dalbergia annamensis, etc.
- Planting density: 6 x 30 m
- Prune the shade trees regularly

➢ Advantages

- Source of wood for fuel
- Reduction of water evaporation
- Reduced irrigation requirement
- Improved working conditions as the plantation is cooler
- Nitrogen fixing tree species reduce the demand for chemical nitrogen fertilizers
- Coffee trees will be healthier and stronger under harsh conditions (e.g. higher temperature due to changing climate) and/or minimum management compared to sun grown coffee trees

Cassia siamea

Leucena spp.



2.9 QUESTIONS AND EXERCISES

1. Describe the characteristics of a good soil for coffee planting.
2. What is soil erosion?
3. Explain 4 methods to prevent erosion.
4. Describe the method to design a plantation along contour lines.
5. What are the reasons for soil acidification and what are the solutions?
6. What are advantages of intercropping?
7. Make an inventory of your own field describing which soil management techniques are used and which need improvement; discuss with your peers and evaluate each other's observations.

MODULE 3. FERTILIZER MANAGEMENT

3.1 WHY IS FERTILIZER APPLICATION NECESSARY?

Growth

FERTILIZER TYPES

INORGANIC FERTILIZER

ORGANIC FERTILIZER

MICRO-NUTRIENTS

Product

3.2 FERTILIZER TYPES

➢ Organic fertilizers

- Remains from pruning
- Compost (e.g. made from household organic waste)
- Microbiological fertilizers

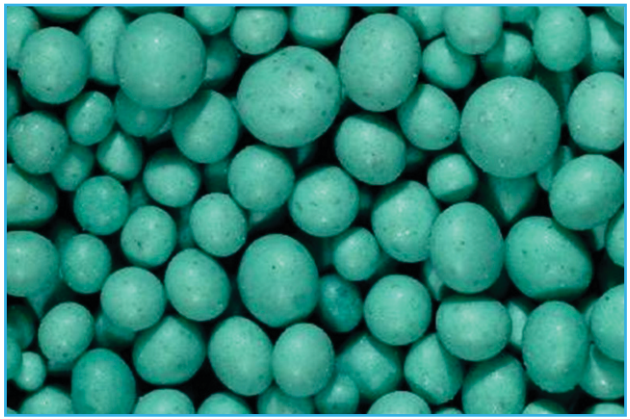
Advantages:

- Organic fertilizers contain many different nutrients (N, P, K, Ca, Mg, etc.)
- One can recycle organic remains from pruning coffee trees, shade trees etc.
- One can reduce the use of chemical fertilizers
- Increase of the soil water and nutrient retention capacity
- Organic fertilizers improve the soil structure
- Because of soil structure improvement it is a tool to prevent erosion

3.2 FERTILIZER TYPES

Mixed fertilizer

Complex fertilizer



➢ Mineral fertilizers

- **Single nutrient fertilizers**

  Contain only 1 macro nutrient

  E.g. KCl (K), Urea (N)

- **Mixed fertilizers**

  Two or more types of fertilizers are mixed mechanically

  E.g. NPK 16-8-16

- **Complex fertilizers**

  Contain at least two marcro nutrients with a chemical bond

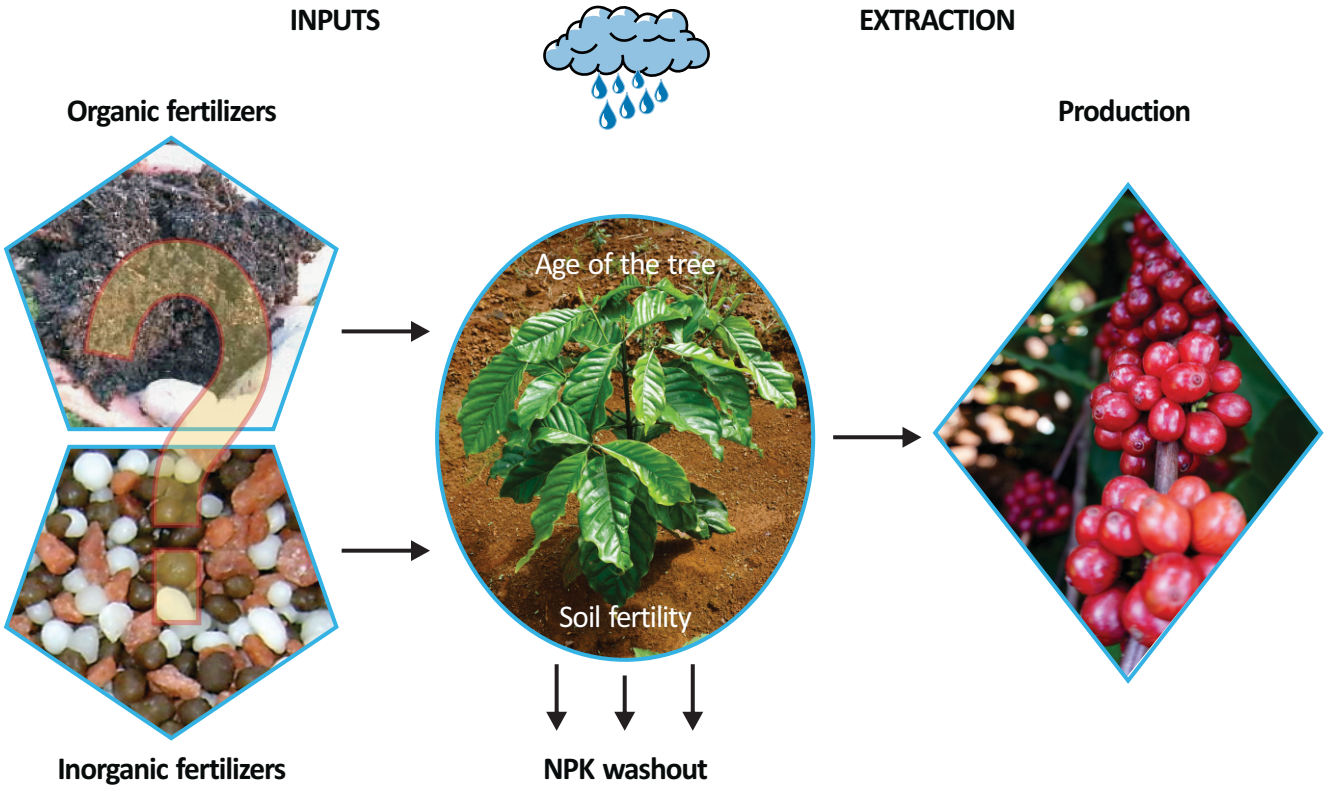
  E.g. Diammonium Phosphate (DAP) contains N and P

3.2 FERTILIZER TYPES

PERCENTAGE (%) OF ACTIVE INGREDIENTS IN COMMERCIAL FERTILIZERS

Name	N	P_2O_5	K_2O	CaO	MgO	S	B	Mn	Zn
Urea	46	-	-	-	-	-	-	-	-
SA	21	-	-	-	-	23	-	-	-
Fused Calcium Magnesium Phosphate	-	14 - 16	-	28 - 30	18	-	-	-	-
Super Phosphate	-	15 - 18	-	-	-	13	-	-	-
KCl	-	-	60	-	-	-	-	-	-
NPK (16:16:8)	16	16	8	-	-	-	-	-	-
NPK (16:8:16)	16	8	16	-	-	-	-	-	-
NPK (15:5:15)	15	5	15	-	-	-	-	-	-
NPK (16:8:14:13S)	16	8	14	-	-	13	-	-	-
NPK (14:7:14)	14	7	14	-	-	-	-	-	-

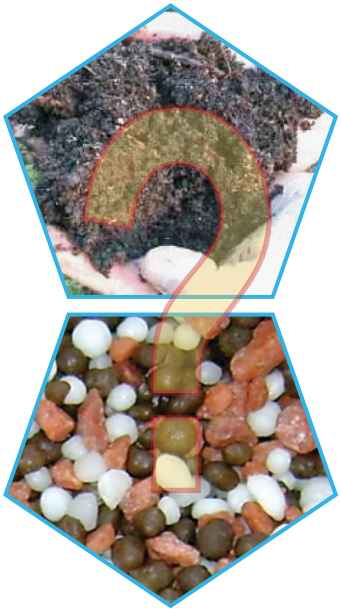
3.3 FACTORS WHICH DETERMINE ANNUAL FERTILIZER REQUIREMENTS



3.3 FACTORS WHICH DETERMINE ANNUAL FERTILIZER REQUIREMENTS

INPUTS

Organic fertilizers



Inorganic fertilizers

EXTRACTION

1 ton green bean (equivalent to 4.5 tons of fresh cherries) contains:

- 41 kg N
  - – 89 kg Urea 46 %
- 6 kg P_2O_5
  - – 37 kg fused Calcium Magnesium Phosphate 15 %
- 50 kg K_2O
  - – 83 kg KCl 60 %

Nutrient uptake efficiency:

N: 30 - 40 %; P: 10 - 15 %; K: 40 - 45 %

Therefore double to triple the amount of the above mentioned fertilizer requirement should be applied to ensure normal tree growth.

3.4 MINERAL FERTILIZER REQUIREMENTS AND TIMING OF APPLICATION

Age of the trees	Kg / ha / year		
	N	P_2O_5	K_2O
1st year (newly planted trees)	60	60	30
2nd year (or 1st year after rejuvenation)	120	75	100
3rd year (or 2nd year after rejuvenation)	150	90	130
4th year onward (3.5 – 4.0 tons of green bean / ha)	280	100	300

Age of the trees	Kg / ha / year			
	SA	Urea	Phosphate	KCl
1st year (newly planted trees)	-	130	400	50
2nd year (or 1st year after rejuvenation)	80	220	500	170
3rd year (or 2nd year after rejuvenation)	100	280	600	280
4th year onward (3.5 – 4.0 tons of green bean / ha)	200	520	700	500

Source: WASI / MARD 1999

3.4 MINERAL FERTILIZER REQUIREMENTS AND TIMING OF APPLICATION

Age of the trees	Fertilizer types	Kg / ha / round			
		1	2	3	4
1st year (newly planted trees)	- SA	-	-	-	-
	- Urea	-	40	50	40
	- Fused Calcium Magnesium Phosphate	-	400	-	-
	- KCl	-	15	15	20
2nd year (or 1st year after rejuvenation)	- SA	80	-	-	-
	- Urea	-	80	80	60
	- Fused Calcium Magnesium Phosphate	-	250	250	-
	- KCl	-	50	60	60

Source: WASI / MARD 1999

- **Round 1:** together with the second irrigation application (January - February)
- **Round 2:** by the beginning of the rainy season (May - June)
- **Round 3:** by the middle of the rainy season (July - August)
- **Round 4:** by the end of the rainy season (September - October)

3.4 MINERAL FERTILIZER REQUIREMENTS AND TIMING OF APPLICATION

Age of the trees	Fertilizer types	Kg / ha / round			
		1	2	3	4
3rd year (or 2nd year after rejuvenation)	- SA	100	-	-	-
	- Urea	-	100	100	80
	- Fused Calcium Magnesium Phosphate	-	300	300	-
	- KCl	-	15	70	100
4th year onwards (3.5 - 4.0 tons of green bean / ha)	- SA	200	-	-	-
	- Urea	-	180	100	160
	- Fused Calcium Magnesium Phosphate	-	350	350	-
	- KCl	50	120	160	170

Source: WASI / MARD 1999

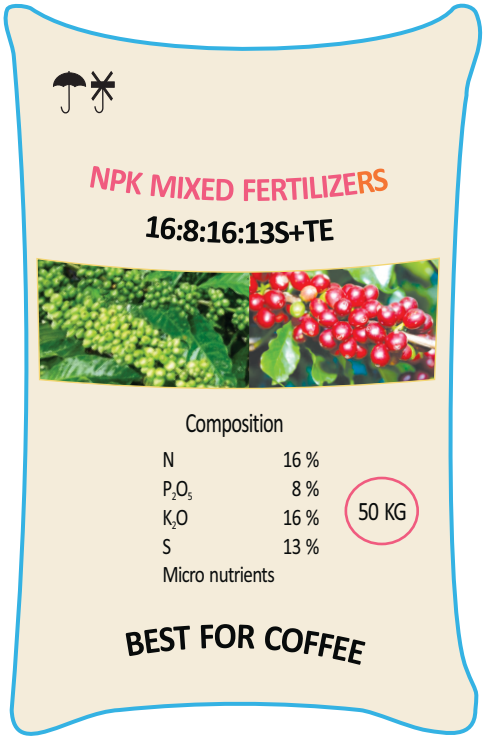
- **Round 1:** together with the second irrigation application (January - February)
- **Round 2:** by the beginning of the rainy season (May - June)
- **Round 3:** by the middle of the rainy season (July - August)
- **Round 4:** by the end of the rainy season (September - October)

3.4 MINERAL FERTILIZER REQUIREMENTS AND TIMING OF APPLICATION

➢ NPK mixed fertilizers

- NPK 16:8:16, NPK 16:16:8, NPK 16:8:14, etc.
- Apply 1.5 - 2.0 tons / ha / year for mature coffee with a yield of 3.5 - 4.0 tons of green bean / ha, depending on the soil fertility and the crop growth status

Increase or decrease the fertilizer application by 10 - 15 % per estimated ton of green bean yield increase or decrease



3.5 ORGANIC FERTILIZER REQUIREMENTS AND TIMING OF APPLICATION

Organic fertilizers and lime	Application dose
Manure (buffalo, cow, pig, chicken, etc.)	• Newly planted trees: 5 - 8 tons / ha • The following years: 10 tons / ha (1 round every second year)
Micro-organic fertilizers	• 1.5 - 2.0 tons / ha / year
Organic debris (mowings; pruning remains from coffee and shade trees; coffee husks, etc.)	• Unlimited • It is recommended to keep all organic remains on the field as a mulch in the planting basins
Lime; based on soil pH analysis	• Apply every second year • 500 kg / ha / application round • Apply by the beginning of the rainy season; distribute evenly

Note: Organic debris such as coffee husks are best decomposed before application.

3.6 CALCULATION OF THE FERTILIZER REQUIREMENTS

QUESTION 1

1 ha of mature coffee trees requires:

- 280 kg N (15 % SA, 85 % Urea)
- 100 kg P_2O_5 (Phosphate)
- 300 kg K_2O (Potassium)

Available products:

SA	➜	21 % N
Urea	➜	46 % N
Phosphate	➜	15 % P2O5
KCl	➜	60 % K_2O

ANSWER

- 280 x 0.15 = 42 kg SA
- 280 x 0.85 = 238 kg Urea

SA = 42 x 100/21 = 200 kg

Urea = 238 x 100/46 = 517 kg

Phosphate = 100 x 100/15 = 666 kg

KCl = 300 x 100/60 = 500 kg

QUESTION 2

1 ha of mature coffee trees requires:

- 280 kg N (15 % SA, 85 % Urea)
- 100 kg P_2O_5 (Phosphate)
- 300 kg K_2O (Potassium)

Available products:

NPK	→	16:8:16
Urea	→	46 % N
KCl	→	60 % K_2O

ANSWER

- N = 280/16 x 100 = 1,750 kg
- P_2O_5 = 100/8 x 100 = 1,250 kg
- K_2O = 300/16 x 100 = 1,875 kg

Select the smallest value; here it is P_2O_5

1,250 kg NPK 16:8:16 contains

N = 1,250 x 16/100 = 200 kg

P_2O_5 = 1,250 x 8/100 = 100 kg

K_2O = 1,250 x 16/100 = 200 kg

In conclusion, N and K_2O need to be added (cf. page 59)

3.6 CALCULATION OF THE FERTILIZER REQUIREMENTS

QUESTION 3

1 ha of mature coffee trees requires:

- 280 kg N (15 % SA, 85 % Urea)
- 100 kg P_2O_5 (Phosphate)
- 300 kg K_2O (Potassium)

Available products:

NPK	→	16:8:16
Urea	→	46 % N
KCl	→	60 % K_2O

ANSWER

1. Calculate the amount of additional nutrients N and K_2O required
   - N = 280 - 200 = 80 kg
   - K_2O = 300 - 200 = 100 kg
2. Calculate the amount of single nutrient fertilizers Urea (N) and KCl (K_2O) required
   - N = 80 x 100/46 = 174 kg
   - K_2O = 100 x 100/60 = 167 kg

3.7 FERTILIZER APPLICATION TECHNIQUES

➢ Newly planted trees

- Mix phosphate with animal dung for basal application
- Mix compost with Urea and Potassium Chloride

Application techniques

- Dig a furrow at a distance of 0.15 - 0.20 m from the stem
- Apply the fertilizer mixture at a depth of 3 - 5 cm in the furrow
- Refill the furrow with soil after application

3.7 FERTILIZER APPLICATION TECHNIQUES

➢ Second year onwards

- Spread fertilizers either in a circle around the trees or at 2 sides along the trees
- Nitrogen and Potassium fertilizers can be mixed and applied on top of the soil after removal of weeds
- Cover the fertilizers always with soil after application
- Always integrate single Phosphorous fertilizers in the soil to assure better availability for the trees

3.7 FERTILIZER APPLICATION TECHNIQUES

➢ Organic fertilizers

- Dig a furrow along the tree outside the canopy extents
- Dimensions

  width: 0.3 m

  depth: 0.3 - 0.4 m

  length: 1.0 – 1.5 m
- Apply organic fertilizer into the furrow together with mineral phosphorus fertilizer
- Refill the furrow with soil
- Any type of organic matter must be decomposed before application to avoid ant and microorganism attacks

3.8 FERTILIZER APPLICATION EFFICIENCY

➢ Save 10 – 15 % of mineral fertilizers

- Remove all suckers and unproductive branches
- Refill the furrows with soil after fertilizing to avoid fertilizer losses through evaporation
- Plant leguminous windbreaks and shade trees (such as Leucaena)
- Make use of all organic matter in the garden (e.g. dry branches, leaves, mowings, etc.) in the form of manure

Application rules

1) Right type of fertilizer
2) Right amount of fertilizer
3) At the right time
4) Right number of application rounds

In order to improve fertilizer application efficiency, it is recommended to take soil samples

How to take a soil sample?

- When: not right after a rainfall event, a fertilizer application or irrigation
- For homogeneous soil types: 1 soil sample per 1 - 2 ha
- Take soil samples from 5 points in the garden (1 in the middle and 4 at the corners)
- Dig a 0.3 - 0.4 m deep hole with a shovel; take soil from the top to the bottom of the hole and put it in a plastic bag
- Mix the soil from the 5 different observation points and extract 1 - 2 kg to send to the laboratory
- Do not smoke when taking soil samples
- Take soil samples at least 5 - 10 meters away from the plantation's borders; avoid sampling close to big trees, avoid termite nests, ant nests or atypical places

3.9 WHICH FERTILIZER TYPES CAN BE MIXED?

Fertilizer types	SA	Urea	Super Phosphate	FCMP(*)	DAP	Lime	KCl	Potassium Sulfate	Compost
SA	+	+	-	-	+	0	+	+	-
Urea	+	+	+	-	+	0	-	-	-
Super Phosphate	-	+	+	-	-	0	-	-	+
FCMP (*)	-	-	-	+	0	+	-	-	+
DAP	+	+	-	0	+	0	+	+	+
Lime	0	0	0	0	0	+	-	-	+
KCl	+	-	-	-	+	-	+	+	+
Potassium Sulfate	+	-	-	-	+	-	+	+	+
Compost	-	-	+	+	+	+	+	+	+

(+) can be mixed

(-) can be mixed right before application

(0) should not be mixed

(*): FCMP: Fused Calcium Magnesium Phosphate

3.10 NUTRIENT DEFICIENCY SYMPTOMS

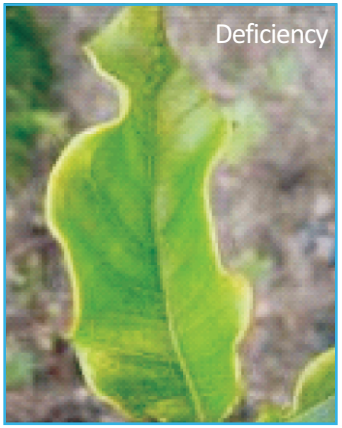
➢ Nitrogen (N)

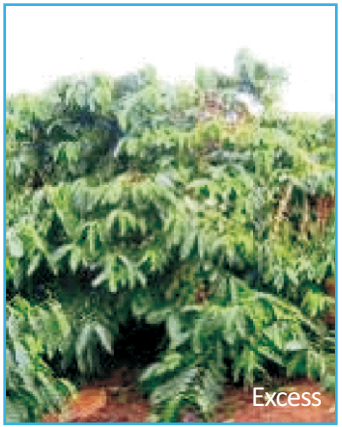
Function

- It makes leaves greener which is a sign of good health status
- It supports leave and shoot growth
- It increases the number of cherries per branch

Nitrogen deficiency

- Becomes first visible on young parts of the trees
- Leaves turn pale yellow and become thin
- Later older leaves turn yellow and are shedded (often on dense fruiting branches first)
- Leaves near the stem and in the lower part of the canopy become yellow first; other leaves are affected later
- Slow development of new leaves and shoots
- Branches could die under extreme deficiency





3.10 NUTRIENT DEFICIENCY SYMPTOMS

➢ Phosphorus (P)

Function

- It supports the development of flowers and cherries
- It improves the coffee bean quality
- It supports root growth and the ability of the roots to absorb nutrients
- It reduces the risk for branches to dry out and shedding of leaves
- It supports increased pest and disease resistance

Phosphorous deficiency

- Retarded root growth
- Insufficient wood formation
- Old leaves on heavily bearing branches turn from light yellow to dark red starting at the leaf tips
- Leaves become dry, hard and are shedded

3.10 NUTRIENT DEFICIENCY SYMPTOMS

➢ Potassium (K)

Function

- It improves nutrient transport in the plant
- It improves the ability to bear fruits
- It increases the weight and size of the beans
- It reduces the number of floaters (low weight cherries, often containing just 1 bean)
- It increases resistance to drought and pests and diseases

Potassium deficiency

- Leaves turn dark black with crooked, necrotic stripes along the leaf margins
- Discoloring starts from the leaf tips inwards to the main vein
- Less noticeable in young leaves
- Under extreme deficiency berries and branches are shedded

3.10 NUTRIENT DEFICIENCY SYMPTOMS

➢ Magnesium (Mg)


Deficiency


Deficiency

Function

- It makes leaves greener which is a sign of good health status
- It produces energy for the trees

Magnesium deficiency

- Deficiency often occurs in case of excessive calcium (Ca) in the soil
- Olive-green discoloration occurs between the veins from the inside towards the leaf edges
- The main vain then turns yellow
- The olive-green colors then turn into a bronze like color, whereas the leaf veins keep their normal green color; the leaves finally resemble a fishbone structure

3.10 NUTRIENT DEFICIENCY SYMPTOMS

➢ Calcium (Ca)

Function

- It is necessary for root growth
- It supports tissue formation
- It helps with plant detoxification

Calcium deficiency

- Leaves turn gradually yellow from the outer edges to the middle of the leaf surface
- The part along the main vein of the leaf remains dark green
- The leave tips crook irregularly inwards
- Dieback of growing shoots occurs


Deficiency


Deficiency

3.10 NUTRIENT DEFICIENCY SYMPTOMS


Deficiency


Deficiency

➢ Sulfur (S)

Function

- It makes leaves greener which is a sign of good health status
- It produces energy for the trees
- It supports better plant transpiration

Sulfur deficiency

- Young leaves and the parts near the leaf tips become yellowish silver
- Leaves become thin; both veins and leave surfaces become yellow
- The leaf edges crook downwards (easy to be torn apart)
- The whole tree will have a yellowish silver color in case of severe sulfur deficiency

3.10 NUTRIENT DEFICIENCY SYMPTOMS

➢ Iron (Fe)

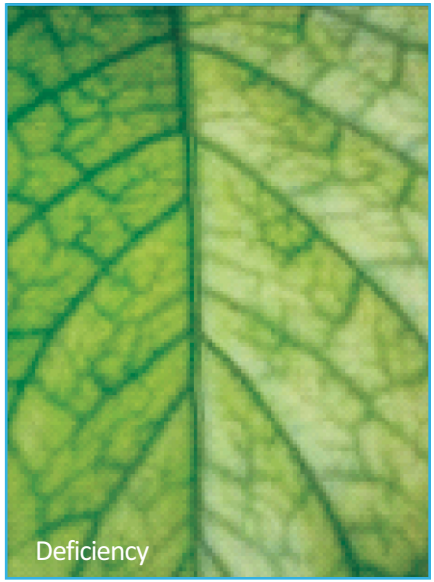
Function

- It makes leaves greener which is a sign of good health status

Iron deficiency

- Leaves will initially develop distinct yellow or white areas between the veins of young leaves
- Severe iron deficiency can lead to spots of dead leaf tissue


Deficiency


Deficiency

3.10 NUTRIENT DEFICIENCY SYMPTOMS

➢ Zinc (Zn)

Function

- Necessary for the plant's metabolism

Zinc deficiency

- Leaves remain small and are deformed
- Leaves become curly and have the form of a knife blade
- Leaves turn entirely yellow or have yellow stripes along the main vein
- Shoots and growing tips develop slowly
- Short internodes especially in shoots and growing tips

3.10 NUTRIENT DEFICIENCY SYMPTOMS

➢ Boron (Bo)

Function

- Necessary for the plant's metabolism

Boron deficiency

- Terminal shoots die
- Leaves are malformed
- Leaves show an olive green and yellow green chlorosis on the top half


Deficiency

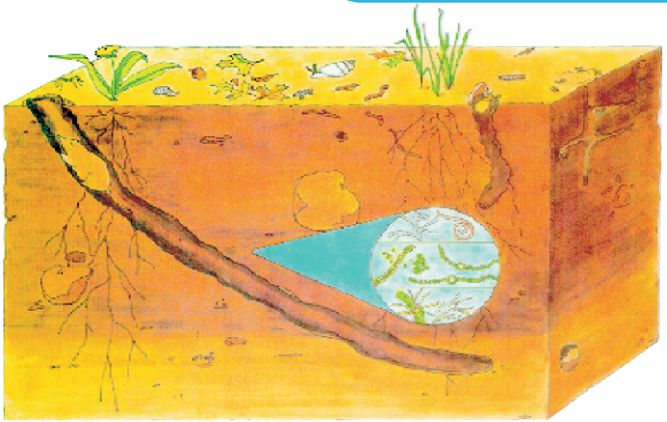

Deficiency

3.11 QUESTIONS AND EXERCISES

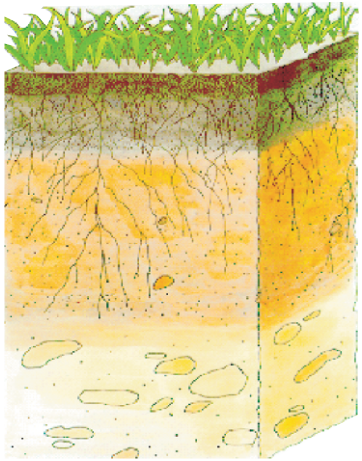
1. To produce 3 tons of green beans, how much nutrients (N, P_2O_5 and K_2O) are taken up by the plants?
2. How to reduce the risk of low productivity for the next harvesting season?
3. Name 3 macro nutrients and their functions.
4. How can one recognize trees with magnesium, iron and phosphorus deficiency symptoms?
5. When do trees need phosphorus and why?
6. What is the importance of applying fertilizer at the right time?
7. How many types of organic fertilizers are there? Present their advantages and what is the best way of organic fertilizer application?
8. A coffee garden is 3 years old with an expected yield of 1.5 tons; available fertilizers are Potassium Chloride, Urea and Superphosphate. Calculate the fertilizer requirements.
9. A coffee garden is 7 years old with an expected yield of 3 tons; available fertilizers are DAP, NPK 15:5:15, Urea and KCl. Calculate the fertilizer requirements and take into account which fertilizers can be mixed.
10. How to enhance efficient use of fertilizers?

MODULE 4. ORGANIC FERTILIZERS

4.1 WHAT IS SOIL ORGANIC MATTER?



Soil ecosystem



- Soil organic matter is that fraction of the soil composed of anything that once lived
- It includes plant and animal remains in various stages of decomposition:
  - Cells and tissues of soil organisms
  - Substances from plant roots and soil microbes
- Well-decomposed organic matter forms humus
- Humus is a dark brown, porous, spongy material with an earthy smell
- In most soils, organic matter accounts for less than 5 % of the volume
- Tropical soils usually contain < 1 % while temperate soils may have up to > 50 % organic matter

4.2 ORIGIN AND TYPES OF SOIL ORGANIC MATTER

➢ Organic inputs (1)

- When plants die, their stems, roots and leaves become a part of the soil organic matter

➢ Metabolism (2)

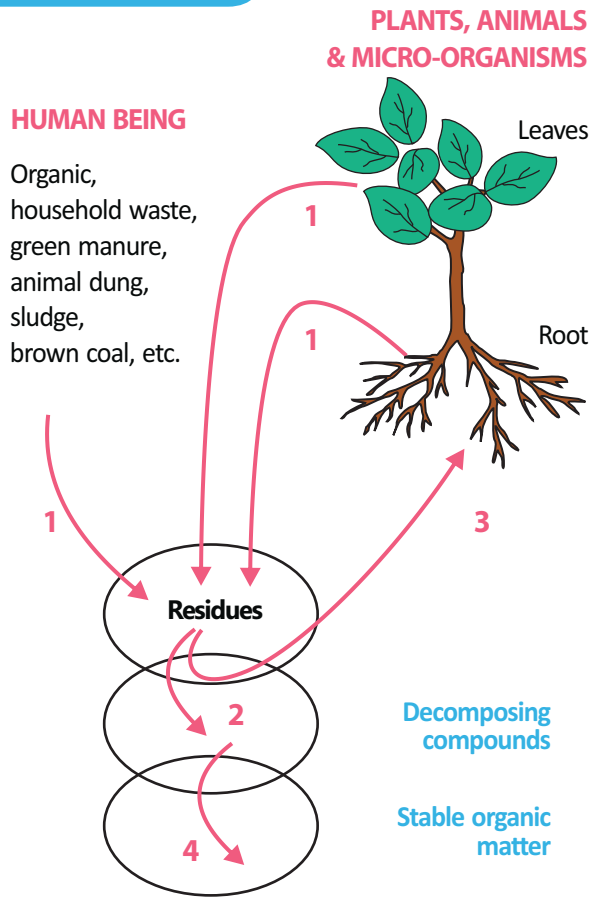
- Soil micro-organisms continuously metabolize organic compounds from one to another form
- They eat plant residues and other organic substances
- They produce by-products, wastes and cell tissue

➢ Micro-organisms feed plant species (3)

- Some wastes released by soil micro-organisms are nutrients for plant species
- Micro-organisms also release other chemical substances that affect plant growth

➢ Stabilization of organic matters (4)

- Eventually, soil organic compounds become stable and resistant to further changes



4.3 WHAT DETERMINES SOIL ORGANIC MATTER CONTENT?

➢ Soil organic matter is the result of two processes:

- Organic matter addition (roots, surface residue, manure, etc.)
- Loss of organic matter through decomposition

➢ Factors affecting addition or loss are:

Soil management

- Irrigation and soil cover crops increase root development and organic residue formation
- Intensive tillage speeds up decomposition and leads to a decrease in soil organic matter

Soil texture

- Clay soils can hold much more organic matter than sandy soils
- Sandy soils are well-aerated, which speeds up decomposition of organic matter

4.3 WHAT DETERMINES SOIL ORGANIC MATTER CONTENT?

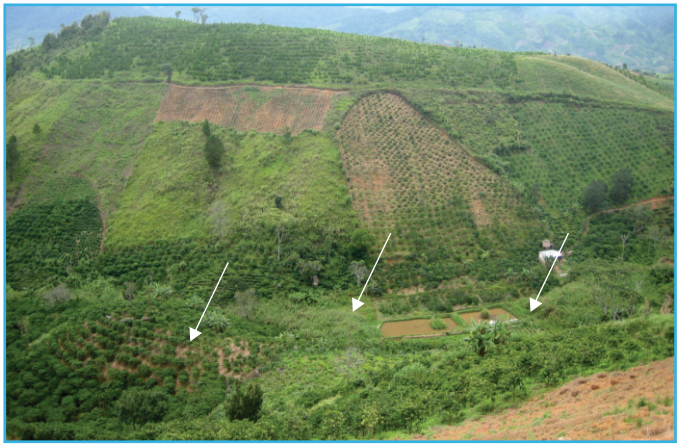
➢ Factors affecting addition or loss are:

Climate

- High temperatures speed up decomposition
- In areas with high rainfall, plants grow fast, adding more roots and residues to the soil

Landscape position

- Low lying areas with poor drainage usually have a high organic matter content because less oxygen is available in the soil to facilitate decomposition
- Landscape depressions also accumulate organic matter that runs of the slopes
- Soils on sloping land usually have a lower organic matter content than soils on flat land

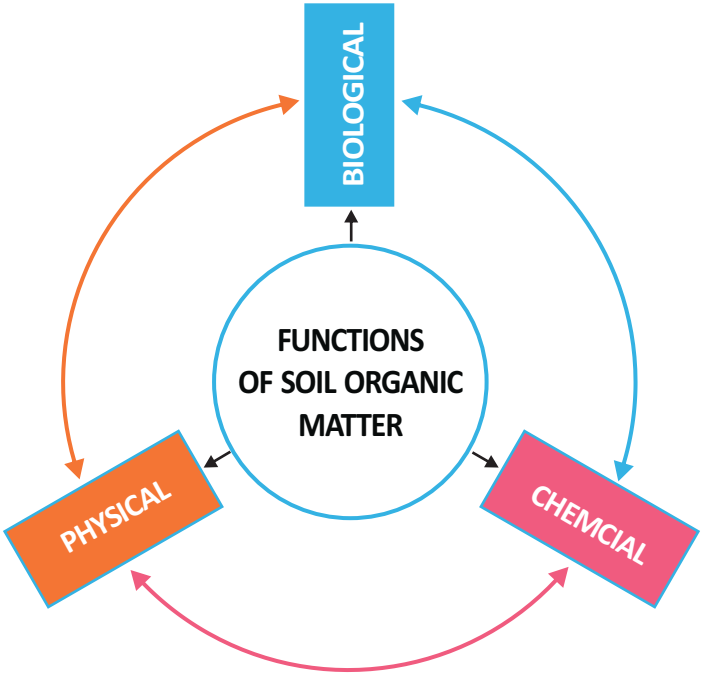


Coffee grows better in depression because of higher soil organic matter content

Vegetation

- In grasslands, much of the organic matter that is added to the soil each year comes from grass roots that extend deep in the soil
- In forests, the organic matter comes from leaves that dropped on the soil surface
- Grassland has a higher organic matter content than forest land

4.4 FUNCTIONS OF SOIL ORGANIC MATTER



- It provides energy for soil bacteria
- It stores and supplies nutrients (e.g. N, P, S, etc.)
- It stabilizes the soil structure by keeping soil particles together; this in turn reduces erosion risks and increases the water infiltration
- Soil organic matter increases the soil's water holding capacity and soil aeration leading to better plant growth
- It prevents the soil surface from compaction
- It makes the soil more friable and less sticky; this makes the soils easier to plough and facilitates better root penetration
- Organic matter increases the nutrient retention capacity of the soil
- It reduces potential negative effects of pesticides on the environment by absorbing pollutants

4.5 LOSS OF SOIL ORGANIC MATTER

- **Erosion**
  - This process selectively detaches and transports particles on the soil surface that have the highest content of organic matter
- **Absorption by micro-organisms**
  - Soil organic matter provides energy and nutrient to micro-organisms
  - Some of the organic materials are incorporated in the cell structures of micro-organisms
  - During decomposition, most of the organic matter is emitted as CO_2 and water and some forms of nitrous gasses
- **Soil tillage**
  - Soil tillage leads to faster decomposition of organic matter because of changes in the soil water content, soil aeration and temperature
- **Land reclamation and forest clearing**
  - Soil organic matter loss occurs when natural forests or grasslands are burnt
- **Organic matter decomposes faster with increasing temperatures**
  - Micro-organisms become more active under higher temperature conditions

4.6 HOW TO PROTECT AND INCREASE SOIL ORGANIC MATTER?

➢ Protection of soil organic matter

- When reclaiming new land, do not apply slash and burn practices, plant cover crops and apply mulch
- Minimize ploughing the top soil; the more tillage, the better the soil aeration and the faster the organic matter decomposes
- Apply anti erosion practices
  - Design terraces and drains to avoid surface water runoff
  - Intercrop with leguminous species
  - Plant shade trees
  - Plant coffee trees and intercrops along the contour lines

➢ Adding organic matter to the soil

- Frequently apply organic fertilizers such as compost, green manure, animal dung, microbial fertilizers, household organic residues, etc.

4.7 COMMON ORGANIC FERTILIZER TYPES

➢ Animal dung

- From pigs, cows, chicken, duck, buffalo, etc.
- Animal dung has a high content of N and P_2O_5

➢ Application

- Apply on top of the soil in the planting basins once every second year
- Apply 4,000 - 5,000 kg / ha / year
- Over-application of animal dung can lead to nutrient imbalances, soil acidification and eutrophication of nearby water resources

➢ Fish residues

- High salt content
- Over-application can lead to nutrient imbalances and soil compaction

Animal	Dung production (kg / day / animal)	Nutrient content (kg / ton or kg / m^3)		
		N	P_2O_5	K_2O
Cow	4.5	5.5	3.5	8.0
Pig	5.8	4.5	4.0	5.5
Chicken	0.2	11.5	14.0	8.0

Source: WASI / MARD 1999

4.7 COMMON ORGANIC FERTILIZER TYPES

➢ Organic fertilizers derived from plants

- Examples are groundnut oil cake, sesame oil cake, cotton seed oil cake, castor oil cake
- Soak the products in water and apply on top of the soil in the planting basins

Type	Nutrient content (%)		
	N	P_2O_5	K_2O
Groundnut oil cake	7.0 - 7.2	1.5 - 1.6	1.3 - 1.4
Sesame oil cake	6.2 - 6.3	2.0 - 2.1	1.2 - 1.3
Cotton seed oil cake	3.9 - 4.0	1.8 - 1.9	1.6 - 1.7
Castor oil cake	5.5 - 5.8	1.8 - 1.9	1.0 - 1.1

Source: WASI / MARD 1999

4.7 COMMON ORGANIC FERTILIZER TYPES

➢ Peat

- Peat consists of partially decomposed plant remains
- It can be found in waterlogged, swampy areas
- Peat can be used to produce bio-fertilizers

Nutrient content of peat (%) in Dak Lak

Acid humus	09
Organic humus component	27
Raw humus	64

➢ Plant residues

- Straw
- Pruning remains such as coffee branches and leaves
- Coffee pulp
- Coffee husks
- Cocoa skins


Peat


Coffee husks


Straw

4.7 COMMON ORGANIC FERTILIZER TYPES

Chromolacna odorata (L) King et Robinson

➢ Green manure

- Green manure is made by leaving the remains of (leguminous) intercrops on the field as an organic matter addition
- It can either be ploughed into the soil or left as a mulch on top of the soil

Effects

- It increases soil fertility through release of nitrogen (for leguminous intercrops mainly)
- The roots of the intercrops absorb nutrients in deep soil layers; hence they recycle nutrients otherwise not available for coffee trees
- Nutrients are returned to the soil by ploughing the organic residues of intercrops into the soil
- Dead roots of intercrops create holes in the soil and improve soil aeration
- A mulch of green manure reduces evaporative water losses and reduces the irrigation requirements
- Some types of plants can grow well on poor soil
- Green manure mulch prevents from soil erosion
- Leguminous cover crops reduce weed infestation

4.7 COMMON ORGANIC FERTILIZER TYPES

➢ Green manure

- **Examples of indigenous plants in Vietnam's Central Highlands**
  - Chromolacma odorata
  - Tithonia diversifolia
  - Cassia tora L.

- **Examples of popular species in the Vietnam's Central Highlands**
  - Vigna unguiculata
  - Thephrosia candida
  - Cajanus cajan (L) Millsp

- **Application**
  - Plough green manure into the soil
  - Bury green manure directly into the soil (in ditches near the coffee trees)
  - Apply in combination with compost

Tithonia diversifolia

4.7 COMMON ORGANIC FERTILIZER TYPES


Vigna unguiculata


Cajanus cajan (L)


Cajanus cajan (L)

➢ Green manure

Type	Green manure production (ton / ha)	Nutrient content (% dry matter)		
		N	P_2O_5	K_2O
Cowpea; Vigna unguiculata	25 - 30	3.14	0.46	0.92
Sunn hemp; Crotalaria juncea	25 - 30	3.15	0.52	1.10
Senna splendida	25 - 30	3.15	0.50	1.00
Hoang pea; Tephrosia candida	30 - 40	3.50	0.52	1.10
Pigeon pea; Cajanus cajan (L)	20 - 30	3.65	0.60	1.50

Source: WASI / MARD 1999


Crotalaria juncea


Tephrosia candida

4.7 COMMON ORGANIC FERTILIZER TYPES

➢ Bio- fertilizers

- Bio-fertilizers are made from peat through biochemical processes
- Bio-fertilizers exist in solid and liquid form
- Bio-fertilizers consist of living or latent micro-organisms which can supply nutrients to plants
- Various commercial bio-fertilizers are available on the market
- Compost is a self-made version of bio-fertilizer

Notes:

- Apply according to the guidelines on the bag
- Store bio-fertilizers in dry and cool conditions and separate from other chemical products such as insecticides, herbicides, mineral fertilizers, etc.
- Do not use expired bio-fertilizers
- Apply bio-fertilizers only in combination with other soil amendments, since they cannot replace other fertilizer type

4.7 COMMON ORGANIC FERTILIZER TYPES

➢ Urban wastes

- Organic waste from urban areas
- There are many different types and qualities
- They usually contain a high concentration of harmful micro-organisms and fungi

Treatment

- Urban organic waste must be treated industrially (chemical or physical) to remove harmful elements before application as soil amendment
- Treated urban wastes can be mixed with organic and inorganic fertilizers

Application

- Similar as for other organic fertilizers such as compost
- Nutrient content: 0.5 - 0.6 % N; 0.3 - 0.6 % P_2O_5; and 0.5 - 0.8 % K_2O

4.8 COMPOSTING

➢ Advantages

- Compost adds additional nutrients to the soil resulting in higher and stable yields
- When applying compost, one can reduce the application of mineral fertilizers
- Compost improves soil properties
- Compost application reduces insect attacks in the plantation
- Application of compost has long lasting effects on productivity
- Compost is easy to produce in the plantation

➢ Composition of compost

- It contains the macro nutrients: N, P, K, Ca, S and Mg
- It contains micro nutrients: Bo, Cu, Mo, Mn, Zn
- It contains plant stimulants such as auxin and heteroauxin and vitamins (e.g. B12, Q)
- The nutrient value of compost varies significantly depending on the organic compounds used

DO NOT apply untreated organic matter, coffee pulp or husks directly on the topsoil

4.8 COMPOSTING

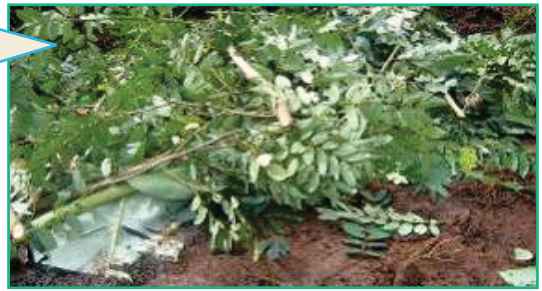
➢ **Materials:** fresh coffee pulp or husks, urea, lime, Fused Calcium Magnesium Phosphate, plant residues, etc.

Step 1: Cover the soil surface with a tarpaulin or banana leaves to avoid nutrient leaching

1

Step 2: Put a layer of small branches (10 cm thick) on the tarpaulin or banana leaves to increase aeration

2



Step 3: Add another layer (25 cm thick) of fresh coffee pulp or husks

3

Step 4: Sprinkle NPK fertilizer or single nitrogen fertilizer and lime over the heap to speed up the decomposition process (micro-organisms that support decomposition use nitrogen)

4

4.8 COMPOSTING

Step 5:

- Add another layer of coffee pulp, straw or small branches
- This will strengthen the heap and prevents it from falling apart

5

Step 6: Add another layer (25 cm thick) of fresh coffee pulp and sprinkle NPK fertilizers, fused Calcium Magnesium Phosphate and lime over the heap

Step 7: Repeat step 3 to step 6 until the heap reaches a height of 1.5 - 2.0 m

Step 8: Cover the heap with a tarpaulin or banana leaves to prevent it from getting wet

6

7

8

4.8 COMPOSTING

After 3 to 5 months, the compost is ready to be applied

Step 9:

- Turn the heap after 2 weeks
- Leave the branches as described in step 2, in place
- Cover the heap again with a tarpaulin or banana leaves as in step 8

Step10:

- From this time onwards, turn the heap once per month
- The coffee pulp and husks will be completely decomposed after 3 - 5 months
- At that time the compost is ready to be applied

Fertilizer application

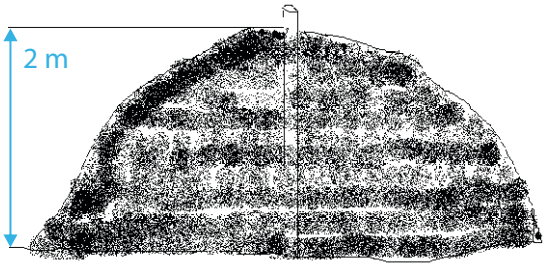
– Apply compost in a furrow beside the trees or in between the rows

4.8 COMPOSTING

➢ 3 composting methods

1) Method 1: Hot composting (tight cover)

- Make a compost heap in the same manner as described before
- Spread lime (1 - 2 %) and phosphorus (2 - 5 %) fertilizer between the compost proportional to the size of the heap
- Cover the heap surface entirely with mud for circa 30 - 40 days
- The temperature of the compost heap will reach 70 - 80^{0}C
- Seeds of weeds and pathogens (such as leaf rust) will be eliminated
- This method leads to fast decomposition and nitrogen loss



4.8 COMPOSTING

➢ 3 composting methods

2) Method 2: Cold composting (light cover)

- This method is similar to hot composting but without a tight cover over the heap
- Cover the heap with dry soil or a tarpaulin for circa 50 - 60 days
- The decomposition process is slower than for hot composting and there is less nitrogen loss
- This method involves a higher risk of contamination with pathogens because of the lower temperature

3) Method 3: Combination of methods 1 and 2

- Apply hot composting in the first two weeks and continue with cold composting
- Treat the coffee pulp with enzymes for faster decomposition
- Sprinkle 1 kg of enzymes, 20 kg of Urea and 1 kg molasses dissolved in water over a compost heap of 1 metric ton

4.9 GENERAL RECOMMENDATIONS

- **Add Trichoderma enzymes when composting**
- **Bury compost in the soil at a depth of 15 - 20 cm**
  - This prevents run-off of fertilizers
  - It avoids direct sunlight and evaporation
  - It reduces the speed of decomposition
- **Combine organic and mineral fertilizers**
  - The combination provides nutrients more effectively to the plant
  - This assures higher yield and better quality
- **Application frequency**
  - Provide compost once per year or every 2 - 3 years to improve soil quality
  - The amount of compost required varies with the soil types and is about 15 - 30 tons / ha

4.10 QUESTIONS AND EXERCISES

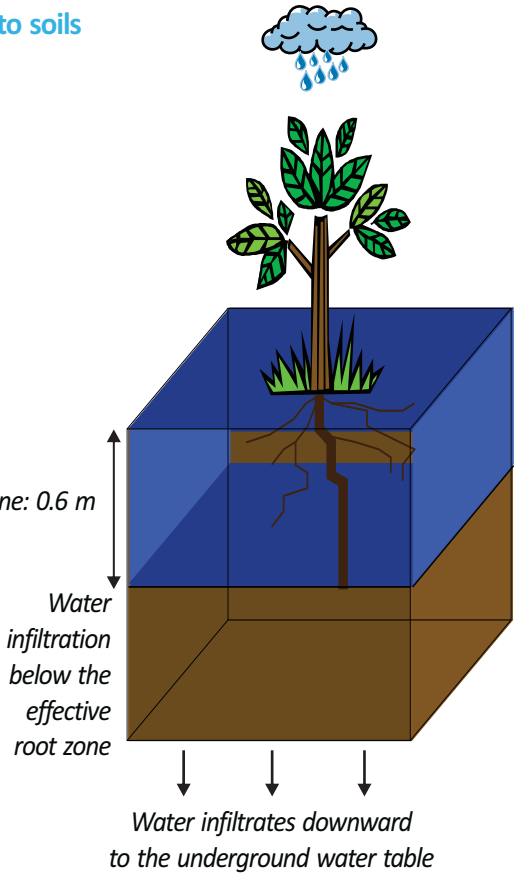
1. Provide a definition for organic matter, green manure and bio-fertilizer.
2. What are functions and benefits of organic fertilizer?
3. How to protect and increase soil organic matter content?
4. Provide 4 types of organic matter that can be used as fertilizers.
5. Why can urban wastes not directly be applied to the garden?
6. Explain how to make compost and how to apply it.
7. Which precautions need to be taken when using bio-fertilizers and why?
8. Name some wild and commonly planted green manures in Dak Lak.
9. What are the advantages of green manure?
10. Task: Evaluate for your own plantation whether you apply organic fertilizers. If so, indicate which type and the benefits or disadvantages you have experienced. If you do not currently apply organic fertilizer, explain why and indicate whether you would start applying and which strategy you would follow.

MODULE 5. IRRIGATION

5.1 RELATIONSHIP BETWEEN SOIL, PLANT AND WATER

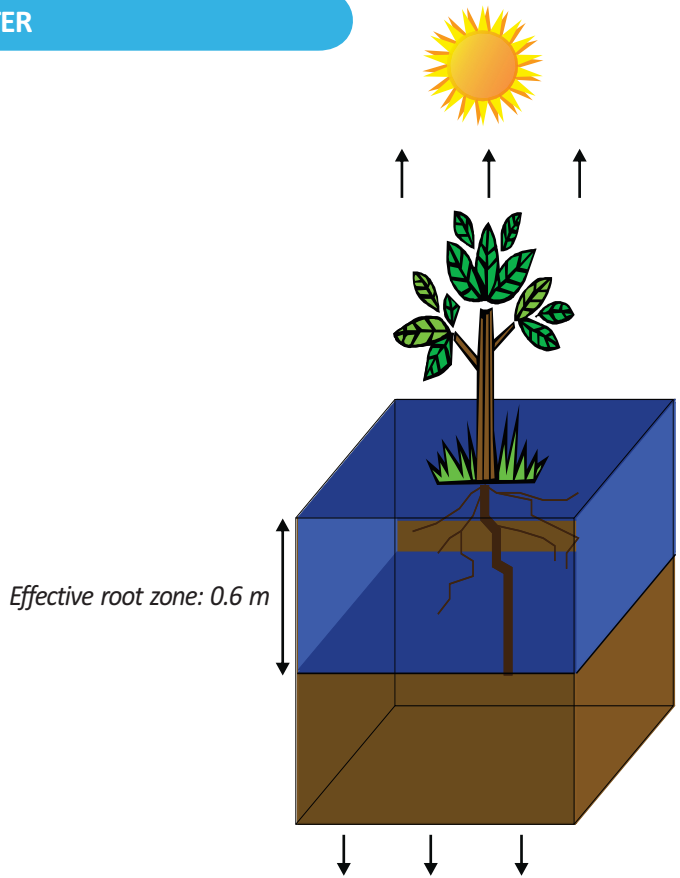
➢ **Prolonged rainfall leads to soils saturated with water**

- Roots die
- Cherries drop
- Loss of nutrients



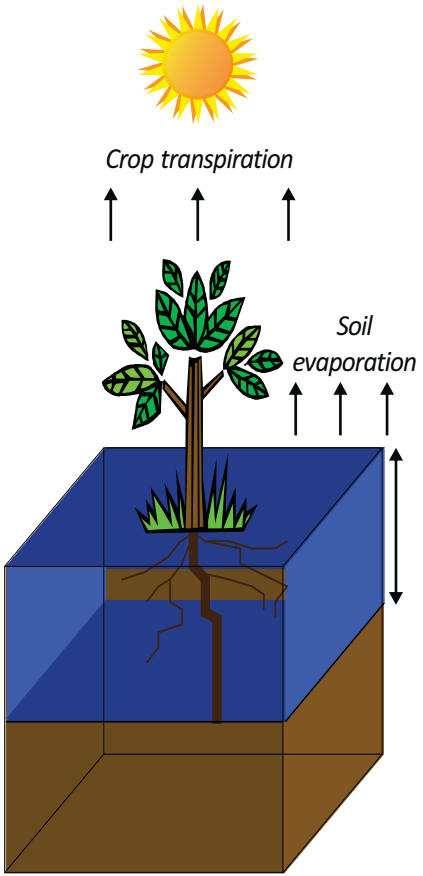
5.1 RELATIONSHIP BETWEEN SOIL, PLANT AND WATER

With a soil moisture content of 37 %, the coffee tree reaches the best growth level



2 days after prolonged rainfall, water drainage occurs due to gravity

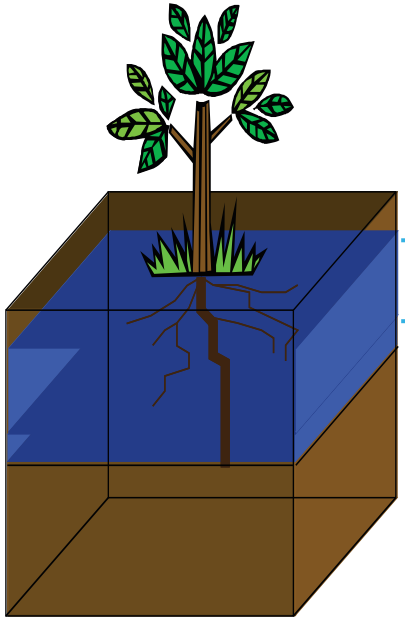
5.1 RELATIONSHIP BETWEEN SOIL, PLANT AND WATER

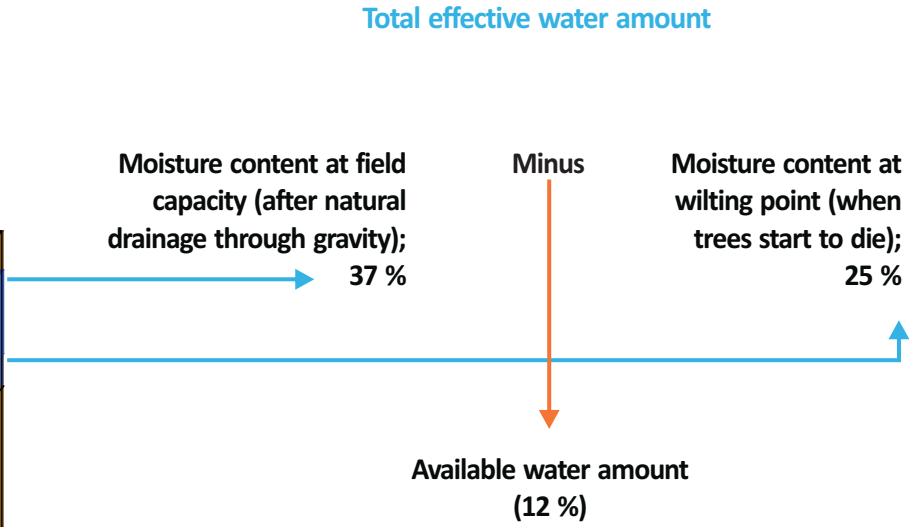


➢ **Under prolonged drought conditions the soil dries out and trees start to wilt**

- Water availability is limited
- Trees are no longer able to absorb water
- Leaves turn yellow and branches dry out
- Leaves are shedded
- Eventually the coffee trees die

5.1 RELATIONSHIP BETWEEN SOIL, PLANT AND WATER





5.1 RELATIONSHIP BETWEEN SOIL, PLANT AND WATER

Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct

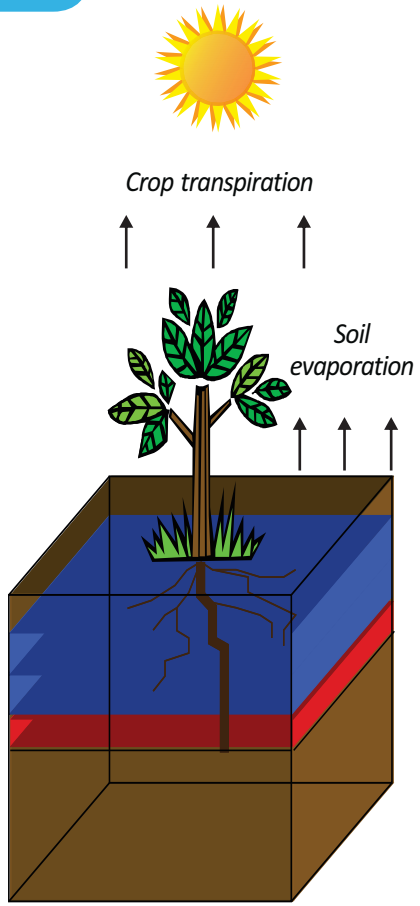
(1) (2) (3) (4)

(5) (6) (7)

- Flower buds start to develop in November
- The initial length of the flower buds is 4 - 6 mm (1); they remain dormant until the end of the rainy season (December)
- Apply irrigation in January - February to stimulate flowering; after 7 - 8 days the buds' water content increases and their length increases 3 - 4 times (2); subsequently the flowers open (3)
- The flowers are pollinated within 24 - 48 hours (4)
- After pollination, the very young fruits (so-called pinheads) remain in a dormant stage with low water requirements until March (5)
- 60 days after blossoming the fruits start to swell, which increases the water requirements; this usually coincides with the onset of the rainy season in early April in Vietnam
- By June the cherries reach their final size (6)
- In August, the coffee beans start to develop and the dry weight of the cherries increases (7)

5.2 IRRIGATION TIMING

When 40 - 50% total water amount in the effective root zone has been evapo-transpired



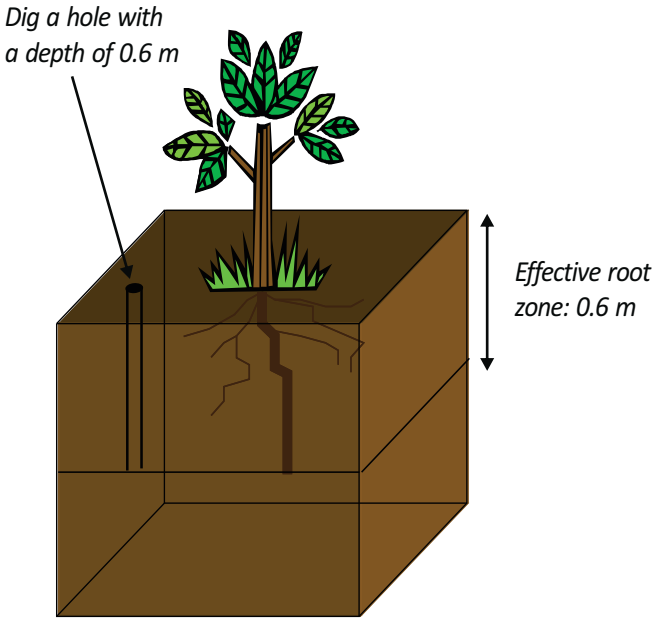
➢ The first irrigation is applied when

- Flower buds are fully developed, having a white color and look like sparrow beaks

➢ What to do if rainfall occurs in the early dry season?

- Dig a small hole in the soil after it stops raining to check the soil moisture
- If the rain water penetrates the soil to a depth of less than 15 cm, additional irrigation is required immediately after the rain to avoid heterogeneous flowering
- In case the rain water penetrates the soil deeper than 15 cm, there is no need for additional irrigation

5.2 IRRIGATION TIMING



➢ Next irrigation rounds

- Monitor the coffee trees in the early morning or late afternoon
- Irrigate when leaves turn yellow, are hanging down or are shedded
- Irrigate when the tree is withering for a few days

SUGGESTIONS

- **Dig a hole with a depth of 0.6 m**
- **Monitor the soil moisture**
- **Apply a new irrigation round if the soil feels rather dry up to 0.6 m depth**

5.3 DISADVANTAGES OF EARLY IRRIGATION

- Inhomogeneous flowering
- Inhomogeneous and early cherry ripening
- Higher harvesting costs
- Harvest will start early and overlap with the rainy season; the harvested cherries are prone to mold formation and quality decline
- Inhomogeneous fruit ripening creates favourable conditions for coffee berry borer
- More irrigation water is required in case of a prolonged dry season
- There is a risk of water scarcity by the end of the dry season
- Lower yield

5.4 IRRIGATION METHODS

➢ Basin irrigation

Advantages

- Low costs
- The soil is only wetted under the canopy, not the entire plantation area
- Easy maintenance of equipment (irrigation hose, pump, etc.)
- More water can be saved compared with the sprinkler irrigation method

Disadvantages

- Labor intensive
- Difficult to manage

5.4 IRRIGATION METHODS

➢ Sprinkler irrigation

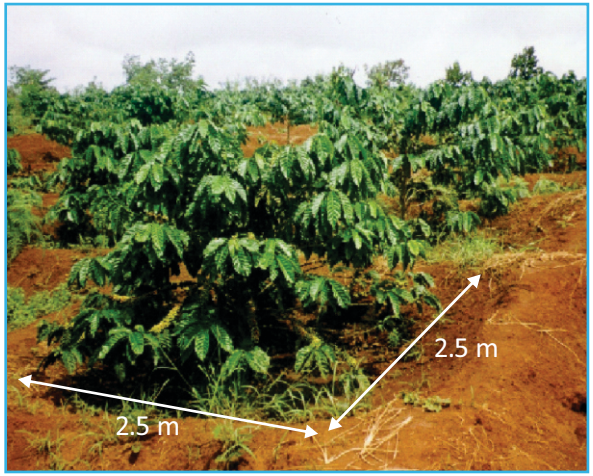
Advantages

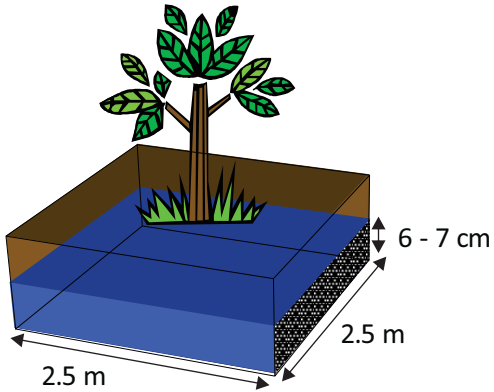
- It looks like an artificial rain, cooling down the atmosphere
- Suitable for different soils and topographical conditions
- This method removes dust on the leaves in favor of photosynthesis
- This method prevents from mealy bug (Pseudococcus risso) infestations

Disadvantages

- Costly equipment
- It requires careful installation in windy areas
- High pressure systems consume more fuel which is costly

5.5 OPTIMUM IRRIGATION VOLUME





➢ Basin irrigation

	liter / tree / round	m^3 / ha
Mature (> 4 years)	350 - 400	390 - 440
Immature (< 4 years)	200 - 300	220 - 330

- The irrigation interval is 20 - 25 days
- Shorter irrigation interval for soils mixed with sand and pebbles

IN PRACTICE

When irrigating, the water depth in the planting basin should be kept at about 6 - 7 cm

Basin surface area: 2.5 m x 2.5 m = 6.25 m^2

6.25 m^2 x (0.06 - 0.07 m) = 0.35 - 0.45 m^3

1 m^3 = 1,000 liters

5.5 OPTIMUM IRRIGATION VOLUME

➢ Sprinkler irrigation

	liter / tree / round	m^3 / ha
Mature (> 4 years)	350 - 400	390 - 440
Immature (< 4 years)	200 - 300	220 - 330

- The irrigation interval is 20 - 25 days
- Shorter irrigation interval for soils mixed with sand and pebbles

IN PRACTICE

How long does one have to irrigate to assure the right volume of water per tree?

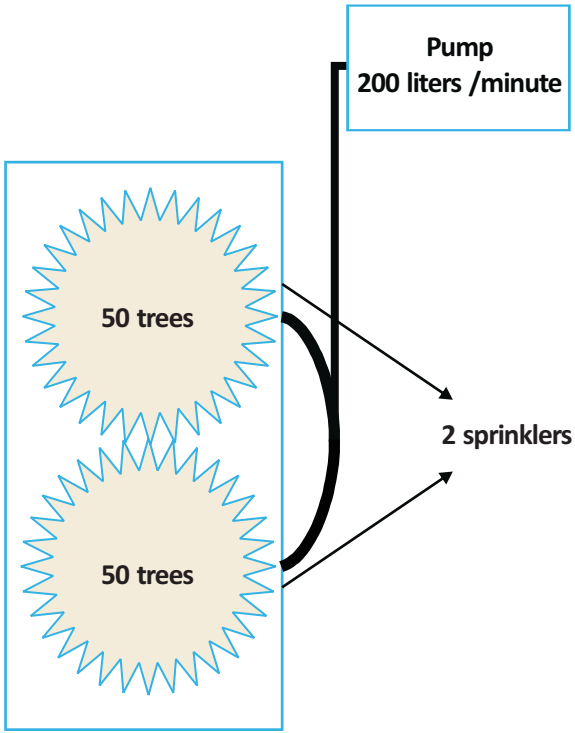
What is the pump capacity?

How many trees are irrigated at the same time?

100 trees x 350 liters / tree = 35,000 liters

Pump capacity = 200 liters / minute

35,000 liters / 200 liters / minute = 175 minutes (or 3 hours)



5.6 DISADVANTAGES OF EXCESSIVE IRRIGATION

- The most important part of the coffee root system extends to 60 cm depth in the soil; excessive irrigation water will percolate below the root system and can hence not be absorbed by the trees
- Higher pumping costs (energy such as electricity and fuel)
- Higher labor costs (man-day)
- Risk of water scarcity
- Reduction of yield and product quality
- Over-use of water for irrigating coffee, reduces ground and surface water resources availability, which endangers water supply for household consumption (e.g. drinking water) and production of hydropower
- Over-irrigation not only affects coffee producers but all other water users (e.g. irrigated rice farming)

5.7 MEASURING THE OPTIMUM IRRIGATION VOLUME PER TREE

➢ Calibration of the required water volume

- Fill a barrel of known volume with water (1)
- Record the time to fill the barrel completely (2)
- Determine the water requirements per basin (take the tree's age into consideration)
- Calculate the time to irrigate 1 basin (3)

1

EXAMPLE

1 barrel = 200 liters

The time to fill a barrel completely is 30 seconds

How long does it take to irrigate 1 basin of mature coffee?

400 liters per tree (basin) is required

400 / 200 = 2 " 2 x 30 = 60 seconds / basin

2

3

5.7 MEASURING THE OPTIMUM IRRIGATION VOLUME PER TREE

4

5

➢ Practical application

- Set the stopwatch at the required time (4)
- Irrigate a basin until the alarm turns on (5)
- Reset the stopwatch and irrigate the next basin

NOTE

Repeat the above calibration procedure whenever a new tube is added or removed and when the engine power is altered

WHY?

The water flow reduces when the distance from the well to the trees gets longer or when the engine power is reduced

5.8 QUESTIONS AND EXERCISES

1. What is the total available water content in the root zone of coffee with roots of 1 m depth and a width x length of 2.5 x 2.5 m? When do I have to irrigate?
2. What are the advantages of sprinkler irrigation?
3. How many cm of water should one apply if the planting holes have dimensions of 3 m x 3 m and the water requirement is 350 liters per tree; how much in case of immature coffee?
4. How long does one have to irrigate mature coffee (total of 525 trees) using 3 sprinklers with a capacity of 25 trees each and a pump capacity of 150 liters per minute? How many times does one need to move the sprinkler installation?
5. Give 7 disadvantages of excessive irrigation.
6. Exercise: Dig a hole of 60 cm and check the wetness of the soil.
7. Exercise: Observe your coffee trees and decide on the water needs.
8. Exercise: Irrigate your plantation with an estimated 350 liters per tree applying a stopwatch.

MODULE 6: PRUNING AND REJUVENATION

6.1 WHAT IS THE PURPOSE OF PRUNING?

➢ Remove unproductive branches

- To guide the nutrient flow directly to flowers and fruit bearing branches
- Development of none fruit-bearing branches requires unnecessary energy from the plant and thus more fertilizer inputs

➢ Remove branches infected with diseases

- To prevent diseases from spreading

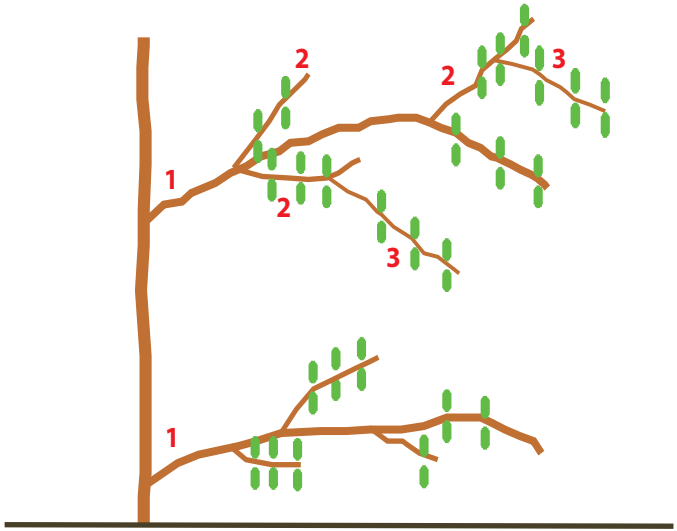
➢ Avoid flowering far away from the stem

- Nutrient transport towards the far ends of the branches is slower and less efficient; it requires more energy from the plant and thus more fertilizer inputs

➢ Open up the canopy

- To increase photosynthesis as the trees will have better access to light
- To reduce pests and disease and facilitate their control because the plantation will be better aerated
- To facilitate coffee harvesting
- To enhance farm management

6.2 WHAT ARE THE DIFFERENT BRANCH TYPES?

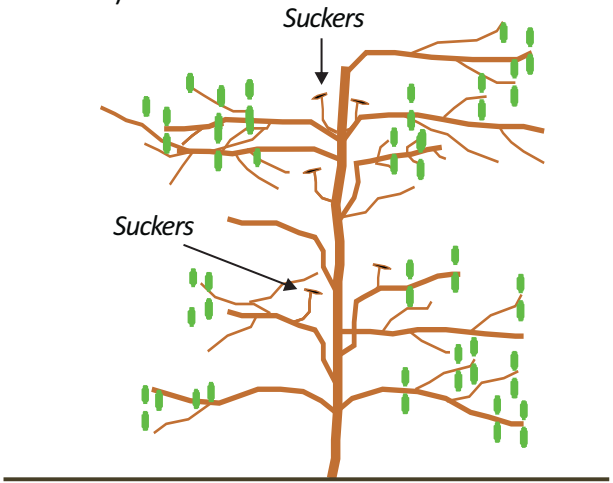


- **Primary branches (1)**
  - They grow directly from the stem
  - They cannot regenerate; i.e. once cut, they won't grow again
  - They guide the nutrient flow to the flower and fruit bearing branches
- **Secondary branches (2)**
  - They grow from the nodes on primary branches
- **Tertiary branches (3)**
  - They grow from the nodes on secondary branches
- **Besides, there are also fourth, fifth, etc. generation branches on coffee trees**

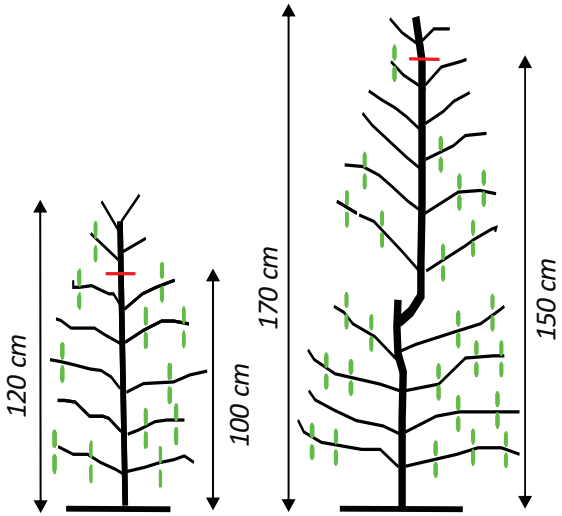
6.2 WHAT ARE THE DIFFERENT BRANCH TYPES?

➢ Suckers

- Suckers can grow from the stem or any other branch type (primary, secondary or higher level branches)
- They have no particular function
- They can be used to regenerate missing parts of the canopy (cf. remedial pruning)
- They can be used as scion for grafting; this should only be considered if the mother tree is healthy, highly productive and disease-resistant (e.g. leaf rust)



6.3 FORMATION OF THE CANOPY STRUCTURE



- **Single stem pruning**
  - Capping or cutting off the top of the stem
- **1st time: When the tree reaches a height of 120 cm**
  - I.e. after circa 3 - 4 years (immature coffee)
  - It could be earlier in case of a fast-growing coffee variety
  - Cut of the stem at a height of 100 cm
  - New stems will develop; select the strongest one to develop the second canopy layer while removing the weaker stems
- **2nd time: When the tree reaches a height of 170 cm**
  - Cut of the stem at a height of 150 cm
  - New stems will develop; select the strongest one to develop the third canopy layer while removing the weaker stems

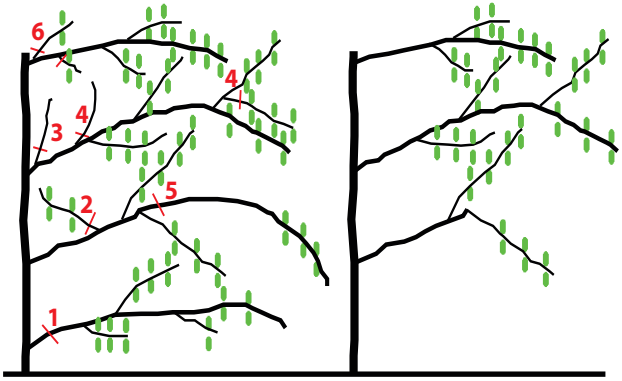
Note:

How to avoid the main stem from splitting due to heavy fruit bearing?

- Cut the stem 2 - 3 cm above the underlying node; or
- Cut 1 of the 2 top fruit bearing branches

6.4 MAINTENANCE PRUNING

- **Cut off lateral branches growing at unfavorable positions such as:**
  - Branches touching the ground (1)
  - Branches growing towards the stem (2)
  - Branches growing vertically downwards
- **Cut off dead, disease-infected, old or stunted branches (3)**
- **Cut off weak branches because they compete with other fruit bearing branches for light and nutrients (4)**
- **Cut off old branches which are expected to produce fewer cherries in the next harvesting season; this enhances the nutrient flow to stronger fruit bearing secondary branches (5)**
- **Cut off secondary branches growing above the main canopy; this provides more light to the lower canopy and hence better photosynthesis (6)**



6.4 MAINTENANCE PRUNING

➢ Timing

- 15 - 20 days after harvesting
- Maintenance pruning is best combined with cleaning the garden

GENERAL RULE

- **Continuously remove suckers throughout the year, in particular when the canopy is too dense**
- **However, make use of suckers in case remedial pruning is required**

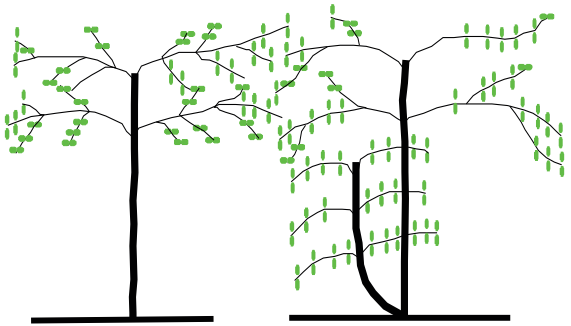
6.5 REMEDIAL PRUNING

When?

- When the lower canopy is sparse or when the tree has an umbrella-like shape (i.e. completely missing the lower canopy)

How?

- Nourish suckers near the soil surface and select the strongest to further develop
- Cut of the top of the new stem when it reaches a height of 1.3 - 1.4 m

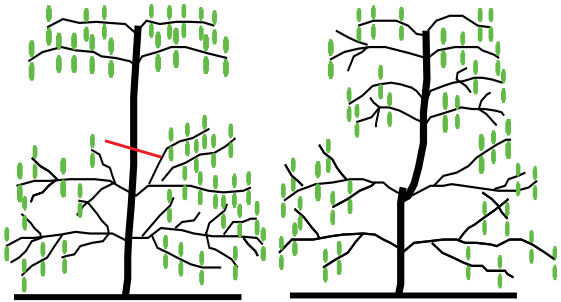


When?

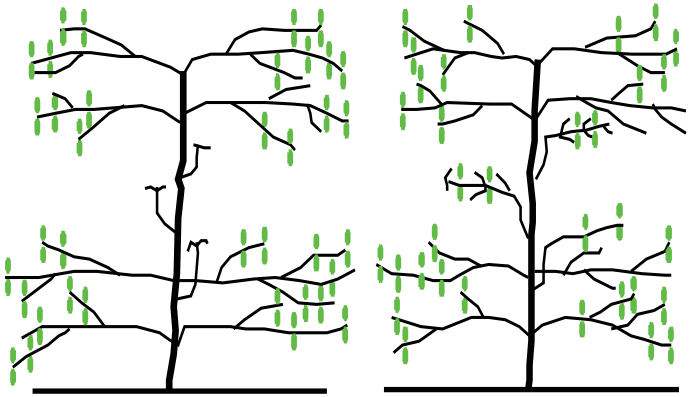
- When the upper part of the canopy is sparse or completely missing

How?

- Cut off the old and poorly developed upper stem
- Nourish suckers at the top and select the strongest to further develop (cf. capping); remove the weakest suckers



6.5 REMEDIAL PRUNING



When?

- When the middle part of the canopy is sparse or completely missing

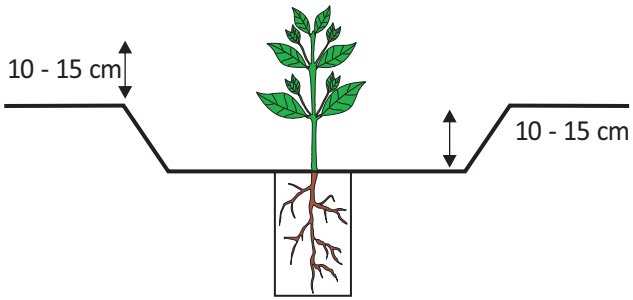
How?

- Nourish suckers that grow out on the stem at the missing canopy part
- When each sucker has one pair of primary branches, select the strongest outer branches and remove all other branches

6.6 HOW MANY TREES PER PLANTING HOLE?

➢ 2 trees per planting hole with single stem pruning

- This technique results in the highest productivity as it makes the best use of 2 separate root systems
- It increases the ability to absorb water and nutrients

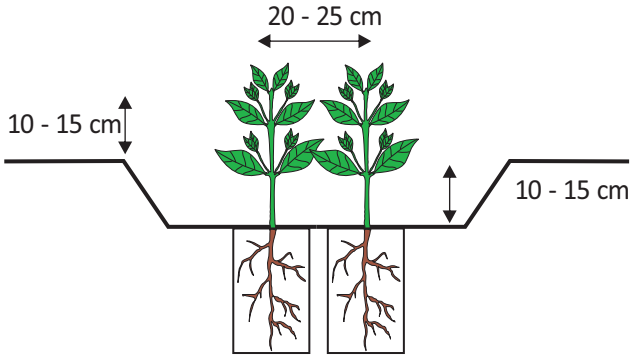


➢ 1 - 5 years

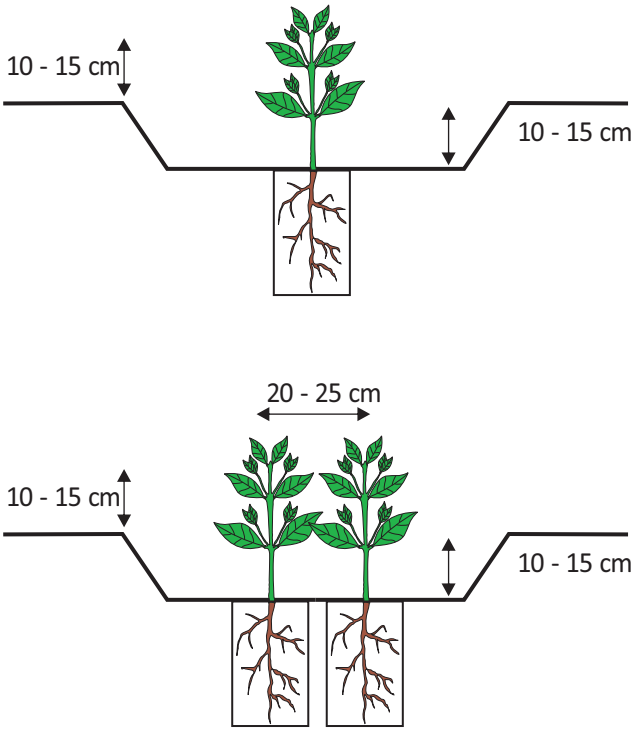
- The canopies of both trees do not yet overlap
- The productivity is higher because there are more trees per unit area

➢ Older than 5 years

- The canopies of both trees overlap
- The productivity per tree declines because of competition for light and nutrients



6.6 HOW MANY TREES PER PLANTING HOLE?



➢ Advantages

- This method allows to monitor the trees' performance and selectively remove trees with lower productivity over time (the goal is to maximize productivity per unit land area)
- Disease-infected plants can easily be removed
- The first generation of Robusta plants in Vietnam originated from seeds; since Robusta is not self-pollinating the first generation tree stand is very inhomogeneous; this caused a high risk for low productivity and leaf rust infection (10 - 20 %)

6.7 REJUVENATION

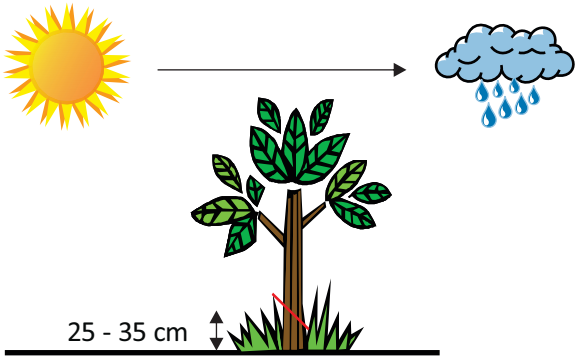
➢ Why?

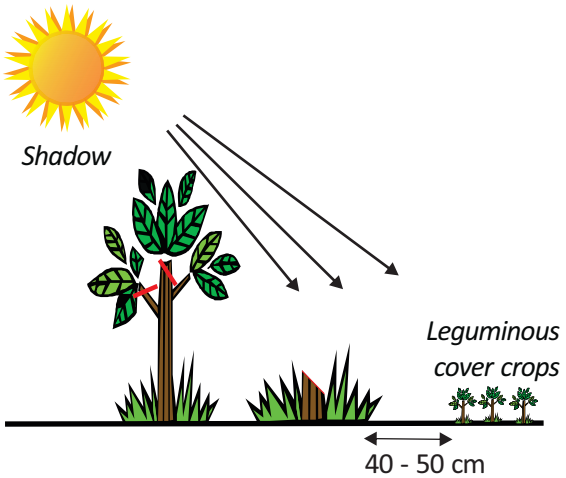
- When the coffee trees become old and unproductive
- When the coffee trees are affected by pests and diseases (e.g. leaf rust)
- Generally between 18 and 25 years

➢ Techniques

- Stumping: i.e. cut down the stem near the soil surface and let new suckers develop into a new stem (natural regrowth)
- Grafting: i.e. cut down the stem near the soil surface and let new suckers develop; graft a scion of a new high productive and disease resistant variety on the strongest sucker; remove all other weaker suckers

6.7 REJUVENATION





➢ Stumping

- **When?**
  - 1 month before the rainy season
  - Rejuvenation should only be considered when the coffee trees are between 18 and 25 years old, with a well-developed root system which is not infected with fungi or nematodes

- **How?**
  - Cut down the stem at a height of 25 - 35 cm above the soil surface in a 45^0 angle facing in Southeastern or Southern direction to avoid direct sunlight on the surface of the cutting so that it won't dry out
  - Make sure the surface of the cutting is smooth
  - Apply 500 - 1,000 kg of lime / ha
  - Plough the soil to about 15 - 20 cm depth, 40 - 50 cm away from the stumps
  - Plant leguminous cover crops (e.g. groundnut, beans, etc.) to improve soil fertility
  - Prune shade trees to provide more light for the coffee trees to develop

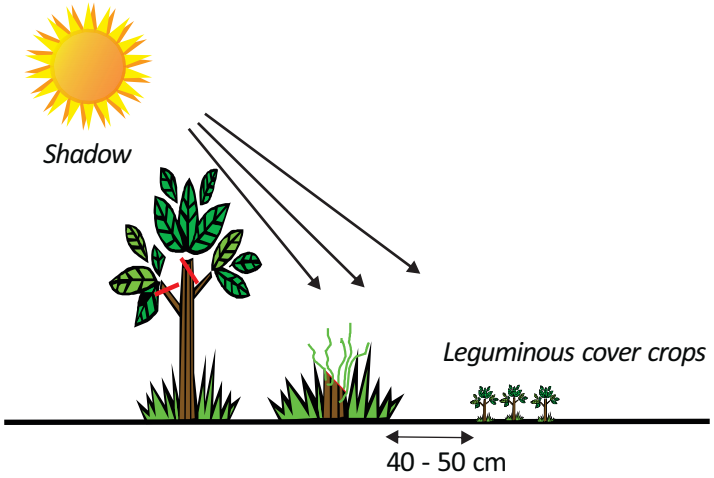
6.7 REJUVENATION

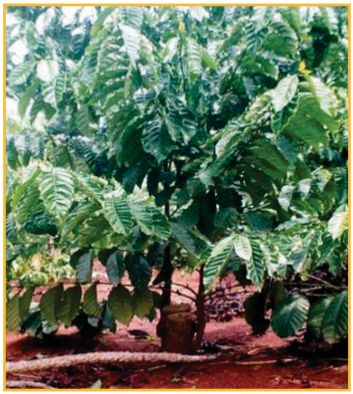
➢ Stumping

- **How?**
  - Select the strongest suckers that develop on the stump
  - Remove weak suckers twice
  - 1st time: select 4 - 5 suckers, 10 - 15 cm tall
  - 2nd time: select 2 - 3 suckers, 20 - 30 cm tall

Note

- Make sure the selected suckers are equally distributed around the stump
- Cap the newly developed stems when they are 1.3 - 1.4 m tall





6.8 QUESTIONS AND EXERCISES

1. Present 5 advantages of pruning.
2. Draw a Robusta tree and specify primary, tertiary and quarternary (4th generation) branches.
3. Give 3 examples whereby suckers can play an important role to increase coffee production.
4. What is capping? When is it used?
5. When is the best time for stumping?

   Why should one combine stumping with pruning of shade trees and planting of leguminous (bean-family) cover crops?
6. Which branches should be removed?

   Give 5 examples.

MODULE 7. PEST AND DISEASE CONTROL

7.1 WHAT IS THE PURPOSE OF PEST AND DISEASE CONTROL?

➢ Advantages of intensive farming

- Strong and healthy plant growth
- Increased productivity
- Improved product quality

➢ Disadvantages of intensive farming

- It creates favorable conditions for pests and diseases
- Excessive use of inputs can lead to nutrient imbalances making the plants more prone to pests and diseases
- Intensive farming usually leads to less biodiversity and makes the crops more prone to external environmental conditions

➢ Monoculture

- In monoculture, only one crop is planted over the entire farm area at a time; this increases the risk for pest and disease infestations

7.1 WHAT IS THE PURPOSE OF PEST AND DISEASE CONTROL?

➢ Under natural conditions there is an ecological balance

- **Advantages**
  - Some (micro)-organisms facilitate the decomposition of organic remains
  - Some (micro)-organisms create nutrients for plants such as nitrogen, phosphorus and potassium
  - Some species (i.e. natural enemies) feed on other organisms that are harmful to agricultural crop production
- **Disadvantages**
  - Some (micro)-organisms are harmful to plants (e.g. insects, fungi, bacteria, etc.) and other living organisms
- **Human impacts**
  - Human activity creates ecological imbalance
  - Some useful and harmful organisms can be eliminated or proliferated through human activity
  - Ecological imbalances lead to a higher risk for pest and disease infestations




7.2 BASIC PRINCIPLES OF PLANT PROTECTION

➢ Organisms which are harmful to one plant species

- E.g. leaf rust on coffee trees *(Hemileia vastatrix)*
- This disease causes serious economic losses
- Therefore, it is important to breed and select disease resistant cultivars

➢ Organisms which are harmful to many plant species

- E.g. insects such as grasshoppers, mealybugs, etc. can destroy many different plant species such as coffee, maize, beans, etc.
- E.g. fungal diseases like root and stem rot can destroy many different plant species such as coffee, banana, beans, etc.
- Epidemic outbreaks of pests rarely occur under natural conditions, as they are controlled by natural predators

➢ How to mimimize negative impacts?

- Application of Integrated Pest Management (IPM)

7.2 BASIC PRINCIPLES OF PLANT PROTECTION

➢ Prevention of crop damage and production decline

- **Do not fully eliminate harmful organisms**
  - It creates ecological imbalances
  - It is a waste of labor time and money
  - It leads to environmental pollution
- **Motto:** ***Try to prevent pest and disease infestation at large scale first through application of good practices and treat infections at small scale*** *(local application of agro-chemicals)*

➢ Good plant protection practices

- Select strong disease-resistant varieties
- Apply fertilizer timely and in a balanced manner based on the nutrient requirements of the crop
- Visit the coffee plantation regularly to check for pests and diseases

INTEGRATED PEST MANAGEMENT

5 RULES FOR INTEGRATED PEST MANAGEMENT (IPM)

1. **Adopt Good Agricultural Practices (GAP) to assure healthy coffee tree growth**
2. **Regularly monitor the coffee plantation**
3. **Apply biological pest and disease management techniques**
4. **Apply mechanical pest and disease management tools (e.g. pruning)**
5. **Only when no other pest and disease management tools are effective, apply chemical measures**

7.2 BASIC PRINCIPLES OF PLANT PROTECTION

1. Adopt Good Agricultural Practices (GAP) to assure healthy coffee tree growth

- Select appropriate varieties
- Prune regularly disease infected branches
- Manage shade trees
- Apply fertilizer timely and in a balanced manner based on the nutrient requirements of the crop
- Irrigate timely with correct water volumes
- Apply mulching
- Weed regularly
- Clean the coffee plantation regularly (i.e. remove disease-infected branches and cherries)
- Regularly clean working equipment and tools (e.g. pruning scissors)
- Remove other plants in the plantation that may host harmful organisms

2. Regularly monitor the coffee plantation

- Regularly check the coffee plantation for pests and diseases
- Analyze the pest and disease damage levels
- Study the weather conditions to anticipate and prevent potential pest and disease outbreaks

3. Biological measures

7.2 BASIC PRINCIPLES OF PLANT PROTECTION

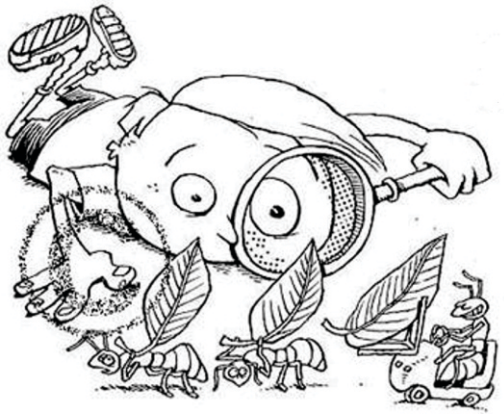
- Protect useful natural enemies: red lady-bugs, (Rodolia sp.), yellow-eyed bugs, mantes, red-eyed bees, etc.
- Create favorable conditions for natural enemies, e.g.:
  - Apply regularly organic fertilizer
  - Apply fertilizer timely and in a balanced manner based on the nutrient requirements of the crop
  - Use probiotics such as Trichoderma, Metarhizium and Beauveria bassiana

4. Mechanical measures

- Stump heavily infected trees and graft pest-resistant varieties on healthy rootstock (not applicable in case of root diseases)
- Regularly check for pests and diseases and remove heavily infected branches or entire trees

5. Chemical measures

- Apply agro-chemicals only when all previously described measures are not effective
- Do not use banned or highly hazardous agro-chemicals; use only agro-chemicals recognized by the government
- Use agro-chemicals in compliance with labor and food safety regulations
- Use agro-chemicals following 4 rules of thumb:
  - Correct agro-chemical for a certain pest or disease



7.3 FUNGAL DISEASES

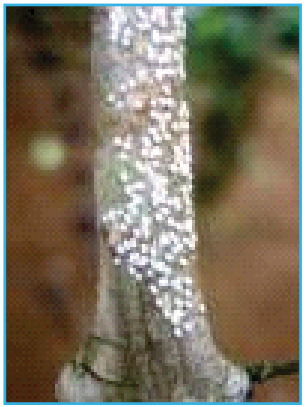
➢ Leaf rust

- **Symptoms**
  - Mainly harmful for leaves (the fungus rarely affects the stem or cherries)
  - Defoliation of the tree leads to reduced photosynthesis hindering plant and cherry growth
  - Leads to productivity decline
- **Causes**
  - High temperatures in combination with high air humidity
  - Selection of coffee varieties which are not resistant
- **Prevention and treatment**
  - Select disease-resistant coffee varieties such as Robusta TR5, TR6, TR9, Arabica Ruiru 11
  - Graft disease resistant and highly productive scions on infected trees (only when the rootstock is healthy)
  - Agro-chemicals should only be used in case of serious infestation
  - Do not use banned or highly hazardous agro-chemicals; use only agro-chemicals recognized by the government

7.3 FUNGAL DISEASES

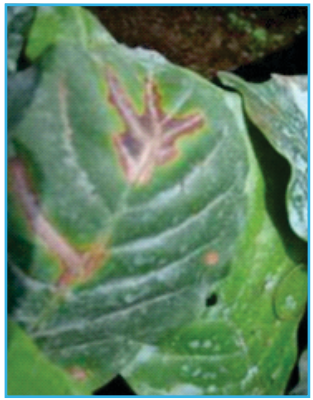
➢ Pink disease

- **Symptoms**
  - Arabica coffee is more susceptible for this disease than Robusta
  - Pink powder appears on branches and cherries
  - The disease occurs in the rainy season
  - Branches dry up and die
- **Causes**
  - High humidity
  - Intensive light
- **Prevention and treatment**
  - Prune regularly to keep the plantation well-aerated
  - Check the plantation regularly in case of abundant rainfall
  - Remove and burn affected branches on the spot
  - Agro-chemicals should only be used in case of serious infestation
  - Do not use banned or highly hazardous agro-chemicals; use only agro-chemicals recognized by the government



7.3 FUNGAL DISEASES

➢ Frogeye leaf spot



- **Symptoms**
  - This disease is mainly found in nurseries and immature coffee plantations
  - Seedlings and young trees show stunted growth
  - Leaves turn yellow and the seedlings and young trees start to defoliate
  - Red ripe coffee cherries turn from yellow to black and become rotten
- **Causes**
  - Bad nursery management
  - Nutrient deficiencies facilitate outbreak of this disease
  - Occurs more frequently on poor, infertile soils
- **Prevention and treatment**
  - Apply organic and mineral fertilizers timely and in a balanced manner
  - Agro-chemicals should only be used in case of serious infestation
  - Do not use banned or highly hazardous agro-chemicals; use only agro-chemicals recognized by the government

7.3 FUNGAL DISEASES

➢ Stem canker

- **Symptoms**
  - Commonly found on the middle part of the stem or nearby the stump
  - The outer bark cracks and turns black
  - The disease blocks nutrient transport in the tree
  - Trees start to wilt from the top downwards
  - The disease spreads quickly
- **Causes**
  - High air humidity in densely planted gardens trigger this disease
- **Prevention and treatment**
  - Regularly check the plantation and try to discover the disease in its early stage
  - Remove the disease-infected parts (pruning) and burn on the spot
  - Uproot and burn wilted trees on the spot
  - Use a sharp knife to scrape infected parts of the bark and burn on the spot; coat the remaining scars with copper-based agro-chemicals

7.3 FUNGAL DISEASES

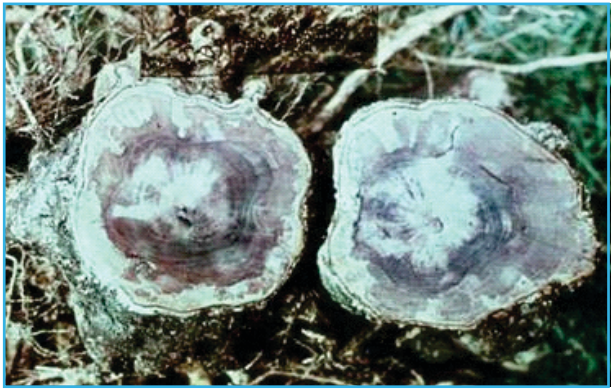
➢ Root lesion

- **Symptoms**
  - This disease is mainly found in nurseries and immature coffee plantations
  - The root collars get rotten, turn black and shrink
  - Trees grow poorly and may ultimately die as they cannot absorb water and nutrients
- **Causes**
  - High soil moisture content due to excessive rain or over-irrigation
  - Too much shade in the nursery
  - Poorly aerated soil
- **Prevention and treatment**
  - Avoid excessive irrigation in the nursery
  - Avoid dense overhead shade in the nursery
  - Regularly turn the soil in the polybags to assure good soil aeration
  - Use well-structured and well-drained soil in the polybags
  - Select recognized, disease free varieties
  - Regularly check the nursery and the field for early detection and uproot infected trees
  - Spray a Bordeaux Mixture 2 to 3 times at an interval of 15 days

7.3 FUNGAL DISEASES

➢ Black collar rot

- **Symptoms**
  - This disease is mainly found in nurseries and immature coffee plantations
  - The root collars get rotten and turn black
  - The trees grow poorly and may ultimately die as they cannot absorb water and nutrients
  - This disease spreads quickly
- **Causes**
  - Too dense overhead shade results in high air humidity
  - This disease is often observed in weak seedlings with curved and weakly developed roots
- **Prevention and treatment**
  - Thin the number of shade trees to favor aeration
  - Uproot and burn on the spot seriously infected trees
  - Spray a Bordeaux Mixture 2 to 3 times at an interval of 15 days for slightly infected trees (still green canopy) with an amount of 2 liters / tree



7.3 FUNGAL DISEASES

➢ Soft collar rot

- **Symptoms**
  - This disease is mainly found in mature coffee plantations
  - It rarely occurs and spreads slowly
  - Trees show poor development and stunted growth
  - The bark around the trees' root collar comes off, internal wood becomes soft and spongy and increasingly dries up
  - Seriously affected trees ultimately die
- **Causes**
  - Unclear (possibly caused by fungi)
  - The disease often occurs in the rainy season in the vicinity of forest belts and fruit trees
- **Prevention and treatment**
  - Regularly check the plantation and try to discover the disease in its early stage
  - Uproot infected trees and burn in situ
  - Apply agro-chemicals with active ingredients such as Fosetyl-aluminium (min 95 %), Benomyl or Copper

7.4 NEMATODES

➢ Nematodes

- **Symptoms**
  - Nematodes feed on the root system of coffee trees (root hairs, lateral roots and primary roots)
  - The tap root decays or swells and the trees can easily be pulled out of the soil by hand
  - The coffee trees are characterized by stunted growth, yellow leaves and defoliation
  - Seriously affected trees eventually die
  - Irrigation water contaminated with nematodes can lead to quick spreading of the disease
- **Causes**
  - Nematode infestation usually occurs in acid soils as a result of unbalanced mineral fertilizer application or lack of organic fertilizer application
  - Nematode infestations often result from transplanting infected seedlings from the nursery to the field whereby the roots of the seedlings were not carefully checked
  - The disease often occurs on land which is newly reclaimed and already infested with nematodes
- **Prevention and treatment**
  - Do not establish a nursery on nematode infested soils
  - Do not use nematode infested soil to fill the polybags in the nursery
  - If new land is reclaimed, check for presence of nematodes
  - In case old coffee plantations are rejuvenated, check for presence of nematodes; in case nematodes are present remove all old roots and consider a 2 - 3 year rotation with other crops

7.4 NEMATODES

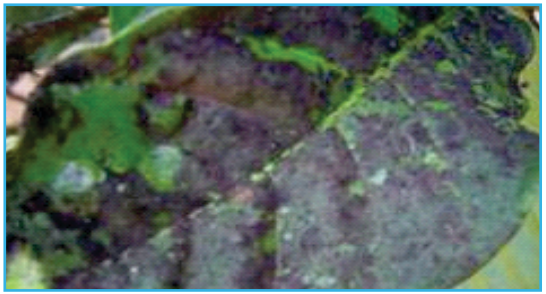
➢ Nematodes

- **Prevention and treatment**
  - Analyze the soil for nematodes before transplanting coffee in the field
  - Apply mineral and organic fertilizers in a balanced manner (avoid soil acidification)
  - Avoid moving infected soil from one location to another in the plantation
  - Avoid surface irrigation from infected to non-infected locations in the plantation
  - Treat infected planting holes as follows:
    + Burn the surface of the planting holes
    + Apply lime (1 kg / planting hole) and organic fertilizers
    + Spray agrochemicals with the following active ingredients: Ethoprop, Carbosulfan, Chitosan or Benfuracarb
  - Remove seriously infected trees and handle the planting holes as described above
  - Agro-chemicals should only be used in case of serious infestation
  - Do not use banned or highly hazardous agro-chemicals; use only agro-chemicals recognized by the government

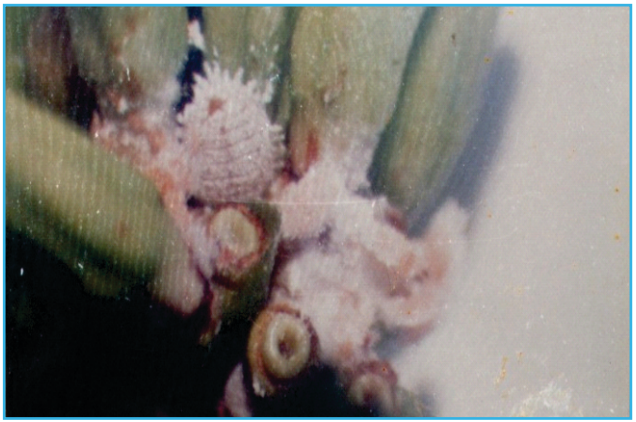
7.5 HARMFUL INSECTS

➢ Green and brown scales

- **Symptoms**
  - This disease mainly occurs in the dry season and at the beginning of the rainy season
  - Scales feed on leaves, stems, branches, shoots and young cherries
  - The disease leads to poor tree growth and yellowing leaves
  - Branches dry out and cherries are shedded
  - Scales produce a sweet substance which attracts fungi
- **Prevention and treatment**
  - Remove seriously infected branches (pruning)
  - Regularly monitor the coffee plantation and avoid ant infestations; ants help scales to spread in the plantation
  - Agro-chemicals should only be used in case of serious infestation
  - Do not use banned or highly hazardous agro-chemicals; use only agro-chemicals recognized by the government



7.5 HARMFUL INSECTS



➢ Cherry and Root Lesion Mealybug (Pseudococcus)

- **Symptoms**
  - Mealybugs mainly feed on coffee cherries and roots
  - The cherries dry out and are shedded
  - Roots get damaged which makes them prone to be infected with fungi
  - Mealybugs excrete a waxy substance which protects them from treatment with agro-chemicals

7.5 HARMFUL INSECTS

➢ Mealybugs (root lesion)

- **Prevention and treatment**
  - Regularly monitor the field for early detection after the harvest or before blossoming
  - Spray infected trees with water under high pressure (in combination with hose irrigation)
  - Prune seriously infected branches
  - Uproot trees which are affected by the root lesion mealybug and burn the trees in situ
  - Agro-chemicals should only be used in case of serious infestation (over 100 mealybugs per tree)
  - Do not use banned or highly hazardous agro-chemicals; use only agro-chemicals recognized by the government
  - In case of severe infestation with root mealybugs, uproot and remove the infested trees and expose the soil to full sunlight

7.5 HARMFUL INSECTS

➢ Coffee berry borer

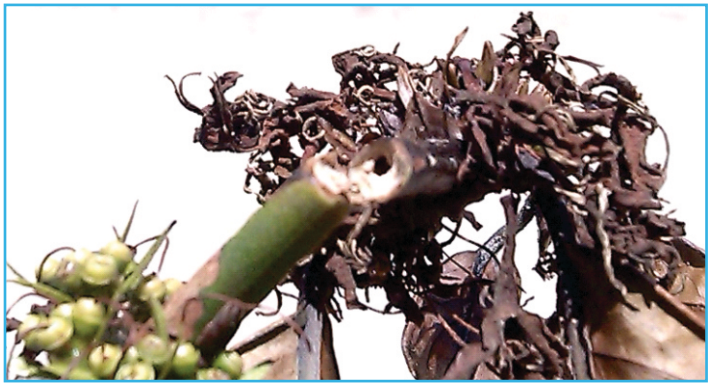
- **Symptoms**
  - The coffee berry borer bores holes in the navel of green and red cherries
  - It creates cavities in the coffee beans to lay eggs thereby reducing the quality of the coffee beans
- **Prevention and treatment**
  - Clean the garden carefully after the harvest
    + Collect all cherries on the soil surface and remove all remaining cherries on the trees to eliminate shelter for the coffee berry borer
    + Apply only fully decomposed coffee pulp or husks as organic fertilizer to minimize coffee berry borer infestation
  - Store coffee beans with moisture content below 13 %
  - In seriously infected fields, spray agro-chemicals with active ingredients Mancozeb 64 % + Metalaxyl 8 % when the cherries are green
  - Agro-chemicals should only be used in case of serious infestation
  - Do not use banned or highly hazardous agro-chemicals; use only agro-chemicals recognized by the government
  - Regularly check and periodically fumigate the warehouse

7.5 HARMFUL INSECTS

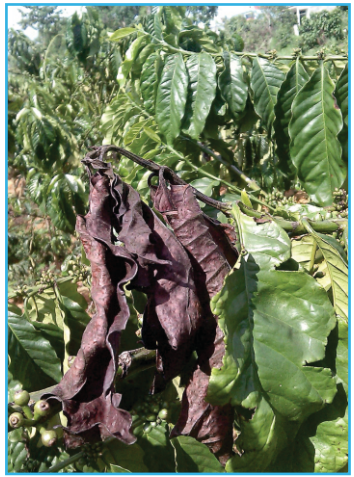
➢ Twig borer

- **Symptoms**
  - The twig borer damages branches, shoots and suckers mainly in the dry season
  - It bores holes in branches and shoots, which hinders nutrient transport; as a consequence branches and shoots dry up and eventually die
  - The twig borer's larvae do not eat branch wood; however the cavities created by the twig borer are an easy entry point for fungi which feed on the inner wood of branches
- **Prevention and treatment**
  - Regularly monitor the field to assure early detection of the twig borer
  - Cut off infected branches (cf. pruning)

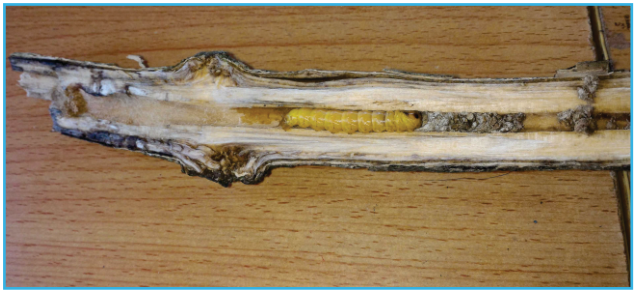
Note: *There are no chemical products that can prevent the twig borer effectively*



Xyleborus morstatti



7.5 HARMFUL INSECTS



➢ Red stem borer

- **Symptoms**
  - The red stem borer bores holes in branches and stems
  - Initially individual infected branches start wilting
  - Infected branches dry up and ultimately the trees die
  - Both immature and mature coffee trees are affected
  - The disease can be recognized when the trees are missing branches or when entire parts of the canopy are missing
- **Prevention and treatment**
  - Regularly monitor the field and look for wood dust caused by the stem borers
  - When fresh boreholes are found on healthy branches, move an iron wire into the borehole to kill the stem borer
  - Remove infected branches

7.5 HARMFUL INSECTS

➢ Termites

- **Symptoms**
  - Termites commonly attack newly planted coffee trees
  - Termites feed on the coffee trees' bark and the woody parts of the root collar
  - Damage of the bark leads to impeded water and nutrient transport in the plant and eventually kills the trees

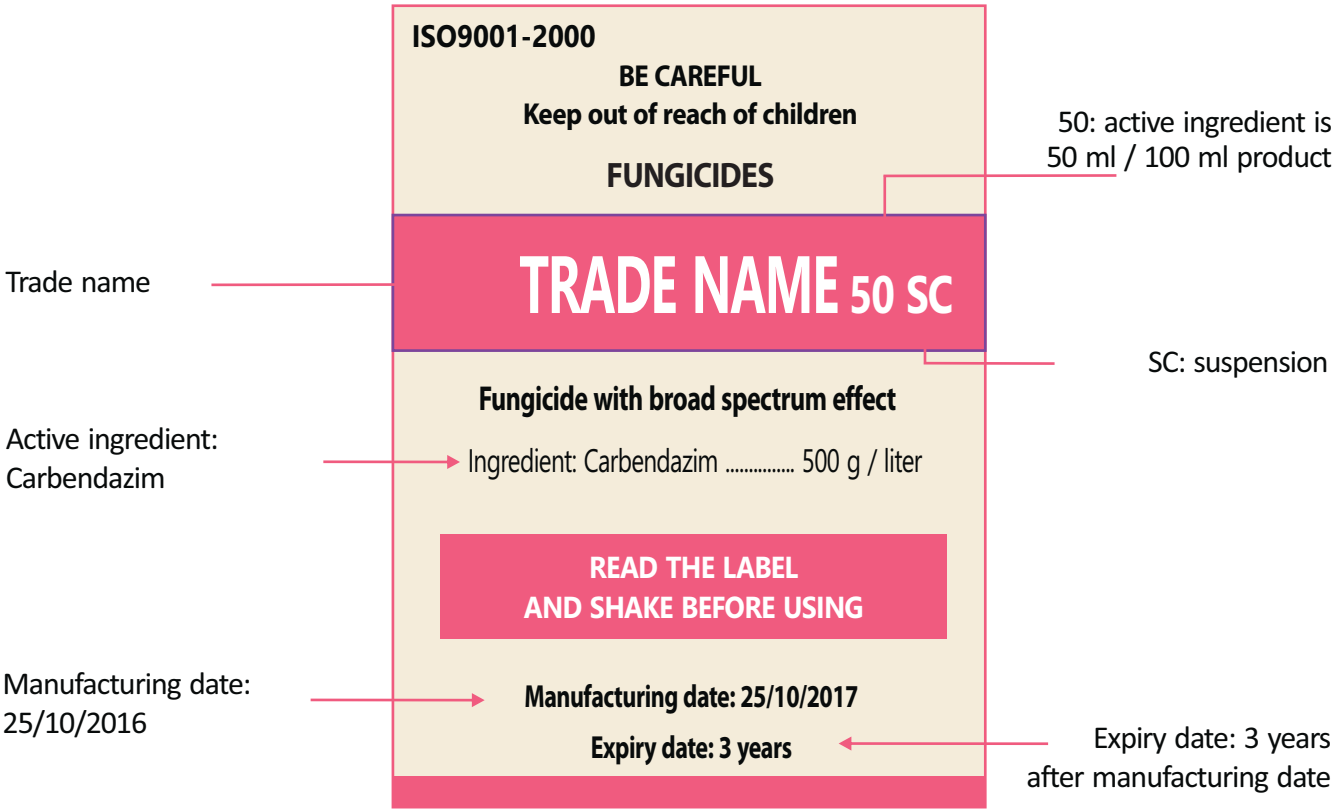
- **Prevention and treatment**
  - Remove termite nests
  - Agro-chemicals should only be used in case of serious infestation
  - Do not use banned or highly hazardous agro-chemicals; use only agro-chemicals recognized by the government

7.6 AGRO-CHEMICAL PRODUCTS

Types	Abbreviations	Properties
Oil emulsion	ND, EC	Products in liquid form, transparent, flammable and combustible
Solution	DD, SL, L, AS	Soluble in water
Absorbent powder	BTN, WP, SP DF, WDG	Products in powder form which can be suspended in water
Suspension	FL, FC, SC	These products need to be well shaken before use
Granules	H, G, GR	These products are in solid form and can be applied directly to the soil
Milk	EW	These products need to be well shaken before use
Powder	D, BR	Insoluble in water

7.7 USER-INSTRUCTIONS FOR AGRO-CHEMICAL PRODUCTS

➢ **Example of a typical label one can find on agro-chemical products**



7.7 USER-INSTRUCTIONS FOR AGRO-CHEMICAL PRODUCTS

➢ Example of a typical label one can find on agro-chemical products

ISO9001-2000

HOW TO USE

Used to control and prevent fungal diseases of plants such as coffee, pepper, fruit trees, beans, vegetables, etc.

Crop types	Diseases	Amount of product / ha	Dosage
COFFEE	Leaf rust	0.5 - 0.8	10 ml / 8 liters of water, 7 - 8 aerosols / 1,000 m^2
RICE	Piricuriose	.....	.....
BEANS	Leaf spot	.....	.....
VEGETABLE	Root lesion	.....	.....
.....	.....	.....	.....

Note: Amount of water per ha/ 400 – 600 l/ha

- Spray as soon as the disease is detected; in case of serious disease infestation spray again after 10 - 14 days
- This product can be mixed with other pesticides or foliar fertilizers. Apply the product immediately after mixing
- Do not mix with alkaline agro-chemicals

Quarantine period

Product harvested 14 days after spraying

Crop types: coffee, rice, beans, etc.

Purpose: Leaf rust, frogeye leaf spot, etc.

Instructions: wear gloves and goggles, avoid spraying opposite the wind direction

Amount of product/ha; e.g. for coffee: 0.5 - 0.8 liter / ha

Recommended concentration: 7 - 10 ml product in 8 liters of water

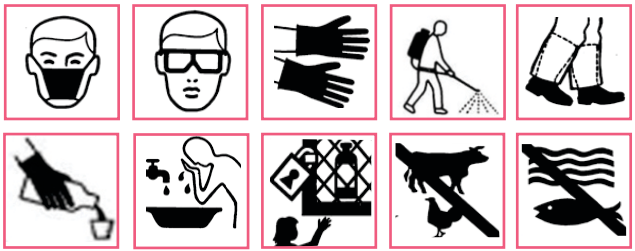
Amount of water per ha: 400 – 600 litres / ha

7.8 SAFE USE OF AGRO-CHEMICAL PRODUCTS

Only use agro-chemicals when no other measures work

- Do not use the same agro-chemical product over a long time to avoid pests to become resistant to the chemicals
- Comply with the following rules of thumb:
  1) Application at the right time
  2) In the right amount
  3) Correct product for the identified pest or disease
  4) Right method of application
- Ensure safe working condition

Symbols of labor safety and hygiene in agriculture



- Check the product label carefully (e.g. expiry date, safety precautions, etc.) before application
- Wear protective clothing such as boots and rubber gloves, goggles, masks etc.
- Do not spray opposite the wind direction to avoid contact with the skin or inhalation of agro-chemicals
- After spraying agro-chemicals, change clothes and shower with soap before eating and drinking
- Store agro-chemical products in closed containers, in a cool and dry place
- Keep agro-chemicals away from food, livestock and poultry and out of reach of children
- Do not wash spraying equipment in surface water sources (e.g. lakes, streams, etc.)
- Do not re-use bottles in which agro-chemicals were stored for other purposes
- Keep spaying equipment out of reach of children
- In case of poisoning, perform first aid treatment and bring the victim to the nearest medical facility; take along the labels of the products used for quick examination by medical staff

7.9 QUESTIONS AND EXERCISES

1. Explain the importance of pest and disease management.
2. What is a natural enemy? Give 2 examples.
3. What is the difference between frogeye leaf spot and leaf rust? Describe how to prevent and treat both diseases.
4. Describe how to prevent and treat nematode infestations.
5. Explain how to use agro-chemicals in a safe manner.

MODULE 8: COFFEE HARVESTING, PROCESSING AND STORAGE

8.1 COFFEE HARVESTING TECHNIQUES

➢ Timing

- In the Central Highlands of Vietnam, the harvesting season occurs from October to December

➢ Methods

- Pick only red ripe cherries manually

➢ First harvesting round

- About 3 - 5 % of the cherries are red and ripe for picking
- Use a basket to collect the cherries

➢ Second harvesting round

- Over 90 % of the cherries are red and ripe for picking
- Use a canvas under the trees to collect the cherries

➢ Third harvesting round

- Pick all remaining cherries on the trees
- Collect also all cherries that have dropped on the soil to prevent from berry borer attack

➢ Fresh cherries need to be processed within 24 hours after picking to avoid quality loss due to fermentation

8.1 COFFEE HARVESTING TECHNIQUES

- **Harvest manually**
- **Do not practice strip picking**
- **Do not pick green, unripe cherries**
- **Avoid breaking branches**

➢ Inportant note

- If flowering occurs during harvesting, it is recommended to stop harvesting 3 days before and after flowering to allow pollination

➢ Benefits

- Maximize productivity
- Maximize coffee quality
- Avoid damaging the trees' leaves and branches to assure maximum crop health for the next season
- Remove all cherries that have fallen on the ground while harvesting to avoid coffee berry borer attack

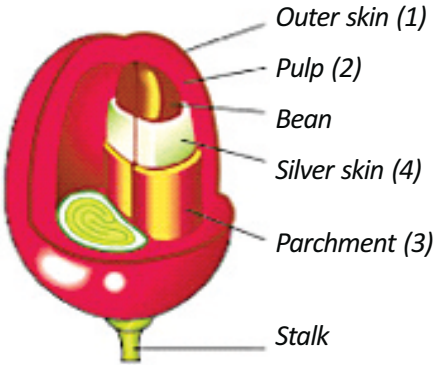
8.1 COFFEE HARVESTING TECHNIQUES

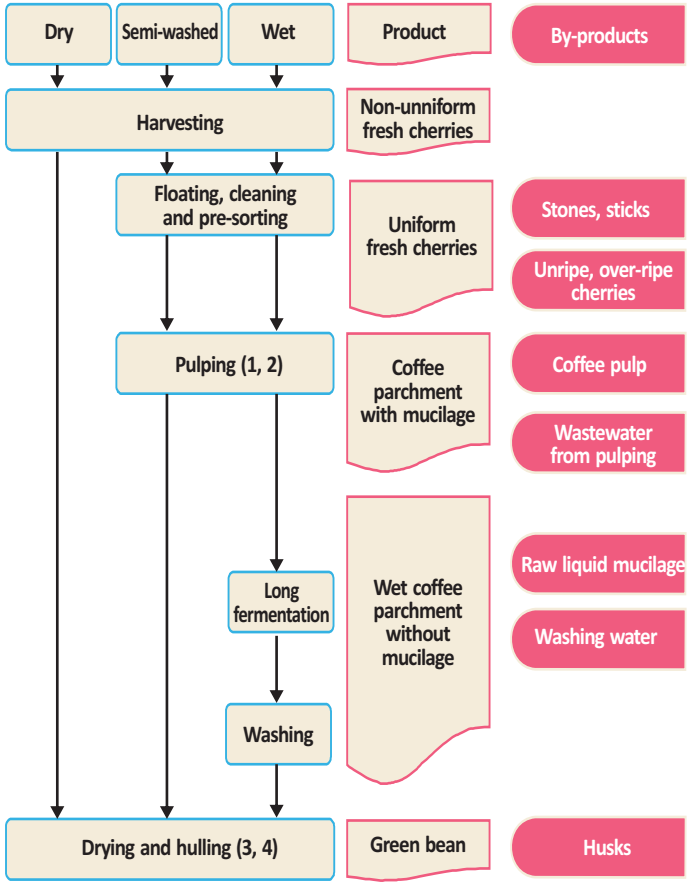
➢ Disadvantages of strip picking (green cherries)

- It reduces the product weight by up to 20 % because green cherries are lighter than red, ripe ones
- Harvesting green, unripe cherries reduces the coffee quality; a high proportion of black and under-developed beans will affect the final aroma and taste of brewed coffee
- By the end of the rainy season coffee cherries are usually still green and unripe; therefore, it will take more labor time and energy to dry the coffee; besides the risk to rewet the coffee during drying is much higher; when coffee gets wet it will be affected by molds which lowers the bean quality
- Early harvesting (green cherries) will make the next crop come sooner; this increases the number of irrigation rounds in the dry season consuming more energy, water and labor

➢ It is recommended to harvest over 90 % red cherries; this leads to better quality which comes at a better sales price

8.2. COFFEE PROCESSING METHODS AND PRODUCTS





8.3 DRY PROCESSING - DRYING WHOLE CHERRIES

➢ Drying whole red cherries

- Dry fresh cherries on a concrete yard or canvas
- Dry the cherries to reach a moisture content of 12 - 13 %
- Spread the cherries evenly out on the patio in a layer with a thickness of 3 - 4 cm
- Turn the cherries 2 to 4 times per day
- Depending on the weather conditions the drying time is approximately 20 - 30 days
- Once the coffee cherries are dry, they are hulled, cleaned and sorted for size, weight and color

- **Avoid rewetting coffee cherries to avoid mold formation and development of Ochratoxin A which can cause cancer**
- **Do not dry coffee on bare soil to avoid a moldy or earthy cup taste**

8.3 DRY PROCESSING – DRYING WHOLE CHERRIES

- **Advantages**
  - It is a simple and easy method which does not contribute to environmental pollution
  - Selective picking results in better coffee quality (target more than 90 % of ripe cherries and less than 5 % of foreign matter)

- **Disadvantages**
  - Sun drying depends entirely on the weather conditions
  - Sun drying is labor intensive in particular for turning the coffee regularly
  - Sun drying requires a large patio; approximately 100 m^2 for 1 hectare of coffee with a productivity of 3 tons of green beans

Mouldy coffee

8.4 DRY PROCESSING – CRUSHING CHERRIES

ADVICE: IT IS RECOMMENDED NOT TO PRACTICE THE CRUSHING METHOD

➢ Crushing

- Fresh cherries are crushed to open up the outer skin and to shorten the drying time
- After crushing, the cherries are dried in open air or mechanically until a moisture content of 12 - 13 %

- **Advantages**
  - The drying time is reduced by 50 - 60 % compared to whole cherry drying
  - The labor costs for turning the cherries is lower since the drying time is shorter

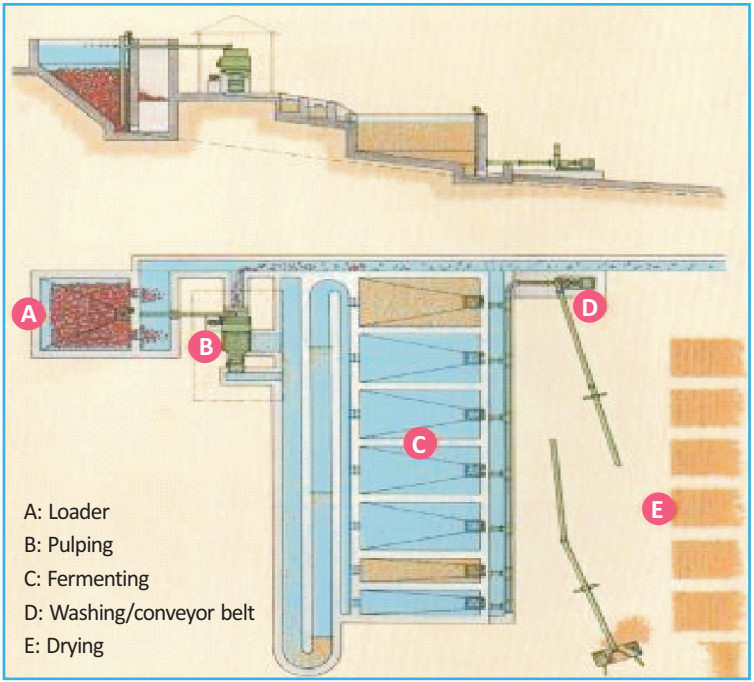
- **Disadvantages**
  - After crushing the cherries are sun dried which depends entirely on the weather conditions
  - Crushing significantly damages the beans and affects the final product quality negatively
  - Increased risk of mold formation and Ochratoxin A development, because molds can easily reach the beans since they are less protected by the pulp layer

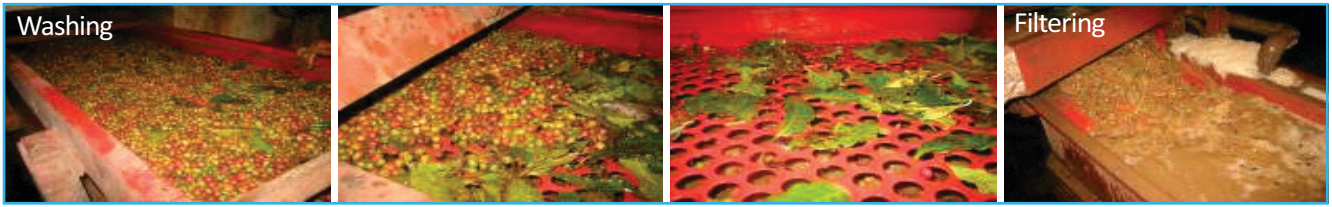
8.5 WET PROCESSING

- Mainly applied for Arabica coffee
- More popular with large Robusta processors

➢ Step 1: Pre-cleaning, washing and floating

- Remove branches, leaves, sticks, and other foreign matter
- The cherries are washed and separated by letting them float in water; floating cherries are usually green unripe, overripe or infected by insects, which makes them lower in weight; they have a lower cup quality; ripe cherries sink down in the water
- Soil, sand, stones, metal and heavy foreign materials will sink to the bottom of the tank and can be removed later





8.5 WET PROCESSING


Separating green cherries


Separating pulped & non-pulped cherries


Separating pulped & non-pulped cherries


Outer skin and parchment


Outer skin and parchment

➢ Step 2: Pulping

- In this step the outer skin and the pulp of the cherries are removed with a mechanical pulper
- Afterwards a rotary sieve separates the pulped and non-pulped cherries
- Pulped cherries are pressed though the drum's sieve, while non-pulped and green cherries (with a harder pulp layer) are separated
- This step in the process requires good skills to avoid damaging the parchment thereby reducing the end product quality

8.5 WET PROCESSING

➢ Step 3: Removing the mucilage

- Mucilage consists of the remaining parts of the pulp and skin covering the parchment; it has a sticky, slimy consistence

Method 1: Biological fermentation

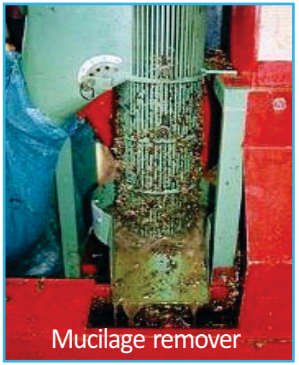
- Keep the coffee parchment in a tank or silo for 18 - 24 hours; the exact fermentation time depends on the outside air temperature
- Scrub the wet parchment periodically by hand to check in how far the mucilage is removed from the parchment
- With this method the mucilage in the center cut of the beans can be removed

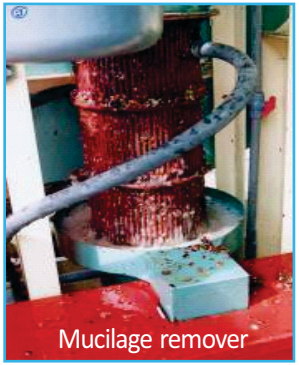
Method 2: Mechanical demucilation

- The mucilage is removed by rubbing the parchment against each other
- This method saves water but the mucilage in the center cut of the beans cannot be removed
- Once the fermentation is complete the parchment is washed with clean water to remove the remaining mucilage, especially in the center cut of the beans


Silo for fermentation

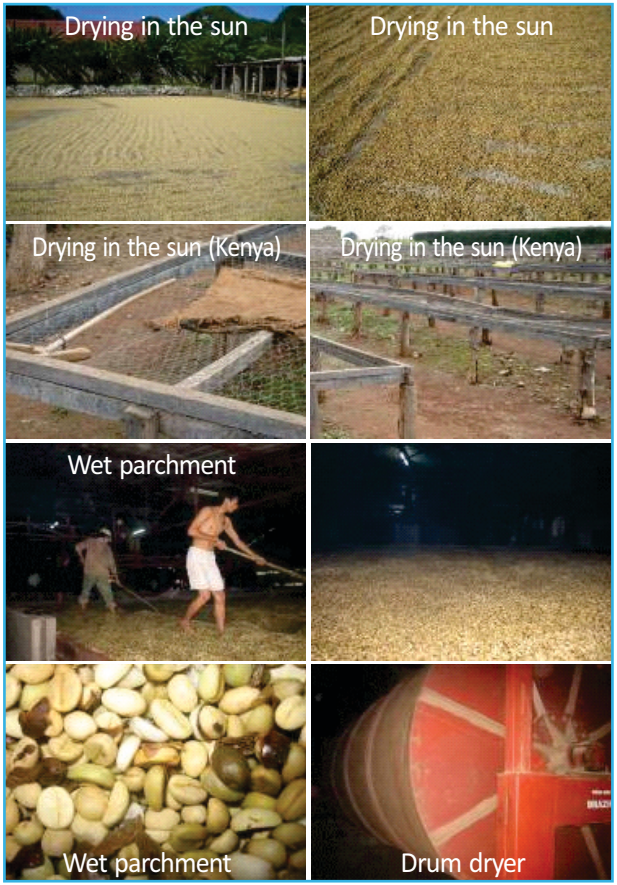

Fermentation tank


Mucilage remover


Mucilage remover

AVOID OVER-FERMENTATION AS THIS LEADS TO A LOWER CUP QUALITY

8.5 WET PROCESSING



➢ Step 4: Drying the parchment

- After washing, the moisture content of wet parchment coffee is over 50 %
- Drying the parchment too fast will affect coffee quality and color
- Spread the parchment coffee evenly on a patio or drying nets to drain the water until 45 % moisture content
- Further dry the parchment under natural conditions (sun) or mechanically
- For sun drying in open air spread the coffee in volumes of circa 15 - 20 kg / m^2
- Increase the thickness of the drying layer when the coffee gets drier to avoid cracked husks
- In case of mechanical drying, dry the parchment at a temperature of 45 - 55^{0}C till moisture content of 11 - 12 %

Notes:

- If the drying temperature is too high, the outer part of the parchment will dry quickly whereas the coffee bean remains moist
- This results in lower quality of the end product and leads to inaccurate measurement of the beans' moisture content

8.5 WET PROCESSING

- **Advantages**
  - One can save investment costs for a large drying patio since parchment is lower in volume then fresh cherries
  - The total processing time is shorter
  - Better coffee quality usually gets a higher price
- **Disadvantages**
  - High investment costs
  - Qualified processing manager is required
  - Risk for environmental pollution caused by waste water
  - Wet processing usually requires scale and large volumes of coffee
  - Small processing units for smallholder farmers exist, but require careful handling to assure good coffee quality

Covering wet parchment to avoid rewetting

Dry, cracked parchment due to fast drying

8.6 COFFEE STORAGE

- **Store only dry whole cherries or parchment with a moisture contentof 12 - 13 %**
  - Process the dry cherries or parchment to green beans right before sales to assure optimal quality
- **DO NOT store fresh cherries**
  - Cherries will rot and coffee quality deteriorate
  - Large storage volume required
  - High moisture content
  - High risk of mold formation and coffee quality decline
  - High risk for coffee berry borer infestations
- **DO NOT store dry green beans for more than 6 months**
  - Increased risk for coffee quality decline e.g. color fading, beans may become spongy, mold formation, etc.
- **Warehouse standards**
  - A warehouse should be clean and well-aerated (e.g. do not store coffee in the same place where coffee is mechanically dried to avoid a smoky cup taste)
  - Treat the warehouse against wood and coffee berry borer
  - Avoid exposure to rain and leaks from the roof

8.6 COFFEE STORAGE

General guidelines

- Do not store coffee which is a food product, together with fertilizers and agro-chemicals
- Store coffee in clean jute bags
- Place the jute bags on shelves or pallets
- Store the bags 0.5 meter away from walls and 0.2 meter above the floor to guarantee sufficient aeration

Check the warehouse frequently

- Look for infestations of wood and coffee berry borers as well as far ants and termites
- Check for leaks in the warehouse's roof

Do not store coffee with high moisture content (> 15 %) near coffee with lower moisture content (12 - 13 %)

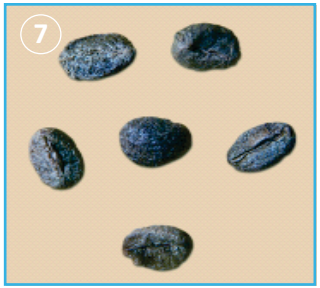
- There is a risk that the moisture content of the drier beans increases

8.7 COFFEE DEFECTS RELATED TO HARVEST AND PROCESSING

- **Earthy cup taste (1):** Because of drying on bare soil
- **Moldy cup taste (2, 4):** This happens when coffee is rewetted during sun drying or when it got rewetted because of leaks in the warehouse's roof during storage
- **Fermented cup taste (3, 4)**
  - Harvesting of overripe cherries
  - The time between harvesting fresh cherries and processing is longer than 24 hours
  - Coffee was rewetted during sun drying
  - Fermentation for too many hours during wet processing
  - Drying coffee in a layer of over 10 cm thickness
- **Smoky cup taste (5):** This happens when smoke is not separated during mechanical drying
- **Phenolic or chemical cup taste (6)**
  - Caused by coffee berry borer infestations
  - Cherries that dropped on the soil during harvest were collected late (i.e. coffee berry borer entered the beans)
  - Coffee beans are stored in untreated warehouses (i.e. high risk for coffee berry borer infestations)
  - Coffee beans are stored in fertilizer or animal feed bags
  - Storage of coffee which is not sufficiently dry

8.7 COFFEE DEFECTS RELATED TO HARVEST AND PROCESSING

- **Foreign matter**
  - Plastic strings (1)
  - Paper (e.g. cigarette boxes, etc.) (2)
  - Stones (3), sticks (4), husks (5)
  - Metal, etc.
- **Immature cherries (6):** Caused by early harvesting and strippicking of green unripe cherries
- **Black beans (7):** Due to harvesting of overripe cherries or cherries infested by insects
- **Broken beans (8):** Caused by crushing fresh cherries or incorrect hulling; it can also happen during the pulping process



8.8 GREEN BEAN COFFEE STANDARDS

VIETNAM'S COFFEE EXPORT QUALITY STANDARDS

Quality requirement	Limit
Moisture content	12.5 - 13 %
Foreign matter	< 1 %
Green beans defects *	3.5 - 8 %
Screening size	> 90 % larger than 5.7 mm

** Total black and broken beans*

8.8 GREEN BEAN COFFEE STANDARDS

NESTLE'S PROCUREMENT STANDARDS

NESTLE STANDARDS 7.1

Parameter	Limit
Foreign Matter (FM)	0.50 %
Moisture Content (MC)	12 %
Defect beans (BBB)	2 %
Above screen 16	90 %
Above screen 12	100 %
Defects in total	12 %
Cup quality	Nestle 7.1

NESTLE STANDARDS 7.2

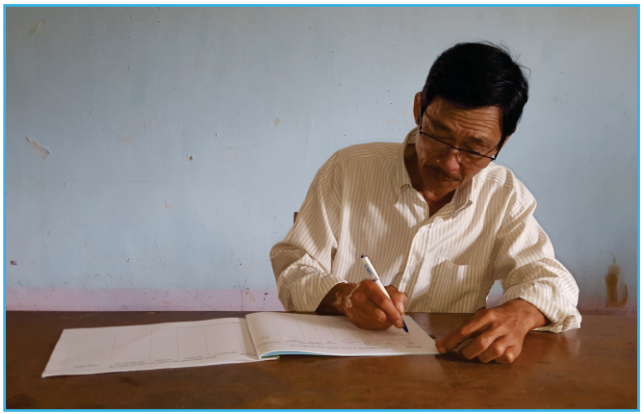
Parameter	Limit
Foreign Matter (FM)	0.50 %
Moisture Content (MC)	12 %
Defect beans (BBB)	5 %
Above screen 13	90 %
Above screen 12	97 %
Defects in total	18 %
Cup quality	Nestle 7.2

8.9 QUESTIONS AND EXERCISES

1. When is the best time for harvesting coffee?
2. Give three advantages resulting from selective harvesting.
3. What are the consequences of picking green coffee cherries?
4. Describe three different processing methods.
5. What are the advantages and disadvantages of dry processing and crushing?
6. Why should coffee not be stored for too long?
7. Describe 3 coffee bean defects and their causes.
8. Analyze in groups of 5 people a standard sample of green beans (300 g).
   - Identify all bean defects you learned about in this module.
   - Calculate the % of defects according standard procedures (cf. CafeControl).
   - Assess whether the sample would be accepted according the Vietnamese standards and according to Nestle requirements.
9. Visit the storage facility of one member in the group.
   - Identify the positive aspects and the shortcomings.
   - Identify simple solutions to improve the storage facilities.

MODULE 9: RECORD KEEPING OF FARM MANAGEMENT PRACTICES

9.1 PURPOSE OF KEEPING FARM MANAGEMENT RECORDS



- To help farmers understand the profitability and main cost centers of the coffee production system
- To help farmers make informed investment decisions and allocate resources over the production year
- To help farmers calculate their production costs per ton of green beans based on labor and input costs (e.g. fertilizers, agro-chemicals, fuel, electricity, etc.); this enables farmers to make informed decisions when it comes to coffee sales prices
- To help farmers determine the correct amounts and types of inputs such as fertilizer and agro-chemicals as well labor to be invested in the coffee plantation in the current and following years
- To enable traceability of coffee from the farm to the processing unit and the end buyer
- To help farmers monitor and measure the effectiveness and impact of new technologies introduced by extension officers, etc.
- Farm records can be used as a tool for farmers to learn from each other about their farm management

9.2 HOW TO KEEP FARM MANAGEMENT RECORDS?

A farm record keeping book (also called Farmer Field Book or FFB) consists of several forms and templates such as:

- General information about the farmer household
- Monitoring water use
- Monitoring fertilizer use
- Monitoring agro-chemical use
- Monitoring coffee harvesting, processing and storage
- Monitoring coffee sales
- Monitoring of machines and equipment used for coffee production
- Monitoring other activities related to farm management
- Monitoring labor and cost/benefits

➢ Important hints

- Record all farm management activities by the end of each day during the entire production cycle
- Record all the information related to purchase and usage of inputs such as fertilizers, agro-chemicals and energy (e.g. electricity, fuel, etc.)
- Record all information about the use of machines, equipment and tools, coffee harvesting, processing and sales
- The information should be recorded in accordance wirh the crop calendar, starting with flowering and ending after the harvest
- The farm records should be kept carefully to avoid them getting spoiled or lost

REMARKS:

Farm management records should be kept for multiple years (at least 5 years); this allows comparison with previous crop seasons and to adjust the management of the current season based on past experience

GENERAL INFORMATION ABOUT THE FARMER HOUSEHOLD

FARMER FIELD BOOK

(YEAR: .....**)**

Farmer's name:.....

Address: .....

Coffee area: ..... *ha*; **Year of planting:** .....; **Expected yield:** ..... *ton(s) of green bean*

9.3 EXAMPLE TEMPLATES FOR RECORD KEEPING

MONITORING WATER USE (YEAR: .....)

Round	Irrigation date	Water amount used (liter / tree)	Irrigation method	Water source	Type of irrigation equipment	Labor (Man-day)	Energy (liter, KW)	Amount
1						(a)	(b)	(=a*c+b*d)
2								
3								
4								
5								
Total								**(1)**

Remarks:

Irrigation method: e.g. hose, sprinkler, drip, etc.

Type of irrigation equipment: e.g. electrical pump, generator, tubes, etc.

(c) Labor cost / man-day: .....

(d) Fuel cost (petrol, gasoline, electricity): .....

9.3 EXAMPLE TEMPLATES FOR RECORD KEEPING

MONITORING FERTILIZER USE (YEAR: .....)

Round	Fertilizing date	Fertilizer type	Amount of fertilizer (kg)	Labor (Man-day)	Fertilization method	Amount
1			(a)	(b)		(= a*c+b*d)
2						
3						
4						
5						
6						**(2)**

Remarks: Ferilizer prices (Write the real price at the buying time) **(c):**

Urea (46 % N) ..... */ kg*

Phosphorous (16 % P_2O_5) ..... */ kg*

SA (21 % N) ..... */ kg*

Potassium (60 % K_2O_5) ..... */ kg*

NPK (16-16-8-13S) ..... */ kg*

NPK (16-8-16-TE) ..... */ kg*

Organic Fertilizers ..... */ kg*

Others ..... */ kg*

..... */ kg*

..... */ kg*

Labor cost: (d)..... */ day*

9.3 EXAMPLE TEMPLATES FOR RECORD KEEPING

MONITORING AGRO-CHEMICAL USE (YEAR:.....)

App. Round	Application Date	Type of disease/pest	Type of agro-chemical	Amount (liter or kg)	Labor (Man-day)	Amount	Contact time (day)	Isolation time (day)
1				(a)	(b)	(=a*c+b*d)		
2								
3								
4								
5								
6						**(3)**		

Remarks: Agro-chemical prices (Write the real price at the buying time) **(c):**

Type 1: ..... */ kg or ..... / liter*

Type 2: ..... */ kg or ..... / liter*

Type 3: ..... */ kg or ..... / liter*

Type 4: ..... */ kg or ..... / liter*

Labor cost (d):... ..... */ day*

9.3 EXAMPLE TEMPLATES FOR RECORD KEEPING

MONITORING HARVESTING, PROCESSING AND STORAGE (YEAR: .....)

Harvesting Date	Coffee Type	Quantity of cherries (kg)	Labor (Man-day)	Price per man-day (...../ day)	Amount
			(a)	(b)	(= a*b)
					(4)

Processing Round	Processing Date	Activities	Labor (Man-day)	Labor cost	Amount	Remark
1		Drying	c	d	c*d+m	
2		Pulping	e	f	e*f+p	
3		Packaging	h	g	h*g+n	
4		Transporting	k	l	k*l+q	
					(5)	

Remarks: Materials/equipment used for harvesting, processing and storage (Write real prices at the buying time)

(m) Canvas: ..... / m^2

(n) Bag:..... ..... / piece

(p) Pulping price: ..... / ton

(q) Transport cost:..... / ton

9.3 EXAMPLE TEMPLATES FOR RECORD KEEPING

MONITORING COFFEE SALES (YEAR:.....)

Selling Date	Buyer (Company / Agent)	Quantity (kg)	Sales price	Amount	Quality		
					Moisture	Black / broken	Foreign matter
		(a)	(b)	(= a*b)			
				(6)			

MONITORING OF EQUIPMENT (YEAR:.....)

No.	Date of repairs / maintenance	Equipment / Spare part	Price of Equipment / Spare part	Quantity	Amount
1.			(a)	(b)	(= a*b)
2.					
3.					
4.					
					(7)

9.3 EXAMPLE TEMPLATES FOR RECORD KEEPING

MONITORING OTHER ACTIVITIES (YEAR: .....)

No.	Date	Activities	Labor (Man-day)	Unit price	Amount	Remark
1.			(a)	(b)	(= a*b)	
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9						
				Total	(8)	

Total expenses = (1) + (2) + (3) + (4) + (5) + (7) + (8) **= X**

Total revenue = (6)

Production cost / kg = X / total yield in kg

Net income / year: ..... = (6) – X

9.4 QUESTIONS AND EXERCIES

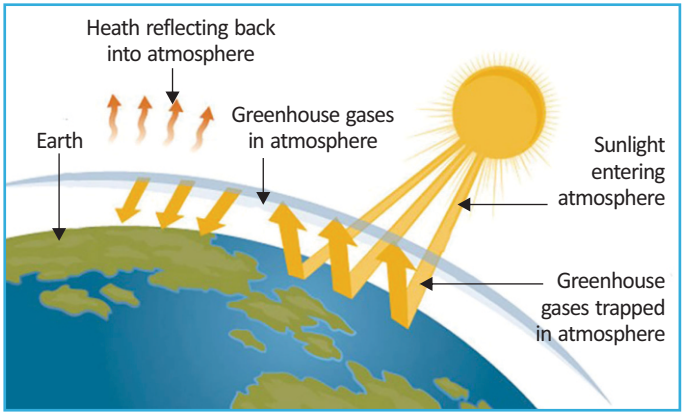
1. Explain the benefits of farm record keeping.
2. What are the main elements of a farm management register?
3. When should record keeping be conducted?
4. Exercise:
    - Identify a farmer who keeps records in your farmer group
    - Analyze whether any useful data are missing and provide recommendations
    - Calculate based on real records:
        - the total investment cost
        - the total revenue
        - the net income

MODULE 10. COFFEE & CLIMATE CHANGE

10.1 WHAT IS CLIMATE CHANGE AND WHAT ARE ITS CAUSES?

➢ Definition

Any significant change in measures of climate, such as temperature or precipitation, lasting for an extended period of time, typically decades (official IPCC definition)



➢ Causes

- Increased emissions of carbon dioxide, methane and oxides of nitrogen
- These extra gases stay in the atmosphere and they absorb more heat
- So the air temperature increases – called the greenhouse effect
- Increase in temperature also affects rainfall amounts and distribution

10.2 IMPACTS OF CLIMATE CHANGE

➢ **Drought** (1)

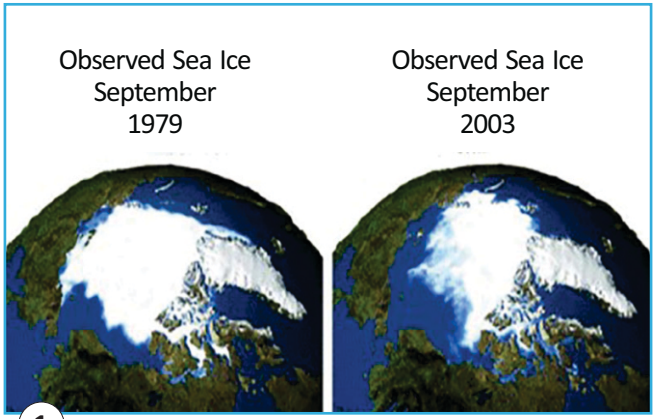
➢ **Flooding** (2)

10.2 IMPACTS OF CLIMATE CHANGE

➢ **Storm** (1)

➢ **Increased incidence of forest fires** (2)

10.2 IMPACTS OF CLIMATE CHANGE



- Increase in global temperature
- Changes in precipitation patterns
- More extreme weather events
- Warming of poles and loss of sea ice = rising sea levels (1)
- Warming of oceans
- Melting of glaciers (2)

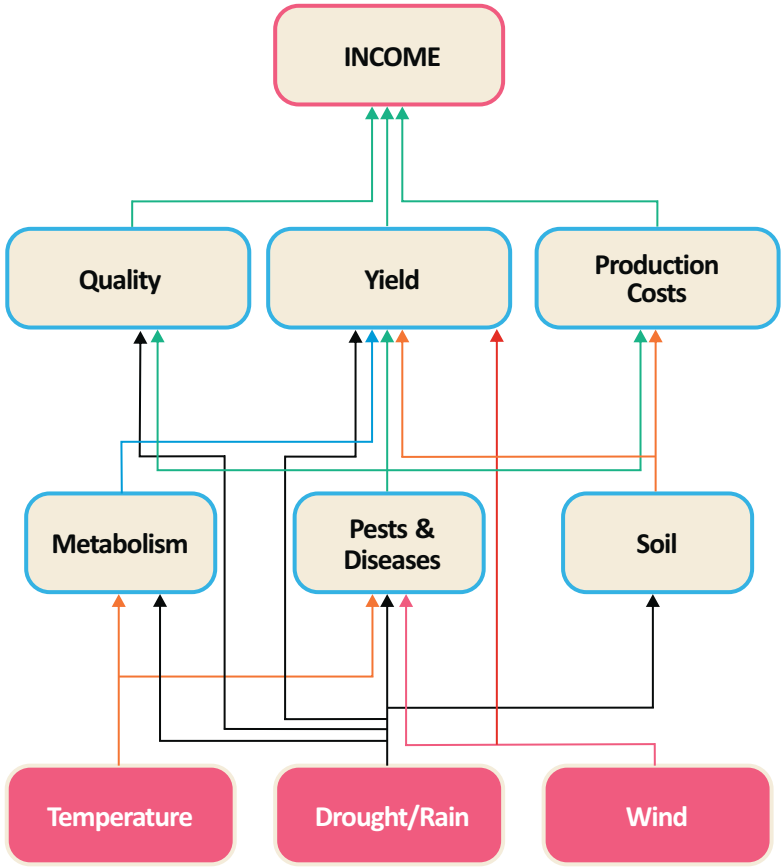
1

2

10.3 RELATIONSHIP BETWEEN WEATHER VARIABLES & COFFEE PRODUCTION

➢ The coffee plant is quite demanding

- Not too hot; not too cold
- Not too wet; not too dry
- High maximum temperatures cause flower abortion
- Higher temperatures cause more pest problems
- The plant needs a dry period, but not too long, to initiate flowering
- Drought during the cherry swelling stage can cause small coffee bean size
- Intermittent rain during the dry season can hinder pollination and reduces potential yield
- Continuous rain can affect flower development and fruit set
- Strong rains cause landslides and soil erosion
- Strong winds can damage trees
- Farmers need regular weather conditions (e.g. for coffee drying)



10.4 IMPLICATIONS FOR ROBUSTA COFFEE PRODUCTION IN VIETNAM

➢ Temperature

- The average temperature has increased resulting in higher evapotranspiration rates and higher demand for irrigation (2)
- The minimum temperatures have increased which may lead to increased risk for pests and diseases (1)
- The maximum temperatures have remained stable
- The diurnal temperature range has decreased, which increases the risk for pests and diseases (2)

➢ Rainfall

- The total annual rainfall has remained stable but becomes more unpredictable
  - Increased variation makes farm planning and coffee drying more difficult
  - Risk for poor coffee quality (moldy) (3)

10.4 IMPLICATIONS FOR ROBUSTA COFFEE PRODUCTION IN VIETNAM

➢ Rainfall

- Heavy rainfall events have occurred more frequently and become more unpredictable
  - This may have possible effects on flowering and pollination (1)
  - It can cause tree damage
  - It can cause soil erosion (2)
- The length of the wet season has remained unchanged
- The number of continuous wet days has decreased
- The number of continuous dry days has increased (3)
  - Risk of wells falling dry during the dry season
  - Shortage of irrigation water

1

2

3

10.5 RECOMMENDED ADAPTATION TOOLS






➢ (no regret) measures (short-term)

- Ground cover (cf. Module 2)
- More efficient irrigation (cf. Module 5)

➢ Experimental trials (mid-term)

- Centralized solar or mechanical drying (cf. Module 8)
- Crop diversification and shade trees (cf. Module 2)
- Composting (cf. Module 4)
- Application of low carbon footprint fertilizers (cf. Module 3)
- Drip irrigation
- Application of hydro-polymers
- Application of biochar

➢ Collect more data (long-term)

- Meteorological
- Groundwater levels
- Pests (e.g. cicadas)

10.6 QUESTIONS AND EXERCISES

1. Describe 3 sources of greenhouse gas emission.
2. What are the impacts of climate change? Provide 3 examples.
3. How do increasing temperatures affect income generation from coffee?
4. Which climatic variables affect coffee yields and how?
5. Describe 1 adaptation option to cope with the effects of more intense rainfall.
6. What is the risk of intermittent rainfall during the dry season and how can one cope with this?

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coffee & climate
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GOOD AGRICULTURAL PRACTICES FOR ROBUSTA COFFEE PRODUCTION

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