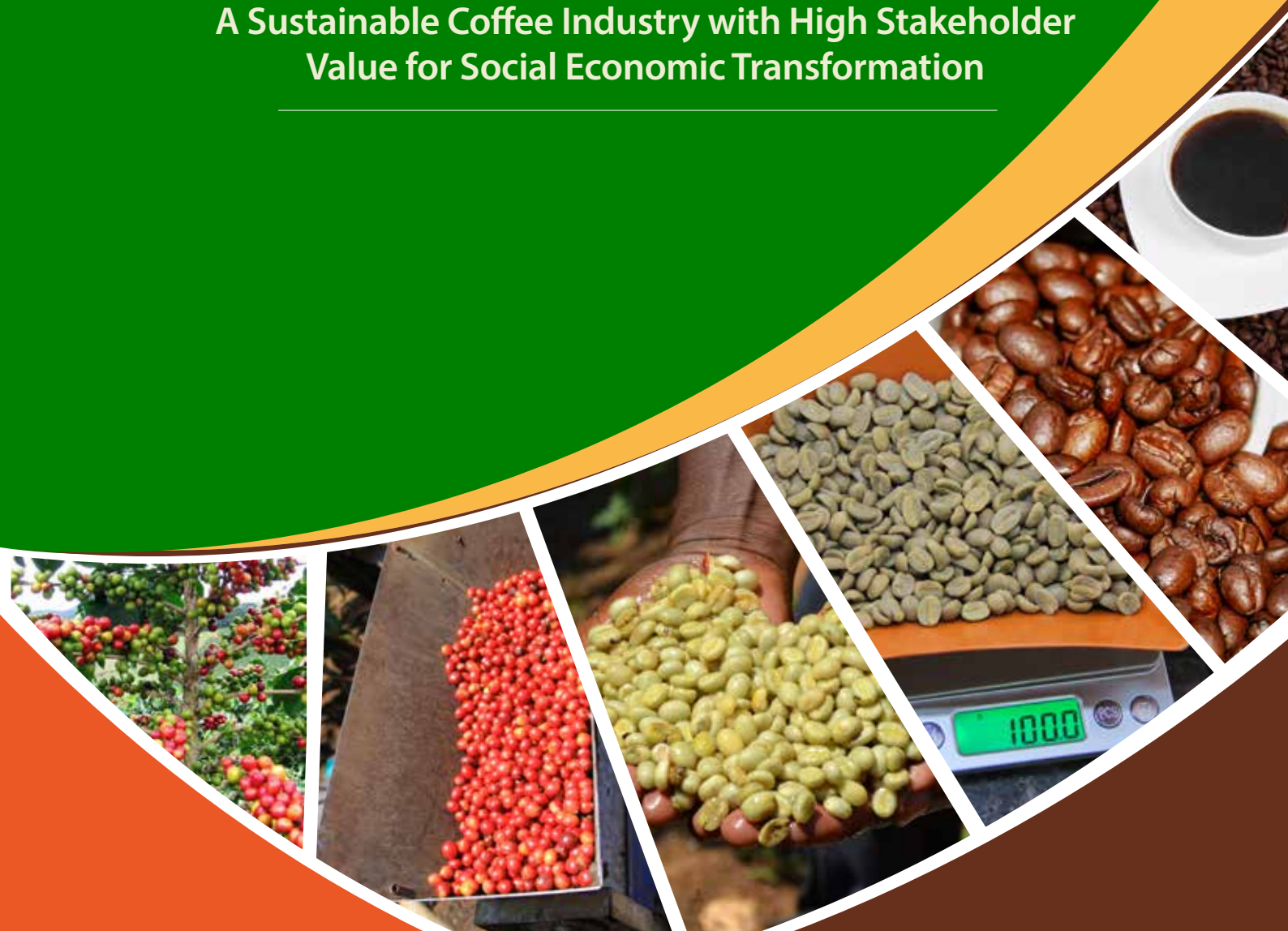
THE MINISTRY OF AGRICULTURE,
ANIMAL INDUSTRY & FISHARIES

Uganda Coffee
Development Authority

ARABICA COFFEE HANDBOOK

A Sustainable Coffee Industry with High Stakeholder Value for Social Economic Transformation



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PREFACE

Uganda's economy is agricultural-based accounting for 24% of GDP and employing over 70% of the population. Coffee is one of the leading commodities where about five million people are engaged in production and other coffee associated businesses. Among traded commodities, coffee is the largest contributor to exports, which for Financial Year 2017/18 was valued at US$ 492 million, representing 16% of total exports. In terms of volumes, Uganda is 1st Commonwealth producer, 2nd African producer and 8th world producer. For Robusta production, it is the world's 4th largest producer.

The market for coffee is assured, sustainable and the demand for good quality coffee is increasing. Currently, global demand for coffee stands at about 150 million bags against 148 million bags in exports, signifying a deficit of 3.3 million bags. Demand is slated to rise to 175.8 million bags by 2020. Given the untapped production potential, Uganda has a rare opportunity to benefit from increasing both the volume and quality of its coffee to supply this increasing demand.

At household level, coffee is an important cash provider. With appropriate investment, farmers can earn incomes of over Ushs 10 million per hectare per year. However, farmers must employ good agricultural practices such as planting high yielding and disease resistant varieties, good field husbandry/management and post-harvest handling practices to improve quality, productivity and value in the coffee farming system. To achieve these, coffee farmers and other value chain actors need relevant, timely and accurate technical, market and other critical information to guide their operations.

It has to be noted that Arabica Coffee has made significant progress in Uganda's coffee production and exports, from as low as 8.2% to the total coffee exports at the time of coffee sub-sector liberalization in 1991/92 to 14% 10 years later and currently at 24.1% of total coffee exports. Conversely, in terms of value, Arabica Coffee has taken a similar stride, from 12% of the total foreign exchange to 23% ten years later and at 28% of total the total foreign exchange earned by the country in 2017/18 Coffee Year.

This handbook has therefore been prepared to guide Arabica Coffee farmers and other value chain players on best coffee production methods in respect to Good Agricultural Practices (GAPs) including soil nutrient management, pests and disease management and control, harvesting and post-harvest handling, coffee farming as a business and coffee regulations.

Uganda Coffee Development Authority (UCDA) therefore strongly recommends this handbook to coffee farmers, extension staff, coffee buyers, processors, exporters and anybody with interest in coffee.

We appreciate the efforts and resources of all those who contributed to the development of this handbook. In particular, United States Agency for International Development (USAID), Feed the Future Uganda, Enabling Environment for Agriculture Activity (EEA), for financial support and UCDA, Research and Academia Institutions, Coffee Associations and other members of the working group for technical input.

Dr. Emmanuel Iyamulemye Niyibigira
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CHAPTER 1

ARABICA COFFEE GROWING IN UGANDA

1.0 Background

Coffee is the second most traded tropical commodity in value in the world after oil. Coffee is Uganda's major cash crop, both in terms of foreign exchange earnings and employment creation. As a producer of coffee, Uganda ranks second in Africa after Ethiopia and eighth in the world. Coffee as a commodity has continued to play a leading role in the economy of Uganda (contributing between 20 – 30% of the foreign exchange earnings), despite the vigorous efforts by government to diversify the economy. Coffee is grown by 1.7 million households in addition to the industry employing over 5 million people through coffee value chain related activities.

It is the country's target to achieve lower middle-income status by 2040. To achieve this, the country targets an income level of about Ushs 20 million per household. Arabica Coffee offers a good opportunity to contribute to the attainment of this target. With good investments and management, income from one hectare of Arabica Coffee can reach about Ushs 10 million and above per year.

1.1 Government policy and strategy for the coffee sub-sector

The coffee industry was liberalized in 1991 and, since then, anyone is free to engage in business at any level in the sub-sector, subject to conforming to the coffee regulations, 1994. Coffee research is centralized and done under NARO through the National Coffee Research Institute (NACORI) at Kituza, Mukono District. Coffee extension is also centralized under the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and offered through UCDA's coffee specific extension in collabouration with other agencies such as National Agricultural Advisory Services (NAADS), Local Governments, coffee associations, private sector, NGOs, farmer organizations/cooperatives and individual farmers.

Arabica Coffee production can be expanded/introduced in new areas of Uganda. Contribution of Arabica Coffee to Uganda's export and foreign exchange earnings has increased from 8.2% in 1991/1992 to 23% in 2017/2018 Coffee Year in quantity and 14% to 28% in US$ value respectively. In fulfillment of the Government's policy and strategy, production is being boosted in old traditional Arabica Coffee growing zones but also being encouraged in new areas. Rapid replacement of the old, low productive Arabica Coffee with high yielding, quick maturing and disease tolerant improved varieties is encouraged. Farmers are being sensitized to grow the high yielding Arabica Coffee varieties, employ good husbandry practices and participate in marketing through their Farm Level Organizations (FLOs) or cooperatives to benefit from bargaining power attained when marketing as a group.

The coffee roadmap targets to increase in production of quality coffee from the current figure of about 6 million bags to 20 million bags, making Uganda one of the top global producers. It targets to increase yield by 3 to 4 times and expand production area by 20% (5% in traditional areas and 25% in new areas). The roadmap also aims at expanding the middle

stratum of commercial farmers from the current 10% to 65% while reducing smallholders from 85% to 25% by 2040. An enabling environment through public-private partnership and collabouration is also envisaged.

In order to reap the economic benefits from coffee production and attain the Government's goal of middle-income status and vision 2040, it is recommended that good agronomic and post-harvest practices be applied by all categories of farmers, processors and traders. These include acquiring good planting material, adopting proper husbandry, ensuring that good pest and disease control methods are undertaken, carrying out good post-harvest handling and engaging in coffee production as a business. This Arabica Coffee Production Handbook acts as a guide in all these aspects.

1.2 Characteristics of Arabica Coffee and its importance

Arabica Coffee can grow up to 12m high in the wild; its leaves are dark green and oval or oblong. A bright red berry is produced which contains two seeds. The fruits contain less caffeine than Robusta. Arabica Coffee grows well in warm, temperate environments, usually at altitudes between 1,300 and 2,500 metres. The plants can grow to around 5 metres in height, although commercial plants are usually kept short. The leaves of the plant are dark green and it produces white flowers and deep red berries. Arabica Coffee farmers pick the berries and remove the flesh, leaving only the bean. The beans are then washed, dried before being sold. In Uganda the four recommended and authorized Elite Arabica Coffee varieties are SL 14, SL28, KP423 and KP162. Benefits of growing Arabica Coffee include:

- Quality and price are rated much higher and is thus, more competitive on the international market because of its superior quality.
- Most gourmet/premium coffee is produced from 100% Arabica beans.
- Can be well integrated with other crops on the farm hence increasing returns to the farmer.
- It is a beverage with documented health benefits.

1.3 Arabica Coffee growing zones in Uganda

Arabica Coffee is one of the two major types grown in Uganda and accounts for 20% of Uganda's coffee volume. It is grown in the highland areas on the slopes of Mount Elgon in the East, Mt. Rwenzori in the West and Mt. Muhabura in the South Western Region, Okoro highlands in West Nile plus other highland areas at an altitude between 1,200-2,500m above sea level as shown in Figure 1. Arabica Coffee is an introduced crop originating from Ethiopia. Arabica Coffee is more competitive on the international market because of its superior quality and generally attracts better prices. Arabica Coffee is grown in 44 districts (51%), with 28 (32%) growing only Arabica while 15 (17%) in Uganda grow both Arabica and Robusta. Current production stands at about 4.2 million bags, 80% of which is Robusta and 20% is Arabica whose average productivity is 0.3kg of clean coffee per tree per year.

1.4 Arabica Coffee varieties in Uganda

The National Agricultural Research Organization (NARO) has improved upon and released 7 varieties of coffee that are high yielding and resistant to coffee wilt disease. These varieties with their description, year of original release and major attributes are presented in Table 1.

Table 1. Arabica Coffee varieties

Arabica Coffee Variety	Description	Year of release	Current status	Major attributes	Remarks
SL14	Barboun. East African varieties from Muguga Quarantine station. Released after Scotts labouratory testing for cup quality	1950/60s	Contemporary variety	Yield up to 2,000kg/ cc/ha/yr; Good cup quality; big beans	Highly susceptible to leaf rust. Less susceptible to CBD than KP lines. Recommended for medium to high altitude areas
SL28	Barboun. East African varieties from Muguga Quarantine station. Released after Scotts labouratory testing for cup quality	1950/60s	Limited distribution due to high susceptibility to leaf rust and CBD	Yield up to 2,000kg/ cc/ha/yr; Good cup quality; big beans	Very susceptible to leaf rust and CBD. Not recommended for cultivation
KP423	Kent. East African variety	1950/60	Contemporary variety	Yield up to 2,000kg/ cc/ha/yr; Good cup quality; big beans	Very susceptible to CBD but less susceptible to leaf rust. Recommended for medium altitude
KP162	Kent. East African variety	1950/60s	Limited distribution due to high susceptibility to leaf rust and CBD	Yield up to 2,000kg/ cc/ha/yr; Good cup quality; big beans	Very susceptible to leaf rust and CBD. Not recommended for commercial cultivation
Variety Ruiru II	Is a compact, high yielding variety developed in Kenya to allow for more intensive coffee production with fewer losses from diseases and pests.	1985	High yielding dwarf hybrid grown by a small number of small scale farmers in Mt Elgon area	High yielding, dwarf hybrid	Tolerant to coffee leaf rust and resistant to coffee berry disease
Variety Catimor 129	Dwarf variety with large bean size Grown by a small number of small scale farmers in Mt Elgon area	1970	Grown by a small number of small scale farmers in Mt Elgon area	Requires careful management to maximize yield without overbearing	Resistant to coffee leaf rust and coffee berry disease. Not popular among farmers due to its' high demand for feeding and lightness of the bean/cherry

1.5 Objectives of the Handbook

Coffee is regarded as the most strategic commodity whose development is being accelerated across the country to enable the sector to continue playing a leading role in wealth creation and fighting poverty at household level. To achieve this, it is critical that Ugandan farmers enhance their production and productivity at farm level in a sustainable way that addresses the social, ecological and economic dimensions. Government approved and launched a new National Coffee Policy 2013 and Strategy and a new National Agricultural Extension Policy in 2017and Strategy. These policies rely in part on a functioning public and private agricultural and coffee specific, extension service. This handbook therefore aims at achieving the following:

- Provide up-to-date technical resource to help build the human resource capacity.
- Assist in building an efficient and effective public and private extension service for Arabica Coffee.
- Increase awareness on the part of the general public on benefits of growing Arabica Coffee.
- Facilitate the growth of Arabica Coffee enterprises especially at medium and large-scale levels in light of the current coffee development strategy for propelling the country into middle-income status.

Produced by UCDA M&E Department
Data Source: UCDA Seedling Database
Shape File Source: UBOS

Figure 1. *Map of Uganda showing the Arabica Coffee growing zones*

CHAPTER 2

ARABICA COFFEE AGRO-ECOLOGICAL REQUIREMENTS AND PRODUCTION SYSTEMS

2.0 Introduction

Some agro-ecological conditions are known to influence Arabica Coffee farming. These include soil, land, topography, amount and distribution of rainfall, altitude, temperature, humidity and wind effects.

2.1 Soil requirements

Arabica Coffee can grow on different soils types but does well on well-drained volcanic soils. For best root establishment, it requires a fertile, well aerated, free draining, slightly acidic, deep soil with reasonable humus content and a minimum depth of about 1m before roots reach an impermeable soil. Arabica Coffee will not tolerate water logging or 'wet feet'.

The best or ideal soils are volcanic red earth or sandy loams with good structure and texture and rich in organic matter. Avoid heavy clay or poor-draining soils, for good productivity. In addition, the soil should be just slightly acidic, with a pH range of 5.5 – 6.5 within which it would be well supplied with all the essential major plant nutrients. Low or high pH will limit crop performance.

2.2 Altitude

An elevation between 1,200m and 2,500m above sea level is ideal for Arabica Coffee growing. Low elevation Arabica Coffee does not possess the best quality required by the world markets. Based on cup tests, areas within 1,500 to 2,500m clearly produce superior quality/premium coffee. High elevation improves the quality of the bean and potential cupping quality. Due to a delay in ripening caused by cooler weather associated with higher altitudes, the inherent characteristics of acidity, aroma and bold bean can fully develop. Bold bean is classified as being between large and medium sized bean, with its width/length ratio bigger than that of a large bean.

2.3 Temperature

Since most Arabica growing areas in Uganda are above 1,500m above sea level, the potential to produce unique Arabica Coffee for specialty markets is high. Arabica Coffee prefers a cool temperature with an optimum daily temperature range of 15°-24°C (59°-75°F). Temperatures higher than 24°C (75°F) cause plant stress which leads to a cessation of photosynthesis. Mean temperatures of less than 15°C (59°F) also limit plant growth and are considered sub-optimal. As Arabica Coffee is susceptible to frost damage, use of shade trees to reduce the incidence is recommended.

2.4 Rainfall and Humidity

Arabica Coffee requires a rainfall range of 1,200-1,800mm per annum, which is well distributed over a period of 9 months. Both the total amount and the distribution pattern are important. Unless there is regular rainfall, young newly planted coffee trees should be irrigated (or hand watered if irrigation is not available) atleast twice a week to ensure that the newly planted seedlings get established. Also, if rain is inadequate during growth, supplemental watering/irrigation to induce uniform flowering and good fruit formation should be carried out. A fairly regular/frequent rainfall pattern throughout the berry development stage is required.

A good soaking of 50mm every 10 days or approximately 20 litre (1 jerrycans of water per plant per day) is required.. Rainfall also triggers the ripening process. Without adequate rainfall/ moisture, flowering may extend over many months making plans for harvesting more difficult and other farm management practices unpredictable..

Excessive droughts can cause the coffee tree to become dehydrated and thus lead to its defoliation and or increased attacks of plagues such as the red spider mite, leaf miner or the coffee berry borer. Excessive rainfall can, on the other hand, also affect the flowering of the coffee tree by either diminishing it or destroying it altogether. Thus, locating coffee plantings near a water supply for possible irrigation as well as for processing of cherry is desirable. Water requirements can also be reduced by use of suitable, well-established shade trees and mulch.

2.5 Wind effects

High winds have an adverse effect on coffee growth because they can cause excessive evapotranspiration and increase the demand for irrigation. Therefore, in windy areas, it is desirable to include windbreakers and shade trees.

2.6 Arabica Coffee production systems

There are two types of Arabica Coffee growing i.e. monocropping (pure stand) and intercropping (mixed stand). Each system has its own advantages and disadvantages.

2.6.1 Monocropping System

Monocropping is an agricultural practice of growing coffee as a single crop or pure stand on one piece or plot of farmland as illustrated and shown in Figures 2(a) and 2(b) respectively.

The advantages and disadvantages of coffee monocropping are highlighted in Table 2.

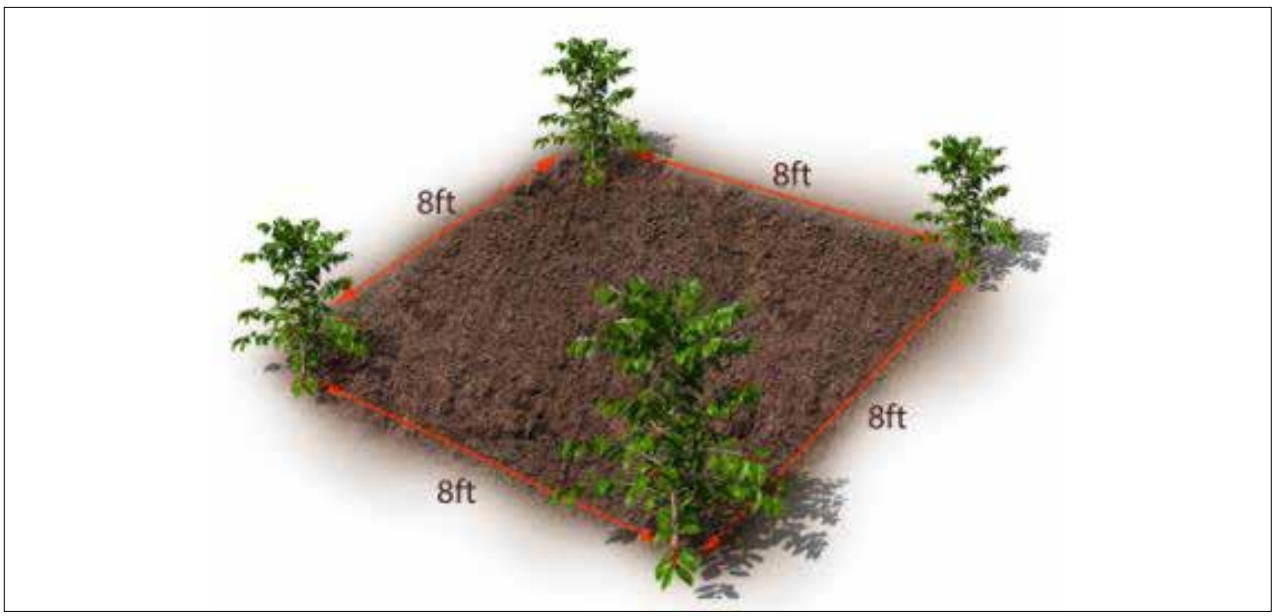


Figure 2(a). *An illustration of Arabica Coffee monocrop at a spacing of 8 x 8ft*

Figure 2(b). *Arabica Coffee monocrop at a spacing of 8 x 8ft*

Table 2. Advantages and disadvantages of Arabica Coffee monocropping

Advantages
• The coffee growing requirements, planting, maintenance including pest control and harvesting are conducted on the same crop across the farmed land. This lower cost of production. • It is much easier to cultivate one kind of crop, in terms of the knowledge and experience needed to do it successfully. • Requires less labour/not labour intensive.
Disadvantages
• May lead to food insecurity. While increased coffee yields are campaigned for, need for food to feed the households is critical. • Growing the same coffee crop year by year depletes valuable soil nutrients that plants rely on and hence this deficiency must be compensated for by increasing amounts of fertilizers. • High livelihood risk in case of crop failure.

2.6.2 Intercropping System

Intercropping also known, as mixed cropping or co-cultivation is a type of farming that involves planting coffee plus one or more other different crops in the same field. While the coffee is still young, there is an area of land between the young coffee trees, which can be utilized to grow various crops, mainly food crops. Recommended intercrops for coffee in Uganda include bananas, non-climbing *Phaseolus* beans, soya-beans, groundnuts and tomatoes.

However, these must be confined to the central 2m of the inter-row, leaving a clear 0.5m between them and the coffee tree.

Two crops can be grown per year during the first two years but it important to note however, that growing beans on the same plots, particularly in the humid areas, may result in serious problems of aphids. This practice therefore, should be avoided. Maize, cassava and potatoes are high nutrient demand crops and are therefore not recommended. The coffee-banana intercropping, as illustrated and shown in Figures 3(a) and 3(b) respectively, is a major type of coffee system in Uganda that is encouraged. During the phase of early establishment, bananas, which are a permanent crop commonly grown with coffee, may be established. The banana will provide shade for the young coffee in the early years while at later years the fallen banana leaves proved mulch cover and manure for coffee. However, if planted in large numbers, bananas may compete with coffee plants for nutrients. For this reason, a banana/coffee ratio of 1:4 is recommended until results of on-going research are validated. In this combination, each banana plant would shade four coffee bushes and each coffee bush would be shaded by only one banana plant. The advantages and disadvantages of coffee-banana intercrop are highlighted in Table 3.

In banana Arabica Coffee intercrop, establish proper spacing for both banana and coffee. Spacing of 8ft x 8ft. (Coffee) and 16ft x 16ft. (Banana) is appropriate.

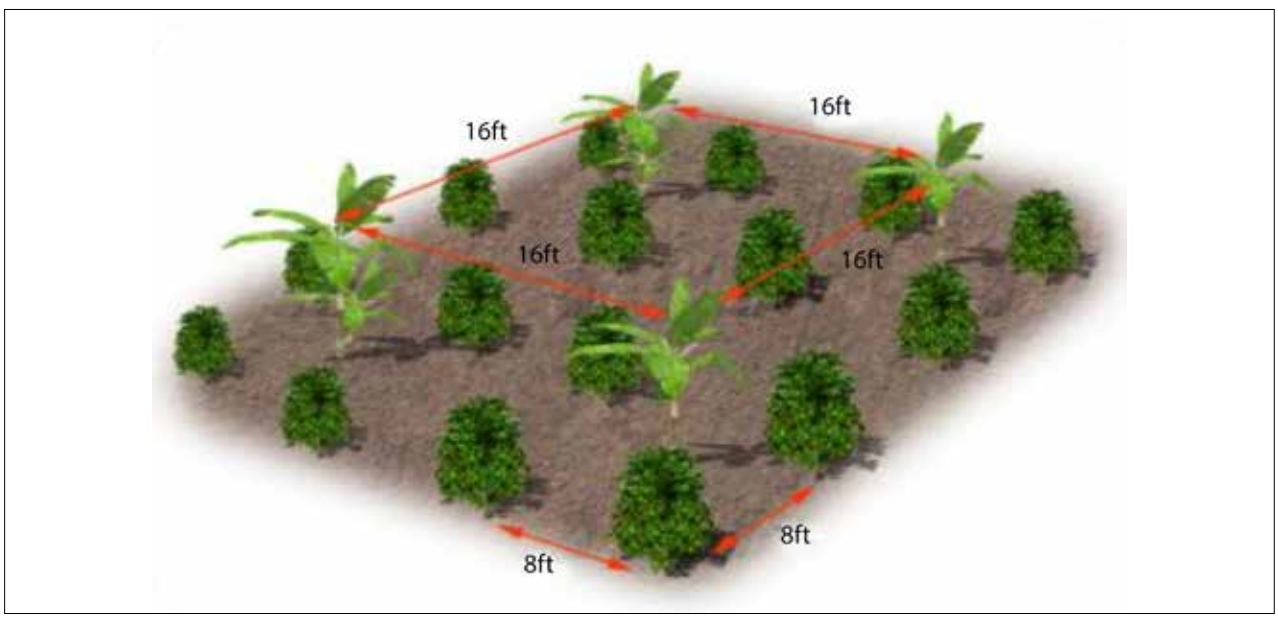


Figure 3(a). *An illustration of Coffee-Banana intercrop at a spacing of 8 x 8ft*

Figure 3(b). *Coffee-Banana intercrop spaced at 8ft x 8ft*

Table 3. Advantages and disadvantages of the coffee-banana intercrop system

Advantages
• Growing bananas in a young coffee field ensures that the farmer gets some return from the land before the coffee reaches the productive stage. • Intercropping banana and coffee reduces the income risk faced by farmers who cultivate a monocrop. • Return to labour is often higher in banana–coffee systems. It increases total revenue/inflow per unit area by about 30% compared to coffee monocropping. • Improves coffee quality. In addition it provides food to the household. • Increases yields by intensifying crop management of both bananas and coffee. • The banana provides shade for coffee, which reduces stress caused by extreme temperatures and strong winds. • The banana crop residues provide mulch that improves soil fertility due to the large biomass turnover from rotting banana leaves. • The permanent canopy and root systems of banana reduce soil erosion by reducing the impact of rainfall on the topsoil and reduced run-off. • Reduces greenhouse gas (GHG) emissions by increasing carbon stocks from both banana and coffee.
Disadvantages
• It increases competition for water, nutrients and light. • It is labour intensive and requires a lot of management and care. • If shade is too dense, the yield potential of coffee is reduced and the coffee will respond poorly to fertilizer.


SPORTS CAP

CHAPTER 3

ARABICA COFFEE FARM ESTABLISHMENT AND FIELD MANAGEMENT PRACTICES

3.0 Introduction

Arabica Coffee farm establishment starts with planning the farm layout where areas for coffee gardens, road network, drying yard, farm houses for family and workers and a coffee store are properly laid out. Then land preparation whose objectives are to facilitate maximum water infiltration and minimal soil movement, safe disposal of surplus water and simplification of irrigation works commences. Once land is cleared and coffee is planted, attention shifts to good management practices. Poor field management significantly contributes to low productivity in coffee. Farmers should therefore make appropriate investments in recommended best field management practices for maximum productivity. The area to be planted with coffee must be prepared atleast 1 year before the coffee seedlings are planted out. There are 10 distinct steps to follow for good coffee establishment:

1. Plan the farm layout
2. Clear the site
3. Plant windbreakers
4. Mark out the rows
5. Establish shade trees
6. Set up water delivery systems
7. Dig holes
8. Select planting materials
9. Plant seedlings
10. Water the seedling

3.1 Plan the coffee farm layout

This should be done in accordance with the guidelines presented in Annex 3.

3.2 Clear the site

Coffee will establish properly only on clean, well prepared land. Prepare the land during the dry season. If the land is under forest, it must be cleared thoroughly, including removal of tree stumps and their roots. However, leave some selected trees for shade. The roots of old tree stumps are frequently a source of infection to the young coffee by the fungus *Armillaria*. This disease can be avoided by ring-barking the forest trees atleast one year before they are felled and cleared. Some important practices for land preparation include:

- Leave some mature trees for shade. Aim for a spacing of 20 x 20m. This gives a good shade cover, while avoiding competition for water and nutrients.
- Before land ploughing, any couch grass (*Lumbugu*) must therefore be completely eradicated either by digging and handpicking it out by hand hoe or use of herbicides such as Glyphosate (Roundup) prior to planting.
- Arable land must be cleared of all previous crops in preparation for planting coffee.
- Carry out deep plough. It is a good way of rejuvenating the soil.
- Plant banana trees for extra shade if required.
- Ground covers should be planted to avoid soil erosion.
- For sloped terrain, establish terraces.

3.3. Plant windbreakers

Windbreakers as shown in Figures 4(a) and 4(b) are usually located along boundaries of the coffee field. They should be established before planting out the coffee

seedlings. Recommended shade trees for Arabica Coffee which may be planted as windbreaks include; *Albizia, Coriaria Ficus mucuso, Cordia Africana,* avocados, jackfruit and mangoes, which are preferably planted at a spacing of 60 x 60ft. The spacing between windbreakers on sloping land however should be closer. Windbreakers are useful because they help to:

- Reduce the speed of wind and evapotranspiration
- Accelerate the growth of young coffee trees;
- Lower the maximum temperature or raise the minimum temperatures within the coffee, especially at high altitudes;
- Conserve soil moisture and reduces erosion;
- Increase biodiversity.

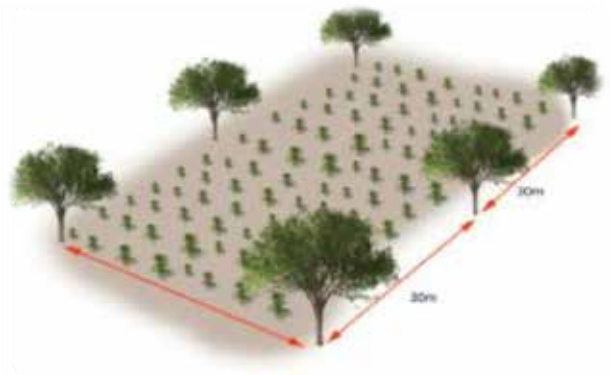


Figure 4(a). *Windbreakers planted at a spacing of 30m on flat gradient*

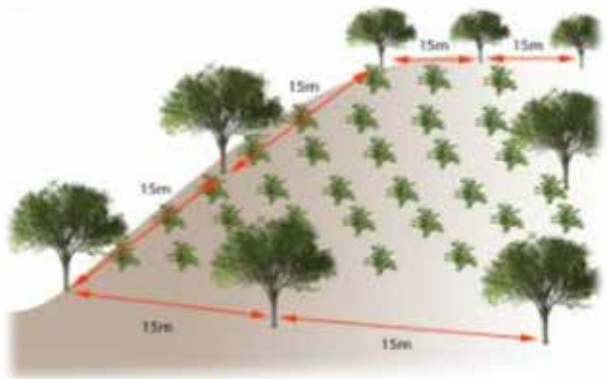


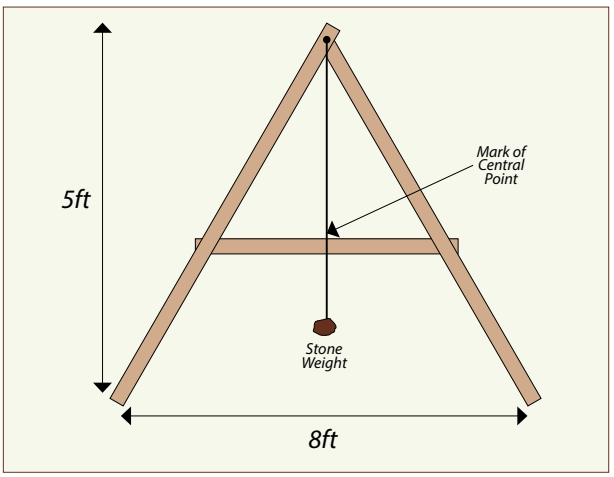
Figure 4(b). *Windbreakers at 15m on a slope*

3. 4 Mark out the rows

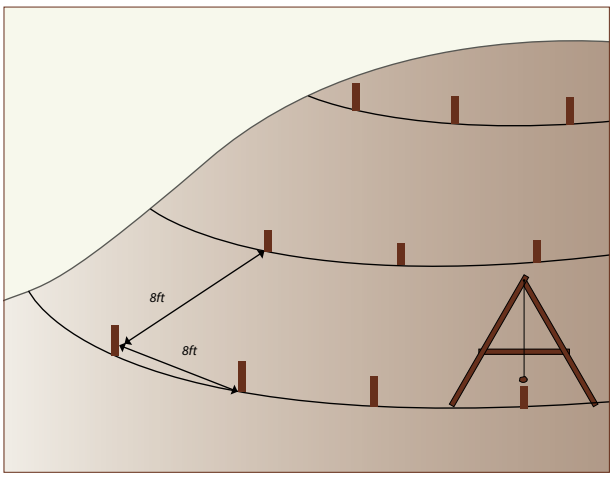
Marking row for planting coffee is important in establishing a coffee farm. The recommended row-direction is following the contour lines. Arabica Coffee varieties SL14, SL28, KP423 and KP162 are planted at a spacing of 2.4m x 2.4 m (8ft x 8ft.). This results in about 680 coffee trees per acre or 1,700 trees per hectare. If the field is on a sloping terrain, first establish terraces as shown in Figure 7 below before marking the planting holes.

- When land is greater than 15% slope, contour planting must be undertaken.
- Construct a simple wooden A-frame structure measuring 5ft. (1.5m) high with legs 4 ft. (1.2m) apart. The horizontal support crosspiece is marked at the central point. A string with a weight (stone or metal object) is attached at the apex of the 'A-frame' and allowed to hang freely, similar to a pendulum (Figure 6).
- Starting at the bottom of the slope, 'walk' the "A-frame" across the slope by rotating it from one leg of the frame to the other. Place a marker at each point on the ground where the pendulum lines up with the centre mark on the A-frame crosspiece. This marker shows the planting hole for each plant on that particular row/contour. Continue for the desired length of the contour line.
- Locate the next contour line at 8ft. (2.4 m) up or down hill from the first row. Follow the same marking procedure until the entire field is marked out.
- Practice water conservation measures like contour trenches, contour terraces, vegetative barriers, bands, grass strips and cut-off drains to avoid soil, water and nutrient loss.

Figure 5 (a). *A frame for establishing contours for*



making terraces in coffee



to mark out the planting holes.

Figure 5(b). *Using a frame to find the contours in a field*

3.5 Establishing shade trees

Given the currents effects of climatic change, shade trees are very important in Arabica Coffee farming as interventions against excessive temperatures and heat stress that is responsible for flower and fruit abortion. Farmers should establish shade trees atleast one year before coffee trees are planted out. Shade trees should not be planted at the same time or after planting the coffee seedlings. Figure 6 shows a coffee field with shade trees.

Figure 6. *A coffee plantation intercropped with shade trees*

Shade trees should be planted in rows throughout the coffee garden and care should be taken to avoid too many shade trees as they may compete with coffee for moisture and nutrients. It is recommended that the spacing of the shade trees be approximately 20m - 40m apart. In warmer areas such as the mid-northern Uganda, shade tree spacing may be reduced to 10m - 15m. Once established it is necessary to carry out proper pruning to allow for sufficient aeration as well as sunlight in the field. This is important in order to avoid high relative humidity that results from too much shadow due to plant congestion in the coffee garden - a condition favorable to disease and pest development such as coffee leaf rust and stem borers.

Best practices for establishing shade trees are summarized below while the advantages and disadvantages of shade trees are presented in Table 4.

3.5.1 Recommended shade tree species in coffee

In uganda, certain tree species are recommended for growing in different regions of Uganda as shed trees as shown in Figure 7.

1. Mt. Elgon region
- *Cordia Africana (*Chichikiri, Chikichikiri, Gugikiri)
- *Albizia coriaria (*Kumulukhu, Chesovio, Guluku)
- *Ficus natalensis (*Gukaire)

2. South and Western Region
- *Ficus natalensis* (Mutooma, Ekitooma),
- *Albizia coriaria* (Musisa, Murongo, Muyenzayenze)
- *Ficus mucuso* (Mukunyu)

3. West Nile Region
- *Ficus natalensis* (Mutuba, Ubi, Laru),
- *Albizia coriaria* (Oyo)
- *Ficus mucuso* (Uwi)

3.5.2 Tree species to avoid as shade trees for coffee

While planting shade trees, it is however important to remember that tree species with the following characteristics need to be avoided.

1. Trees that are alternate host to Arabica Coffee pests
- Avocado
- *Albizia chinensis;*

2. Hardwood trees that attract pit sawyers
- *Grevillea robusta*
- *Maesopsis emimii* (Musizi);

3. Trees that take very long to grow
- *Milicia excelsa (*Mvule*);*

4. Trees that can only provide a conical shaped shade
- Eucalyptus
- Jackfruit trees;

5. Trees that have leaves, which take very long to decompose
- Pine
- Jackfruit
- Avocado

6. Trees that produce thorns as these are very difficult to tame
- *Erythrina abyssinica* (Ejjirikiti)

7. Poisonous trees.

Table 4. Advantages an disadvantages of shade trees

Advantages
• Protects coffee bushes from heavy rainstorms and hailstorms.
• Reduces the intensity of wind speeds and soil erosion and act as windbreakers.
• Protects coffee plants from high solar radiation and limit evapotranspiration
• Limits weed growth.
• Provides organic matter in soil.
• Reduces plant metabolism and encourages more regular flowering.
• Increases biodiversity by promoting higher populations of birds, predators of coffee pests and pollinators of coffee plants thereby improving fruit formation.
• Helps to stabilize the soil by reducing soil erosion and water runoff.
• Is a requirement for organic coffee growing.
• Bean ripening is slowed thereby improving bean density and cup flavour.
• Contributes to efficient utilization of nutrients by taking up leached nutrients outside the reach of the coffee tree and returning them to the topsoil through falling leaves which act as mulch.
• When leguminous trees such as *Caliandra spp* are used as shade trees, they fix Nitrogen from the air to restore soil fertility and structure.
• Some shade trees are a source of foliage for domestic animals and others provide a source of firewood in rural households when pruned to regulate shade
Disadvantages
• They compete with coffee for nutrients and water.
• Require regular pruning and thinning which is labour intensive.
• They reduces photosynthetic activity and causes elongation of internodes both of which result in lower yields.
• Risk of coffee leaf rust is more rampant in coffee with high shade tree cover.

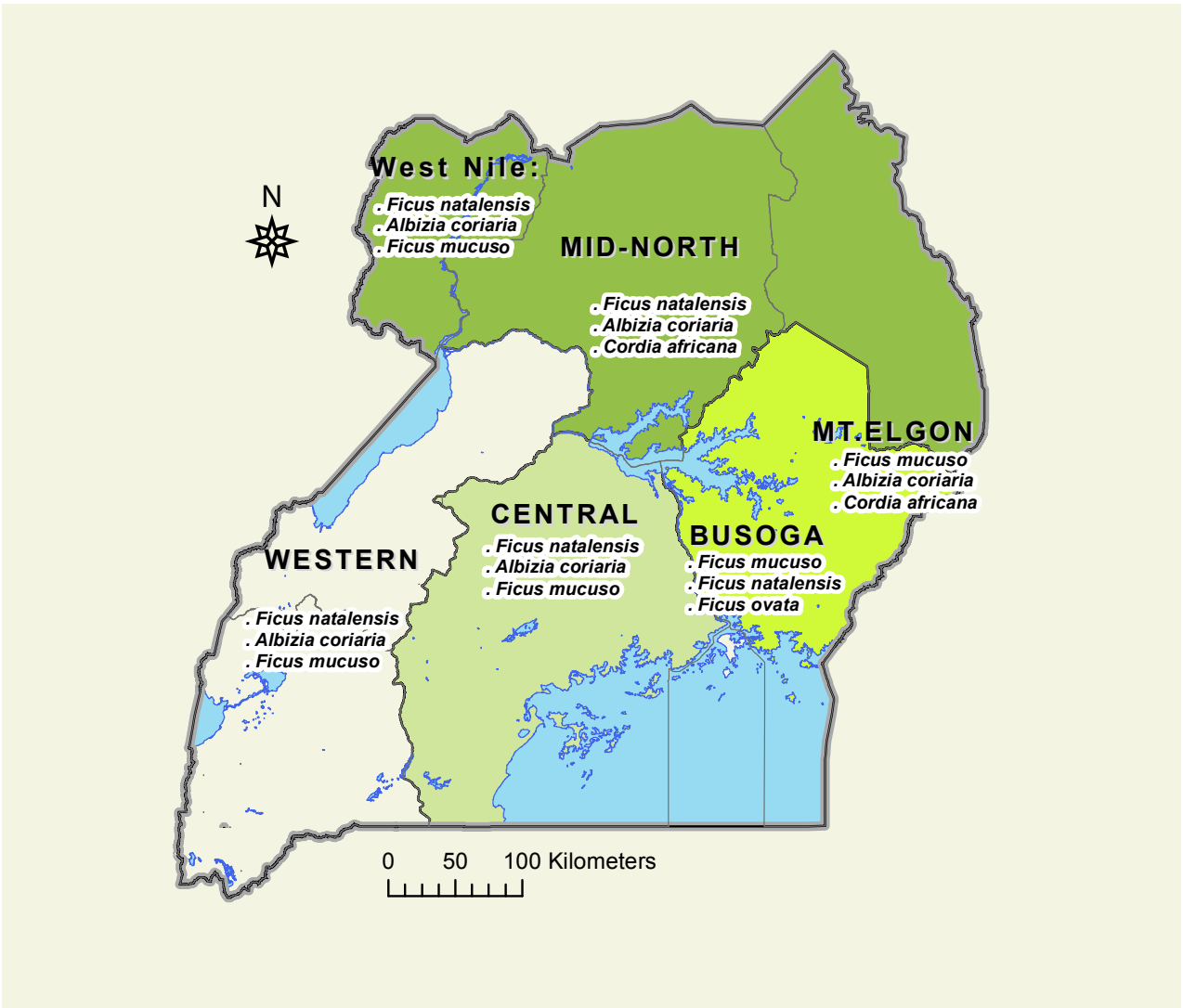


Figure 7. *Map of Uganda showing recommended shade trees by region*

3. 6 Set up water delivery systems

Planning for water conservation and its future availability is important while preparing the coffee field. The importance of water delivery systems cannot be over-emphasized today given the erratic climate change effects. Irrigation or water delivery systems should be installed prior the planting of coffee trees. In setting up water delivery systems, the following must be considered:

- A reliable water source
- Pumping systems and filtering system
- Main distribution network
- Control heads, valves, automation and emitters (micro-sprinklers or drippers).

Water sources may include underground water sources, overhead water tanks/reservoirs or directly from lakes, rivers and springs. Pumping systems can be motorized, solar powered or manual. Farmers can also dig water channels to distribute rainwater into the coffee garden. They are different options for setting up water delivery systems depend on a farmer's income and technical advice from water experts. Figure 8 shows the various water delivery systems available for both large and small scale coffee farmers.

Drip irrigation

Overhead irrigation

Overhead water reservoir

Water dam

Hand pump

Solar powered water pump panel

Figure 8. *Options for water delivery systems*

"Installing water delivery systems is a climate change mitigation measure"

3.7 Dig holes

The hole is the foundation of coffee production and productivity. Digging holes before the planting season helps the farmer to be ready for planting coffee at the start of the first rains. Hole preparation process, as shown in Figure 9, is as follows:

- Marking with pegs positions where the coffee seedlings will be planted.
- This is followed by digging circular holes of 60cm (2ft) deep and 60cm (2ft) in diameter at the marked points. This should be done atleast 3 months before planting as it allows for better water and root penetration through the soil.
- When digging the holes, keep the fertile topsoil separate from the subsoil.
- Refill the holes with manured soil about a month before planting. Where possible, mix the topsoil with a 20-litre basin of well-decomposed manure before refilling each planting hole. If inorganic fertilizer is available, you may mix at planting one handful of Triple Super Phosphate (TSP), Single Super Phosphate (SSP) or Di-Ammonium Phosphate (DAP). Phosphorus stimulates root growth.
- Finally, heap the soil above the ground level to allow for sinking when the soil settles.

Figure 9. *Digging the planting hole (2ft x 2ft)*

Figure 10 illustrates the steps taken in preparing good Arabica Coffee planting holes.

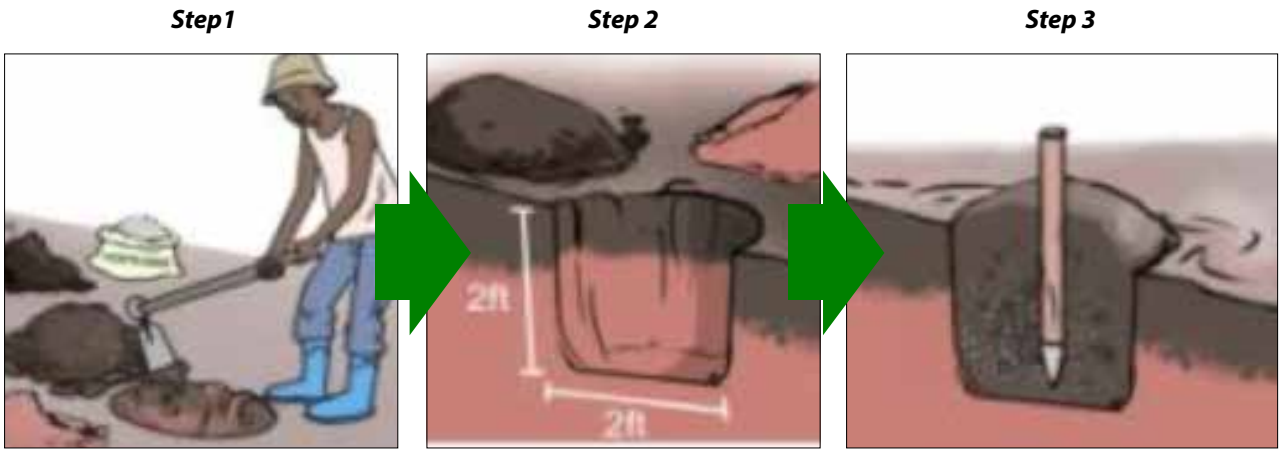


Figure 10. *An illustrated process for preparing coffee-planting holes.*

3.8 Select good planting materials

It is important to buy good, clean planting material in order to expect a good yield. Start by seeking guidance from the Uganda Coffee Development Authority (UCDA) officer in your district or your sub-county agricultural officer, or the National Coffee Research Institute (NaCORI) or obtain seedling from a certified coffee nursery.

Therefore;

- Get coffee seedling with 4 – 5 pairs of true leaves for elite Arabica seedlings, as shown in Figure 11, one month before the onset of the rainy season.
- Always use seeds from a certified source.

Figure 11. *A healthy good seedling suitable for planting*

- Reject any seedlings with signs of pests and diseases, especially root mealybugs, aphids and other sucking insects. This prevents introducing pests and diseases into your garden.
- Do not buy seedlings if the roots protrude far beyond the polythene pots because the taproot may be damaged.
- Avoid seedlings with twisted taproot (J-root system) as shown in Figure 12.

Figure 12. *A coffee seedling with unsuitable J- root*

3.9 Planting out

Prior to the actual planting of coffee seedlings in the prepared holes, wet the soil to a depth of 60cm (2ft). Ensure that roots protruding beyond the polythene pots are trimmed off before planting. Then open up the soil mound in the centre of the filled holes sufficiently to fit the size of the potted plant (accommodate the taproot and other roots) up to collar level. Remove the polythene pots before planting.

Carefully loosen caked soil around the roots to ease water uptake and root development. Place the seedling in the centre of the hole up to collar level to

"Use of good clean planting material is a climate mitigation measure"

allow for some sinking when the soil settles. Ensure that no depression or heap of soil is made around the plant. Regularly inspect the planted field to identify any dead plants and replace them as soon as possible to have a full-planted garden growing at the same pace as shown in Figure 13.

Protect each planted seedling from sunshine by providing a temporary shade (tree branch/split banana pseudo-stems) and also provide cover at the base of the planted seedling. Water the plantlets if necessary.

For rain-fed agriculture, plant coffee plants 2 to 3 weeks after the onset of the rainy season. Planting should be done early in the morning or late in the evening. Avoid planting when conditions are windy or hot and dry.

However,for farmers with a good catchment of water and can afford watering/irrigation, planting during dry season towards the onset of the rains is the best practice.

3.10 Water the seedlings

Coffee needs sufficient water to grow well right from planting through to its initial establishment. Water the seedling before and immediately after planting. Watering of coffee trees should be intensified during drought.

If there is insufficient rainfall, both shade trees and coffee will need irrigation or hand watering for a few weeks until they get well established. Table 5 highlights coffee water requirements and irrigation frequency for the different growth stages of Arabica Coffee. With supplementary rains, the frequency may be reduced to twice a week and once a week for occasional irrigation. Resource poor farmers are advised to use bottle irrigation shown as shown in Figure 14.

Figure 13. *A young Arabica Coffee garden without gaps*

Figure 14. *A coffee seedling with a water bottle irrigation and grass as mulch*

Table 5. Arabica Coffee water requirement and irrigation frequency at different growth stages

Coffee growth stage	Amount (Lt) of water required per tree per day	Irrigation frequency per week (no. of times)
≤ 6 months	2 Litres	3
1 year	3 Litres	3
2 years	5 Litres	3
3 years (peak growth stage)	7 Litres	3

3.11 Arabica Coffee field management practices

Arabica Coffee under recommended management will produce atleast 1kg - 2kg clean coffee (FAQ) per tree or 1,680kg - 3,360kg clean coffee (FAQ) per hectare per year. This can be achieved with minimum maintenance cost, if the farmer undertakes recommended husbandry practices, such as regular mulching with organic residues like bean haulms, maize stalks, banana leaves, animal manure and coffee husks, proper canopy management, adequate soil and water conservation measures. The recommended management practices include;

"Watering is an important climate change mitigation measure"

- Weed control
- Mulching
- Water for production and irrigation
- Soil and water conservation
- Use of cover crops
- Nipping/capping
- Pruning and de-suckering

3.11. 1 Weed control

A weed is any undesired plant growing within the coffee field. Control of weeds should be done before they seed (fourth leaf stage), applying fertilizers or mulching. Weeds compete with plants for water and nutrients and can lead to reduced crop growth, low yields and poor quality coffee beans if allowed to grow. At the end of rains, carry out clean weeding since weeds compete with the coffee for the diminishing moisture. Maintain clean weeding until the start of next rains. It is important to keep the young coffee plantation free of weeds. There are three basic methods of weed control exist. These are cultural, mechanical and chemical.

Cultural weed control is done by hand weeding, mulching, close spacing of crops or using cover crops. Mechanical weed control is done by hoeing, slashing or using a simple engine driven weeding implements such as motorized weeding equipment as shown in Figure 15. Do not weed using a hoe in the rainy season as it increases the risk of soil erosion. Also use a hoe for young coffee and a forked hoe for mature coffee use to avoid injuring the root system of the coffee plants.

Figure 15. *Motorized weeding equipment*

Chemical weed control is the use of herbicides to manage and control weeds. It is advisable to slash the weeds first before spraying the re-growth with herbicides. Use recommended herbicides with active ingredient of glyphosate such as "Round-up" for grass weeds. "Round-up" works best on mature weeds that are about to flower and most especially couch grass (*Lumbugu*). Use the recommended rate of 2 litres per hectare for annual grasses and 4–6 litres per hectare for perennial grass. In the case of difficult grass, complete eradication requires blanket spraying. However, in a field under good weed control the perennial grasses will usually appear in patches. These should be spot sprayed.

3.11.2 Nipping/capping of Arabica Coffee seedlings

To maximize benefits from Arabica Coffee, it is recommended that production is based on the multiple stem system (preferably 3 stems) through nipping exercise. This is done at a height of 15–40cm above the ground by clipping off the tips of the growing seedling to encourage development of two stems. This practice should be done between 4-6 months and when the planted seedling has not exceed 30-40cm.

The two developed shoots should be groomed to allow them grow into future coffee bearing stems.

However, some farmers may chose to bend the seedlings to develop the suckers though this process is not commonly practiced in Arabica Coffee. If they do so, two suckers as nearest to the ground as possible should be chosen and groomed to grow alongside the seedling stem so that the coffee stump grows to maturity with three coffee bearing stems.

3.11.3 Mulching

Mulching is the covering of the topsoil between crop rows and columns and around coffee trees with dried or rotten plant residues such as dried grass, maize stalks, bean haulms, coffee husks, straws and compost manure. Maize or sorghum stalks are very good for mulch because they contain a lot of potassium, which is important in coffee crop nourishment. Any organic material can be used as mulch and should be well spread over the grou

ve not yet spread out. Therefore, young coffee plants should be ringed with mulch at planting time to suppress weed growth and also conserve moisture.

It is also essential that a good layer of mulch be maintained and made up to atleast 5 - 15 cm deep each season. However, ensure that the mulch does not touch the trunk of the coffee tree to avoid infections and rotting (the tree may develop collar rot and in some cases, ants and other pests may use it as a bridge to attack the tree). Mulch should be placed atleast 15 cm from the stem in case of a young plant and 30 cm (1ft) from stem in case of a mature coffee tree. The advantages and disadvantages of mulching areas outlined in Table 6.

Table 6. Advantages and disadvantages of mulching

Advantages
• Improves yield by facilitating better regulation of moisture levels in the soil, thereby increasing soil moisture retention and improving surface water infiltration into the soil.
• Reduces the watering requirements –thereby minimizing costs of irrigation.
• Protects the soil surface from erosion.
• Encourages more productivity through building the growth of additional surface roots.
• Fertilizers applied to coffee are conserved by mulching due to reduced surface run off and easier access to roots than on dry land.
• Maintains temperature balance in the soil.
• When used for prolonged periods mulch controls weeds thereby suppressing the cost of labour and herbicides in managing weeds.
• Builds up topsoil fertility and improves uptake of nutrients through the general amelioration of soil structure and improved microbial activity.
• Limits excessive uptake of manganese, which may build up rapidly to high levels in acid soils. It also increases the potassium level in the soil.
Disadvantages
• May be a costly process especially with regard to sourcing and purchase of mulch material and the additional labour required for its application.
• May increase incidences of certain pests e.g. leaf miner, termites and dusty surface beetle.
• Pesticides may need to be applied especially in areas prone to ants that destroy mulch.
• May increase risk of fire. In such a case, leaving some rows unmulched is advised.
• Mulches may lead to a deficiency in or total unavailability of zinc and Magnesium.
• Prolonged use of Elephant grass and swamp straw as mulch can in the long run cause yellowing and death of the coffee bush/plant.
• If mulch touches the stem of the young tree, the tree may develop collar rot or may be a bridge for ants and other pests to attack the coffee plants.

"Mulching is an important climate adaptation and mitigation measure"

3.11.4 Water for Production and irrigation

Water is the backbone of agricultural production. Therefore, all effort must be put in place to ensure that the planted coffee has access to adequate water to sustain it during establishment and productive stages. In one of the biggest coffee producing country in the world, Vietnam, it is revealed that in priority, the following are the most required for good coffee production and productivity:

- Water
- Fertilizers
- Variety

Water access to plants can be through different delivery mechanisms and irrigation is one of them. Irrigation is the artificial application of controlled amounts of water to plants at specific intervals for the purpose of sustaining their survival and producing a crop during water stress periods such as droughts. The main purpose of irrigation, therefore, is to supplement rainfall (in rain fed agriculture) so that the growing season of the coffee crop can be extended for increased yields. Benefits of irrigation are as follows:

- Increases production by up to 50% or more, especially when rains are below normal.
- Increases the bean size hence the proportion of premium grades and thus enhances quality.
- Induces flowering.
- Protects the tree from damage arising from overbearing when there is drought.
- Enhances fertilizer application efficiency.
- Enables continuous vegetative growth during drought.

At planning and design stages, it is important to determine clearly the crop water requirements so that the source and quality of water can be put in place to adequately satisfy the peak demands for the coffee. Planning must therefore ensure adequate water volume required for the proposed acreage capable of irrigating the coffee throughout the drought periods. To supply water through the irrigation system, it is important to consider the dam storage capacity and application rate (cubic metres water dispensed per hour) required during the irrigation time frequency and replenishing time for the utilized water. If the water supply comes from a bore hole, the sustainability of the water yield must be properly analyzed and its compatibility with the required irrigation rate confirmed.

Therefore, the timing of irrigation is influenced by some prevailing physical considerations at the farm, but as a rule of thumb, irrigation water should be applied to the coffee crop when 50% of available moisture is determined to have been depleted. The key months for irrigation is the dry period after the seasonal rains have receded until the next rainfall. However, in hotter, drought prone areas, irrigation may be required throughout the year if it has been established to be a worth while investment. Coffee needs to be irrigated when:

- A new garden has been prepared and ready for planting but the rains are inadequate.
- The flower buds are fully formed and there are no rains.
- The pinheads are breaking dormancy (7^{th} week from fruit set) and the rains fail.
- The rains are insufficient during bean filling.
- The rains fail during the ripening stage.
- The coffee trees are under stress due to drought.

Other considerations include;

Rainfall: Both the amount and the distribution throughout the year are important. The requirement for irrigation should be based on peak rainfall needs.

Evaporation: This is influenced by amount of sunlight, temperature and humidity prevailing over the respective time period and the moisture required by the crop for optimum growth. The higher the evaporation rate, the higher the frequency of irrigation.

Evapotranspiration rate: The evaporation of water from the undersides of the leaves from the crop itself is influenced by temperature, wind and humidity conditions. The higher the evapotranspiration rate, the higher the frequency of irrigation.

Conservation tillage: Some soil conservation practices such as deep tillage allows for the optimum use of rainwater and irrigation water.

Shade trees: The need for a good balance, because they may compete with the coffee plants for water. However, they also reduce the transpiration losses from the coffee plants and a balance needs to be well established.

Mulch: Mulching, especially in the first 3 seasons, ensures efficient use of irrigation water, increases crop yield and improves soil conservation. Failure to mulch increases irrigation needs.

Types of irrigation systems

Farmers must be aware of the advantages and disadvantages of each system since the success of any irrigation system is dependent on its attendant management costs. The common irrigation systems include:

1. Drip irrigation
2. Overhead irrigation
3. Basin irrigation
4. Under tree irrigation
5. Bottle irrigation

Drip irrigation

This is a type of irrigation system that allows water to drip slowly directly to the roots of plants, either from above the soil surface or buried below the surface. The goal is to place water directly into the root zone, minimize evaporation and maximize efficiency. It is the most preferred type of irrigation since it is economical and efficient in water usage. Water is delivered through the laid out drip lines that have equal spaced openings. Drip irrigation on the other hand involves slow and low volume application of water to the coffee. Use of micro jets is another version of the drip irrigation. The advantages and disadvantages of drip irrigation are presented in Table 7.

Table 7. Advantages and disadvantages of drip irrigation

Advantages
• Low evaporation and runoff water losses compared to overhead and basin systems • Increased efficiency of water use • Low physical labour costs • Cost of weed control is reduced • Easier to use in fields with irregular levels and shapes. • Avoids unnecessarily wetting of the inter-rows. • Enables combining fertilizer application with irrigation (fertigation) thereby saving fertilizer application costs and increasing fertilizer efficiency. • Delivers highly uniform water distribution to coffee trees. • Coffee foliage is not wetted thus no risks of washing down protective fungicides.

Disadvantages
• Requires high initial investment capital. • Clogging of the emitters if the water is not properly filtered and equipment not properly maintained. • Susceptibility of the PVC pipes to rodent damage. • The system requires periodic back-flushing and flushing out drip lines. • The sun affects the drip tubes thus shortening their lifespan. • Levelling for uneven surfaces must be done, thus increasing on labour costs.

Overhead/Sprinkler irrigation

Uses sprinklers or guns to apply water from a central place and distribute above the coffee bushes, thus the name overhead. Water is piped to one or more central locations within the field and distributed by high pressure sprinklers or guns. The advantages and disadvantages of overhead irrigation are presented in Table 8.

Table 8. Advantages and disadvantages of overhead irrigation

Advantages
• Suited to a range of topographies and field dimensions. • Land leveling is not essential for uneven surfaces. • Foliar fertilizers and fungicides can be applied in the irrigation water economically and with minimal extra requirements. • It removes dust on the leaves, thereby improving photosynthesis • Triggers flowering
Disadvantages
• Requires high initial investment capital. • Is the most uneconomical in water usage, using almost two times the water used with drip or basin irrigation systems. • Predisposes the coffee trees to disease attacks as it removes any protective chemicals that have been applied. • In case water used is from a saline bore hole/source, foliage may be scorched by the salts. • Due to the high pressure and the more water requirement compared to other systems, it involves high costs of power/energy. • Wind distorts sprinkler patterns and may cause uneven distribution of water.

Basin irrigation

This type of irrigation involves holes being dug in form of basins between coffee trees and water-fed into the dug basin-like holes and allowed to infiltrate into the soil. Fields where basin irrigation is used are set up to follow the natural contours of the land but levelling and land grading enables construction of large rectangular basins that are more appropriate for mechanized farming. Basin irrigation can be used for coffee due to affordability of initial investment costs. The advantages and disadvantages of basin irrigation are presented in Table 9.

Table 9. Advantages and disadvantages of basin irrigation

Advantages
• Requires little initial investment costs compared to drip system or overhead systems.
• Uses less water (almost a half) compared to overhead system, thus enhances sustainable water use.
• Not affected by wind as is the case with overhead irrigation.
• Water infiltrates the soil from the basin and minimizes losses due to runoffs and evaporation.
• Basin pits help control soil erosion by checking the speed of runoffs and collecting the washed soils, in addition to storage and enhancing penetration of running water.
• In case water used is from a saline bore hole/source, foliage is not scorched by the salts.
• It enables saving costs of energy required to pump water since it uses less water.
• Coffee trees are not predisposed to disease attacks due washing off any protective chemicals that have been applied.
Disadvantages
• Not easy to determine or control amount of water to the plants.
• Rubber hose pipes used during filling the basins are susceptible to damage during transfers from one place to another.
• The basins easily get filled with eroded soil and require reopening regularly.
• The water around the base of the trees can exacerbate the *Fusarium* fungus leading to Coffee Wilt Disease (CWD).
• Water usage efficiency might be compromised through water leaching from the basins.

Under tree irrigation

This type of irrigation involves use of small sprinklers to apply water under the trees without wetting of foliage and fruit. It uses under tree sprinklers that are strategically placed to target large portions of each tree's root zone. The advantages and disadvantages of under tree irrigation are presented in Table 10.

Table 10. Advantages and disadvantages of under tree irrigation system

Advantages
• More efficient water use
• Greater uniformity of water application.
• Enhances plant growth, crop yield and quality from strategic irrigation
• In case water used is from a saline bore hole/source, foliage is not scorched by the salts.
• Coffee trees are not predisposed to disease attacks due washing off any protective chemicals that have been applied.
Disadvantages
• The water around the base of the trees can exacerbate the Coffee Wilt Disease (CWD) in coffee.
• Operation and management requires more consistent oversight than alternative irrigation systems.
• Triggers weed growths on a wider area that is sprinkled with water

Bottle irrigation

This is ideal for small-scale farmers and most particularly, for newly planted coffee. It involves the use of plastic water bottles to apply water under the tree canopy. Farmers should frequently monitor the bottles to refill them with water when it is finished. Table 11 presents the advantages and disadvantages of bottle irrigation.

Table 11. Advantages and disadvantages of bottle irrigation

Advantages
• It is affordable to low income farmers.
• It is simple to operate and manage.
• Coffee foliage is not wetted thus no risks of washing down protective chemicals.
Disadvantages
• It may not be easy for rural farmers to get enough plastic bottles.
• Plastic bottles may become an environmental pollutant if not properly disposed of after use.

3.11.5 Soil and Water Conservation

Soil and water conservation measures are important in minimising loss of soil fertility through erosion and the retaining moisture for the coffee, especially in the dry periods. The following practices have been devised to conserve soil and water in the coffee garden:

- Rainwater harvesting pits
- Terracing along contours
- Construction of water retention bands
- Planting of cover crops and soil retention grass
- Planting shade trees
- Mulching

Rainwater harvesting pits

Rainwater-harvesting pits, as shown in Figure 16, are constructed in the dry season with recommended dimensions as guided by the Field Extension Worker.

The size of the pit should be chosen in relation to the water requirements of the farm, space availability, water catchment area and availability and labour.

The pits are dug in the dry season and may be filled with water manually. Water may be left to drip through the coffee root zones or the pits may be lined with polythene sheets and used to store water for manual application to the plants.

Figure 16. *A rainwater-harvesting pit*

Terracing along contours

Terracing along contours is effective in cases of steep slopes to reduce soil erosion by minimising rainwater runoff. On a gentle sloping land, terraces may be spaced 10m apart and on a steep slope spacing of 8m apart may be used as shown in Figure 17.

Figure 17. *An illustration of "Fanya juu" and "Fanya chini" water catchment channel*

Construction of water retention bands

Construction of water retention bands such as pits/ troughs at some points of the terrace, as shown in Figure 18, conserves rainwater and facilitates its availability to the neighbouring coffee trees by way of gravity flow thereby nourishing the coffee trees during the dry period. A small amount of oil may be added to the trapped water to prevent breeding of mosquitoes.

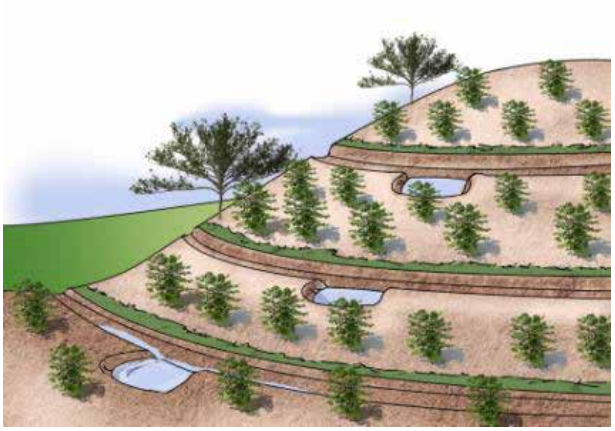


Figure 18. *An illustration of water/soil retention bands*

Planting Grass and Vegetation

Grasses such as vetiver grass, *Paspalum spp* and leguminous plants such as *Tithonia diversifolia or* Napier (Figure 19) should be planted at the edges of the gardens and ridges of terraces/contour bands to reduce soil erosion. Besides controlling soil erosion, *Tithonia spp* has been known to enrich the soil with Nitrogen and Vetiver grass has favourable qualities for animal feed and its pruning by products can be fed to domestic farm animals.

Figure 19. *Planted Napier grass for water and soil conservation in a coffee shamba*

Planting shade trees

Shade trees are very effective in reducing soil erosion and leakage of soil nutrients to a deeper ground level beyond the reach of coffee roots.

Planting cover crops

Planting of cover crops such as *Indigofera spicata, Mucuna, Phaseolus spp, Lablab* and Groundnuts can help to prevent soil erosion and retain soil moisture in both Arabica and Robusta Coffee. Use *of Indigofera spicata* as a cover crop is shown in Figure 20 (Robusta Coffee garden).

Figure 20. *Indigofera spicata as a cover crop*

Mulching

Mulching for both Arabica and Robusta Coffee is a proven way of conserving soil water and moisture and should be put to good use by farmers as shown in Figure 21 (Robusta Coffee garden).

Figure 21. *A well mulched coffee garden as a water conservation measure to reduce soil erosion*

3.11.6 Use of Cover crops

Cover crops are crops intercropped/planted with coffee with the aim of providing soil cover during the growing season of the main crop. These crops are usually leguminous creeping plants that will not compete for light with the main crop. They should have a special ability to fix Nitrogen from the air and return it back into the soil.

The most common cover crop species include: *Indigofera spicata, Mucuna pruriens, Crotalaria, Lablab spp. Desmodium, Stylosanthes gracilis and Flamingia spp.* The planting of leguminous groundcover crops below the coffee trees or between the lines of the coffee trees are associated with the following benefits:

- Control erosion and protect the soil from the direct beating effects of rainfall. Cover crops increase vegetative and residue cover during periods when erosion potential is high, especially when main crops do not furnish adequate soil cover.
- Increase porosity of the soil, which increases the infiltration rate of rainwater thus reducing erosion. "Soil porosity" refers to the amount of pore, or open space between soil particles.
- Directly contribute to increase in vegetative biomass, which when it decomposes, releases organic matter into the soil. Increase in organic matter also increases microbial activity and aggregation of the soil particles.
- Cover crop root channels and animal activities such as those of earthworms form macro- pores that increase aggregate stability and improve infiltration.
- Helps prevent nutrient loss. Decomposition of increased biomass provides a slow release of nutrients to the root zone. Legume cover crops fix atmospheric Nitrogen back to the soil that becomes available to the crop.
- Reduces soil temperature and conserve soil moisture. Cover crops can lower soil temperatures by as much as 40^0C or more at midday, especially where there is no shade. They also increase water infiltration and regulate soil temperature. For instance, *Indigofera spicata* keeps the surface of the soil moist and lowers the surface temperature.
- Cover crops have the ability to slow down the development of weeds. Competition between coffee and the cover crops can be minimized by cutting back the cover crop at the end of the rains leaving the foliage on the soil surface as mulch.
- Use of cover crops is a good climate smart agricultural practice. Figure 22 shows *Flemingia* and *Leucaena* cover crops.

Flemingia cover crop

Leucaena as cover crop

Figure 22. *A cover crop to prevent soil erosion in a coffee shamba*

"Coffee cover crops are a climate change adaptation measure"

3.11.7 Pruning and De-suckering

Pruning is the removal of broken, dead, unproductive, aged, diseased and pest damaged stems. It is an essential task for maintaining strong and healthy coffee trees. Pruning is done to create well-structured, healthy trees that give good cherry yields over the productive cycle. Pruning helps to get rid of uneconomic branches thereby helping to maintain tree foliage balance, which in turn considerably reduces the amount of inputs such as fertilizers or pesticides to be applied. The result of good pruning is more light penetration, more strength and more cherries on the coffee trees. A more open canopy also allows more air circulation which in turn reduces humidity and temperature within the tree bush. The benefits of pruning are illustrated in the box below.

Benefits of pruning coffee

- Maintain the correct balance of the leaf area for optimum crop yield and improve the quality of the produce.
- Eliminates unnecessary competition for nutrients by removing unproductive wood, hence allowing the tree to produce good crop yields year after year.
- Removes weak branches that will not yield, or that will yield minimal crop.
- Eliminates excessive humidity that would predispose fungal development through better air circulation.
- Improves tree tolerance to drought and prolonged crop survival against water stress during prolonged drought.
- Creates better access to the canopy of the tree when spraying pesticides.
- Reduces the die-back caused by over-production and keeps the tree in a state of vigorous and productive growth.
- Controls the height of the tree thereby making harvesting easier.
- Creates conditions that are less favourable to pests and diseases infestation

Pruning is best carried out at the end of the main crop harvest every year. For pruning to achieve its desired benefits, it is important to follow the following procedures:

- After harvesting the coffee, look out for any trees or branches that will not bear again or only produce minimal and small coffee cherries. This is the right time to remove such trees or branches.
- Use a pruning bow saw, sharp secateurs or a pruning saw for removing unwanted shoots of coffee trees. The pruning tools are shown in Figure 23. Ensure that the tools are cleaned using 75% ethanol, spirit or 25% dilution of Jik before and/or after use on a coffee tree to prevent spreading disease from tree to tree. After use, keep the metallic tools oiled to prevent rusting.

Figure 23. *Pruning tools: bow saw* ***(a)****, secateurs* ***(b),*** *and pruning saw* ***(c)***

- The number of stems should be kept to the optimal 2 stems or a maximum of 3 to maintain optimum productivity.
- Remove all suckers on the stems and secondary and tertiary branches to maintain the tree to remain strong or vibrant to enough give good crop yields.
- When there are many suckers, the coffee plant will divert some nutrients to feed them instead of all the nutrients going to the fruit bearing stems for higher productivity.
- Remove all suckers (de-suckering) all the time during the year and keep only the good branches so that they will optimize nutrients from the soil and receive enough light to give good yields and quality cherry.
- Branches that are close to the ground and not bearing must also be removed as they can be a conduit for pests and diseases infection. Prune off any affected branches at the site (in-situ) and not dragged through the farm as this can easily lead to the spread of diseases such as Coffee leaf rust. Figure 25 shows well-pruned Arabica Coffee trees.

The "suckers" (water shoots) should be removed using secateurs when they are still very young, tender and succulent so that the tree is not "wasting" food and energy on shoots that are not required for production of coffee. De-suckering is done to avoid wastage of nutrients to unwanted suckers, open up the canopy, enhance productivity and to achieve less disease and pest incidences.

A properly pruned coffee tree

Benefits of proper pruning – a heavily bearing branch of coffee

Effect of proper pruning after 6 to 9 months showing a heavily bearing branch

Figure 24. *An illustration of well-pruned coffee*

"Proper pruning/good canopy management is a climate change adaptation measure"

CHAPTER 4

REHABILITATION OF OLD ARABICA COFFEE FIELDS

4.0 Introduction

The majority of Arabica Coffee farms in Uganda are well over 50 years old and are producing coffee below their potential. Poor agricultural practices can lead to the deterioration of coffee trees to the point where they require total stumping to enable the rehabilitated tree rejuvenate itself. Figure 25 is an example of a coffee field that urgently needs Rehabilitation and/or Renovation (R & R). It is important that rehabilitation be accompanied by good agricultural practices to prevent the same decline from happening on the selected shoots again. Old coffee trees if totally ignored would continue to produce less and less coffee up to a point when they can no longer be rehabilitated to produce profitable yields and at this point, they can only be replanted through a plantation renovation programme. In such a case, young high yielding seedlings are planted to replace the old unproductive coffee trees.

Figure 25. *An old Arabica Coffee field that is over-due for stumping*

Rehabilitation, therefore, refers to pruning or stumping of coffee trees to rejuvenate and improve their productivity by bringing it back to its youthful, productive cycle. This involves cutting down very old and unproductive stems to enable new shoots to grow in order to renew their production cycle. It is therefore an extremely important activity for the farmer to maintain good income stream from coffee.

On the other hand, renovation refers to complete uprooting of old unproductive trees and re-planting the field afresh with new and high yielding coffee seedlings. Therefore, renovation implies the replacement of old coffee trees with new, young high yielding and/or disease tolerant varieties. Renovation with new disease resistant and climate tolerant varieties can help farmers adapt to the changing climate. Apart from when farmers use poor agricultural practices, rehabilitation and renovation of coffee trees can be mitigating approaches in cases of sporadic attacks by pests and diseases. Renovation may be done in situations where:

- Pests or diseases have irreversibly affected coffee trees and renovation is the only option.
- Superior coffee varieties are availed and yields and resultant incomes associated with such new varieties warrants the renovation investment and compensates for the associated implementation risk;
- Climate forecast models suggest that there will be significant change to the suitability of already existing varieties, even when good agricultural practices are applied.

- Trees produce less and small coffee berries due to old age and where it is not economical to rehabilitate them but better to have fresh replanting of the coffee field.

4.1 Rationale for rehabilitating old coffee trees

Coffee rehabilitation could benefit many smallholder Arabica Coffee farms in Uganda as most of them have trees that have already surpassed the 40-50 year age bracket and are grossly unproductive. The underlying need for rehabilitation should start with understanding some agronomic fundamentals, including soil analysis, root and stem analysis and the variety that is already planted and how well it is intrinsically suited to future needs (e.g. climate change). It is also important to note that the need for rehabilitation may be pre-determined by several other factors, which may include:

- **Age of trees -** trees which are younger(less than 40 years) typically do not need to be replanted but rehabilitated through stumping.
- **Disease -** where by stems of coffee trees are badly damaged/affected by diseases or pests
- **Poor agricultural practices –** such as abandoning coffee under weedy conditions, poor fertility management leading to poor quality trees which must be rejuvenated by stumping.
- **Climate change -** with an increasing level of extreme droughts which requires farmers to adapt by reducing the number of stems per coffee bush to save the trees from complete drying or replant the entire field by the drought tolerant coffee variety.

Once the underlying needs are analysed, the next step is to decide which option delivers best results. There may be scenarios where a mix of renovation and rehabilitation is the best way forward, especially where some parts of the garden may be completely damaged and require renovation, while another part of the garden requires rehabilitation.

4.2 Coffee Stumping practices

Stumping coffee is a practice of selecting and cutting down elderly and unproductive stems existing on a coffee bush. It is done to rejuvenate/renew the stem cycle by enabling the entire tree stump develop young vigorous shoots which make the coffee tree produce more cherries once again. When the coffee tree has reached 10 years old from initial planting, its bearing heads are less than one metre, produce less than 2kgs of fresh cherries per tree and its stems become too tall for coffee pickers, the coffee bush is due for stumping or "change of cycle". After initial stumping, the subsequent production cycles should be renewed (converted) after every 7 years.

Current Arabica Coffee varieties can sustain good yields up to 40-50 years during which productivity is sustained by renewing cropping cycles through stumping. Stumping involves pruning off/cutting back all the unproductive stems from the coffee bush, leaving only one vigorous stem (the breather) for assisting the stumped tree to remain alive and feed the developing suckers until they are mature enough to be on their own as seen in Figure 26.

Figure 26. *Rejuvenation process using a sucker*

4.2.1 Purpose of Coffee Stumping

- Remove unproductive coffee stems and branches.
- To guide the nutrient flow directly to productive areas of the coffee tree, such as flowers and fruit bearing branches.
- Stops development of none fruit-bearing branches

that would unproductively consume water, energy, nutrients and other inputs without meaningful coffee production.

- Remove branches infected with pests and diseases.
- To prevent pests and diseases from spreading.
- Bring back flowering heads to reachable height while harvesting.
- Prevent nutrient transport towards the far ends of the branches which is slower and less efficient in wider canopy; it requires more energy from the plant and thus more fertilizer inputs.
- Open up the canopy for sunlight and 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 other farm management activities.
- Enhance stem and crop survival during drought periods.

4.2.2 The stumping/cycle conversion procedure

i. It is advisable that the farmer stumps the entire garden if it is due. However, he/she may divide the garden into parts and sequence the stumping at different periods to enable continuous income from the coffee farm.

ii. The stems should be cut at a height of 6 inches (0.5ft) from the ground, at 45^0 (degrees) slanting slope to allow water to run off and prevent stump rotting (Figure 27). The cut should be smooth to prevent mould and disease attach.

iii. Cut down other stems and retain one single stem breather. The stem left works as breather and continues feeding the stump until dormant buds open up into grown shoots (suckers).

iv. The stem to be left should be the most out bending (if possible in the direction of the sun set) stem to avoid growing of etiolated and weak suckers. It should also not be in the middle of the stump to enable removing it without damaging the developed suckers at a later stage.

v. Always disinfect the pruning tools using 90% ethanol, 25% diluted Jik or genuine methylated spirit before starting the stumping process, after cutting the previous tree before moving to the next tree and at the end of the day's pruning activity to prevent spread of disease pathogenic agents from one coffee tree to another. Used tools passed over hot burning charcoal also can be used to disinfect the tools. Always keep the pruning saw, bow saw and secateurs oiled to prevent rusting resulting from disinfectants and coffee tree sap.

vi. Select and leave well positioned suckers that will facilitate growth of the tree into the ultimate shape and will allow good room for growth.

vii. When suckers are approximately 20cm (8inches) tall, select 3 or at most 4 healthiest stems and groom them for the next cropping cycle. Suckers that grow at the top of the stump should be removed as these will have weak support in the third year onwards and may easily break off with heavy crop.

Figure 27. *Angle at which the pruning saw is set on the stem to be stumped*

Note: Stumping in which all the stems are cut off without leaving a breather is not recommended because this may result in drying and death of the entire coffee tree stump. In the case of one tree stem, the stem should be cut 3 quarter way and bent off but left to continue feeding the stump till shoots sprout and later cut off when the suckers are well developed and strong enough on their own as seen in Figure 28

Figure 28. *Stumped old coffee tree (full stumping) showing re-growth of suckers*

In a good Arabica Coffee management system, it is recommended that stumping, also referred to as "change of cycle/cycle conversion" takes place initially at 9 or 10 years after planting and thereafter, it should occur every 6-7 years to enable the coffee bush be brought back to a fresh productive stage. The vigor and physical appearance of the coffee trees at the end of the periods recommended above is also influenced by the fertility of the soils and intensity of farm management practices by the farmer.

There are 3 approaches to stumping and 3 types of stumping and these are as explained in Table 12.

Stumping Approaches include;

1. Phased Stumping

Farmers who may not want to lose all their income by stumping the entire garden at once. It is advised to phase the stumping and aim at completing the entire garden over a period of 2-4 years (depending on the size of the garden). Phased stumping involves dividing the coffee farm into different parts and then systematically stumping completely the chosen one at a time. For example a farmer may divide the farm into two or more parts around year 7 and in the first phase, 50% or 25% of the field is systematically stumped. After the first year when the stumped portion starts to bear crop, the second 50% or another 25% of the farm is also systematically stumped. The practice continues until the entire garden is full stumped. The advantages of this system over non phased stumping is that the labour costs are spread over a long period of time hence increasing affordability and the farmer is able to sustain production hence revenue from the coffee farm.

2. Non Phased Stumping

This is where the farmer systematically stumps the entire garden at once. The advantage of this system is that the garden stand is kept uniform and generates a bigger cash flow when the suckers mature and start bearing the crop. However, stumping costs are not spread over a period of time thus becoming expensive to do at once and the field will be out of production and zero revenue from coffee for one year. However, during this period, the coffee can be intercropped with the recommended annual crops, such as leguminous beans for the farmer to continue earning income and also control dominance of weeds due to surface exposure.

3. Staggered Stumping

This involves cutting down only some of the non-productive stems in the coffee garden at the end of every harvesting season. The farmer only stumps a few randomly selected bushes (coffee trees) out of the whole garden and leaves others intact. This approach also has got advantages of spreading labour costs over a long period of time hence increasing affordability and the farmer is able to sustain revenue from the farm.

However, the biggest disadvantage is that the unstumped coffee bushes compromise the quality of suckers on the stumped bushes due to over-shading them, which leads to etiolation, scanty vegetative growth and poor production of those suckers. The stems on the coffee trees will always be of varying stages/age which makes objective planning for fertilizer requirements very difficult.

Table 12. Different types of Stumping

Multiple Breather Stumping

- This involves cutting down only selected non-productive stems on the coffee trees in the coffee garden at the end of every season/year. For instance, 1 out of 3 stems on the coffee trees is stumped each year, implying the entire garden will have multiple stems on the coffee bushes at the end of the stumping period.
- A major drawback of this system is that the stems on the coffee trees will always have an age difference that results in objective planning for fertilizer requirements difficult.
- The resultant suckers (shoots) grow under a lot of shade. This forces them to etiolate in the process of fighting to get sufficient exposure to sun light, thus develop scanty (very few) bearing vegetative branches and very poor crop production. Also as a result of thin stems and tall height, they bend and break easily from wind forces.

Single breather Stumping

- This involves cutting down all the other stems of all coffee trees in the shamba after 7 or 10 years but leaving only one stem per tree, which would act as a breather/mother stem.
- The maintained breather stem keeps supporting the coffee bush through complete physiological processes and also produces some crop which brings revenue for the farmer.
- Later this breather stem is also cut off/removed after 1 year (after harvesting the main season crop carried on the breather), by which time the suckers that were induced will have fully matured to support themselves and will already be giving a crop to the farmer.
- Single breather stumping can be carried out at once in an entire coffee garden even if the farmer has no alternative income. Such stumped coffee fields can also be intercropped with cover crops like beans, groundnuts and peas to earn extra income, control weed growths resulting from surface exposure and to add Nitrogen to the soil and hence improve productivity.
- This type is highly recommended for use by farmers because of its ability to develop good quality and highly productive suckers. It also has minimal risks of stump drying.

Full/Complete Stumping

- This is where all the stems on each coffee tree are cut back without leaving a breather.
- With this type of stumping, the entire stems are removed in one instance or at once. Again the stem should be cut at an angle of 45^0 for the reasons mentioned in the previous section. The cut should be made around 15cm/0.5ft above the ground level.
- The advantage of this system over others is that the developing suckers are fully exposed to sunlight and vegetative growth is intact on the stems, resulting in highly productive future stems. The disadvantage is that the field will be out of production for one year, hence no revenue from the coffee farm and there is also a high risk of stumps drying due to a period of incomplete physiological activity (due to lack of breather) before the shoots re-develop on the stumps.

Stumping in which all the stems are cut without leaving a breather is not recommended because it may result in death of the entire coffee tree stumps.

4.3 Management of Coffee after Stumping

After stumping, a light tillage (preferably using forked hoes) of the soil (not deeper than 10 cm) is recommended to re-instate the balance between roots and above ground matter. Furthermore, it stimulates the formation of new hair roots and loosens the soil that has been compacted over the years, allowing for a leguminous intercrop to flourish. After stumping, an abundant number of suckers may grow from the stump as seen in Figure 29.

The majority of these suckers should be cleanly removed with secateurs before they grow big and hard. Three or a maximum of four vigorous suckers should be selected and left on the stump depending on the objective by the farmer as seen in Figure 30. The suckers selected for future-bearing stems should be well spaced from one another at the base of the stump to enable appropriate vegetative expansion as they grow and also minimize competition for space and light between them. The breather stem should be cut off early enough to as not to shade the underneath suckers to avoid etiolation and poor quality suckers as seen in Figure 31.

Figure 29. *A stumped coffee tree with rejuvenating suckers maintained for multiple stem system after 3-6 months*

Figure 30. *A stumped coffee tree with new (rejuvenating) suckers after 9 months*

Figure 31. *A stumped coffee tree with bearing suckers after 2 years*

4.3.1 Recommendations for 6-7 Year Coffee Pruning Cycle

This is the period when stems are reduced down from three or four to one single stem. Have the coffee farm properly weeded before cutting down the mature stems. This will allow some time for the suckers to grow before any disturbances related to weed control. The one stem left is known as a breather. It keeps the stump alive and also allows the farmer to continue harvesting some coffee. Ensure proper disinfection of tools used for stumping. This is to avoid the transfer of live disease pathogens from one tree to another. As more suckers develop, carry out a frequent and vigorous sucker selection operation for the next six months to 1 year as illustrated in Figure 32.

Figure 32. *A coffee tree with 2 stems removed leaving 1 "breather" stem*

After 1 year, you should have selected 3 vigorous suckers of the same height, good health and those that are well positioned around the stump to act as your future bearing stems as illustrated in Figure 33. During this period the production is mainly from the breather stem and cover crops (if planted). During this period, great attention should be paid to ensure that the breather stem does not shade the suckers and inhibit their growth, resulting in etiolated/poor quality suckers.

Figure 33. *Appearance of stumped trees after cutting off the two stems*

The "breather" stem is also pruned off/cut back after harvesting the crop at the end of year 1 from the time of stumping as illustrated in Figure 34. Suckers will thereafter stand-alone reaching a height of more than 1.5m and start bearing the crop.

Figure 34. *Status and appearance at the end of year 2 after cutting off the two stems*

At the end of year three, the lower-most twigs have exhausted more than 90% of their production area moving from the main stems and should be cut off. The lower primaries continuously become weaker and unproductive and should be progressively pruned off (cut) from the stems as they become unproductive. These primaries have already given a crop and have no future bearing potential. Most of them are drying up and only struggling to bear at the tips. The energy that would be wasted in sustaining the struggling lower primary branches is, when cut off be diverted to more productive branches for optimum utilization and improved yields.

At the end of 4 years, the stems have reached full maturity and it is recommended to maintain them in that state for about 3 more years after which change of cycle is re-started as illustrated in Figure 35.

Figure 35. *Status and appearance of the coffee plant during year 3 – 4 after stumping*

Summary

- Stumping involves cutting/sawing off all the unproductive stems, leaving only one stem breather to assist each of the stump to remain alive and support the suckers to develop.
- Stumping should be done carefully with a smooth cut at an angle of about 45 degrees slanting downwards and facing outside the stump and slopping away from the breather stem to prevent water from collecting and causing disease attack. Smoothening off the stump is therefore a must do.
- Stumping is carried out on older trees, which are not producing well, or have too many long branches and not producing enough large cherries.
- The initial change of cycle in a coffee plantation is recommended to take place every 9-10 years after planting and 6-7 years thereafter to enable the coffee bush to be brought back to a fresh productive stage.
- Single stem stumping ensures that there will be some little crop from the single stem (breather) for the first year after stumping for the farmer to generate income from.
- To avoid loss of income in the first year after stumping, it is advisable for farmers to undertake stumping in a phased manner.
- After stumping, the critical time is between 3-6 months from the time of stumping so that and by end of year 1, the farmer has attained the preferred future bearing stems.

CHAPTER 5

SOIL FERTILITY MANAGEMENT IN ARABICA COFFEE FARMING

5.0 Introduction

For high coffee yields, there is need for adequate and timely supply of both macro and micronutrients to the plant. The nutrients can be supplied from various sources such as inorganic fertilizers or organic fertilizers such as compost manure from plant materials. A fertilization program needs to be developed based on inherent soil characteristics and expected production level.

In a 'closed' environment such as a rainforest, nutrients are recycled on their own and plants are more or less self-sufficient. However, where plants are grown in a commercial environment like Arabic Coffee growing, it is necessary to replenish the nutrients that are removed from the system through the harvested crop. Without additional nutrients in some form of fertilizer, coffee yields will continue to decline as nutrients are removed through the harvested coffee beans.

For sustained productivity, coffee requires a high level of fertility and an intensive fertilizer program is therefore essential. Fertilization can be a means of providing and maintaining optimal quantities and combinations of ingredients into the soil to ensure that the plant is continually nourished. The coffee tree requires certain elements in large quantities such as Nitrogen, Phosphorus and Potassium and these occur in many chemical forms, including organic and inorganic. These elements that are referred to as macronutrients. Other elements are required in very small (micro) quantities but are essential for plant growth include; Zinc, Copper, Magnesium, Calcium, Boron, Iron, Manganese, Molybdenum, Sulphur and Chlorine.

Quantities of macro and micronutrients in the soil and plants are determined through the soil and leaf analysis procedures.

5.1 Soil Analysis

Sampling and analysis of both coffee leaf and soil should be done atleast once every year to determine the current nutrient and pH status of the coffee garden. The results together with expected yield on the trees are then used to determine the fertilizer quantities required for the next application schedule. This is essential for proper and cost effective use of fertilizers as opposed to a blanket application. Farmers are advised to approach extension workers for advice on how to conduct and access soil and leaf testing services.

To help farmers determine the best coffee nutrition practices, soil and leaf analyses are recommended. The objective of soil sampling is to get a representative sample of soil in the plantation block for nutrient analysis. Three samples per hectare block is adequate, provided the three samples are composites from the 20 sites sampled. Soil sampling services are currently available at a fee from the plant, soil and water analytical labouratories at Makerere University and Kawanda Agricultural Research Institute. The following practices are suggested for soil analysis.

- Soil sampling should preferably be done once a year, before flowering. Do not sample after fertilizer application. Do not sample next to shade trees.

- Without scrapping away soil, remove surface litter such as leaves before sampling.
- Using a clean auger, take samples from both the top and sub soil with soil auger or hand hoe and place top-soil and sub soil separately in clean buckets and label them. Clean the auger or hand hoe after sampling each of the sites.
- Sample from a minimum of 20 sites in the middle of coffee rows away from drip lines per hectare block.
- Do not pick samples under shade trees, below coffee tree drip lines, valleys on the farm and from with in a range of 10 metres from animal sleeping places and domestic waste composting pits.

Spread out each sample on a paper bag or plain paper and dry slowly on raised benches under shade and protected from rain. Well aerated rooms can also be used to air dry soil and leaf samples. Samples are usually air dry in four to five days. Once dry, take samples to your nearest soil analysis labouratory.

5.2 Leaf Analysis

The objective of leaf sampling is to get a representative sample of coffee trees for macro and micro nutrient analysis in the plant tissue. Pre-flowering period is preferred sampling time if only one sample is taken each year. More frequent sampling (every four months) is highly desirable for large plantations, especially if nutritional problems occur. Leaf samples from 16 trees per acre can constitute one composite sample made for analysis. A minimum of 100 leaves is needed for each composite sample.

- Sample in the morning where possible when leaves are the most turgid (full of water). Do not sample after any application of foliar fertilizer sprays.
- Using clean hands, remove the 3rd or 4th pair of leaves from the tip of an actively growing branch of average size trees only as shown in Figure 36.
- Do not sample from obviously sick, excessively healthy or odd/unusual coffee trees. Do not pick diseased, injured and insect damaged leaves.
- Sample a minimum of 16 trees per acre diagonally across the block and properly label them.
- Areas of different tree size, age, soil types, fertilizer or other major differences should be treated as separate samples.
- Samples need to be dried at room temperature or under shade and well spread on clean sheets of paper or nylon bags if they are not sent for analysis within one to two days. If sent to the labouratory with in 2 days, leaf sample drying is normally done at the labouratory at 60 to 65°C until they become dry and brittle.
- Store samples at room temperature in paper (not plastic) bags, away from direct sunshine, rains and contamination.

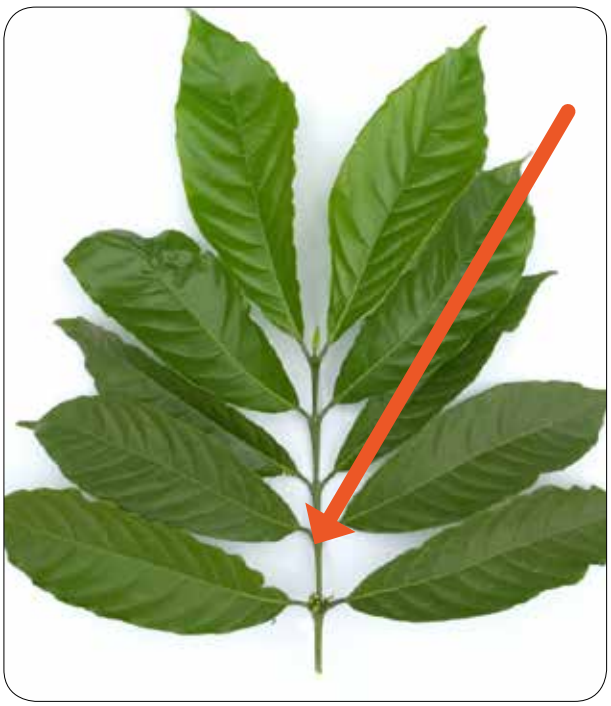


Figure 36. *The position of coffee leaves for sampling*

In addition to soil and leaf testing, nutrient deficiency can be diagnosed by visual appearance of the coffee plant. However, some symptoms such as tip burns, chlorosis or necrosis, which are characteristic of some nutrient deficiencies, may also be as a result of other stress factors such as herbicide scotch, weeds, diseases, pest damage or water stress. For proper diagnosis, a farmer is advised to consult an extension worker.

5.3 Coffee Nutrition

5.3.1 Benefits of fertilizing Arabica Coffee

Arabica Coffee quantity produced per unit area improves significantly when soils are well managed for optimum fertility. Fertilizer application can increase yields of Arabica Coffee under good management from the current average of 1 metric tonne up to 3 metric tonnes of FAQ per hectare per year. In addition, fertilizer application improves plant's resistance to diseases, tolerance to drought and leads to better quality of coffee beans. Therefore continuous soil management for high levels of fertility is key to achieving the best, particularly when combined with other good farm management practices. Plant nutrients are classified into two categories as macronutrients and micronutrients.

5.3.2 Importance of Macronutrients

Macronutrients are nutrients required by the plant in large quantities. They mainly include Nitrogen (N), Phosphorus (P) and Potassium (K).

Nitrogen is necessary for vegetative growth. It increases tree-bearing capacity and enhances coffee bean size.

Phosphorus is necessary for root development, promotion of early berry maturity and increases bean density.

Potassium is necessary for berry development and ripening, enhanced mucilage formation, promotion of healing injured tissue especially after picking, pruning and hailstorm damage and regulation of water uptake from the soil.

A summary of the importance of each macronutrient and their respective deficiency symptoms is highlighted in Table 13.

Table 13. Macronutrients, their functions and deficiency symptoms in coffee

Macronutrient	Use	Deficiency symptoms
Nitrogen (N)	• Plant growth • Photosynthesis • Formation of chlorophyll (green colour) • Water uptake • Formation of enzymes • Formation of hormones	• Slow development of new leaves and shoots • A uniform yellowing over whole leaf or faint yellowing between the leaf veins • Leaves rapidly becoming pale yellow with a dull green sheen • Entire plant becoming pale yellow with sparse vegetative growth • Leaves becoming yellow green at advanced stages • Whitish veins may be present in lower-leaves • Leaf drop (often on dense fruiting branches first) • Discolouration (yellowing) and rolling up of leaves, starting with older ones • Die-back of tips **Symptoms are shown below:**  *Healthy (left) and deficient (right) plants*
Phosphorus (P)	• Root development • Flowering • Cherry ripening • Photosynthesis • Respiration • Formation of Energy compounds	• A uniform yellowing over the whole leaf or light yellowing between the leaf veins • Young leaves remain dark green • Faint yellowing between the veins of older leaves at advanced stages • Dead spots may be present • Stunted growth due to retarded root growth • Pale leaves (starting with younger ones) **Symptoms are shown below:**  *Early signs (left), advanced signs (right)*

Macronutrient	Use	Deficiency symptoms
Potassium (K)	• Fruit quality • Water balance (H_2O gradient pressure) • Disease resistance • Photosynthesis • Berry filling • Cherry ripening	• Discolouring starts from the leaf tips inwards towards the main vein • Localized dead tissue or yellowing between the veins of older leaves • Initial yellowing on the leaf edges followed by development of dead spots • Dead tissue increases until the whole leaf edge is covered • The veins and the midrib remain green • Discolouration • Leaves turn dark black with crooked, necrotic stripes along the leaf margins • Less noticeable in young leaves • Under extreme deficiency, berries and leaves are shed off **Symptoms are shown below:**   *Top; Early signs (left), advanced signs (right) Below; Signs on a whole plant*

5.3.3 Visual nutrient deficiency identification

In addition to soil and leaf testing, nutrient deficiency can be diagnosed by visual appearance of the coffee plant. However, some symptoms such as tip burns, chlorosis or necrosis, which are characteristic of some nutrient deficiencies, may also be as a result of other stresses such as herbicide scotch, weeds, diseases, pest damage or water stress. For proper diagnosis, farmers are advised to consult their extension workers or carry out soil and/or leaf analysis.

5.3.4 Importance of Micronutrients

These are nutrients required by the plant in small quantities. Plant micronutrients include Zinc, Boron, Iron, Sulphur, Magnesium, Calcium Copper, Manganese, Molybdenum and Chlorine

Zinc is re-known for boosting flower initiation and formation, enhanced fruit formation and leaf size and sets the inter-nodal spacing on the branch and the stem.

Boron promotes shoot and root growth, facilitates flower fertilization by enhancing pollen germination through the stigma to the ovary. Consequently, it facilitates optimal flowering and fruit setting, facilitates protein production and regulates uptake of water from the soil together with potassium.

Iron helps in the production of chlorophyll, which is required in food formation, promotes bean colour and together with copper, iron facilitates energy transfer during food manufacture.

Magnesium is major constituent of chlorophyll, which facilitates the making of plant food and enhances bean colour (the bluish green colour of the coffee beans) and initiation of root formation.

Calcium is necessary for growth of terminal buds and flower formation and plays a key role in bark formation. It also facilitates root and apical growth, while directing the overall movements of nutrients uptake.

Sulphur is an important nutrient for plant growth, disease resistance, seed production and protein synthesis.

Manganese helps in photosynthesis and manufacturing enzymes.

Molybdenum helps in Nitrogen metabolism.

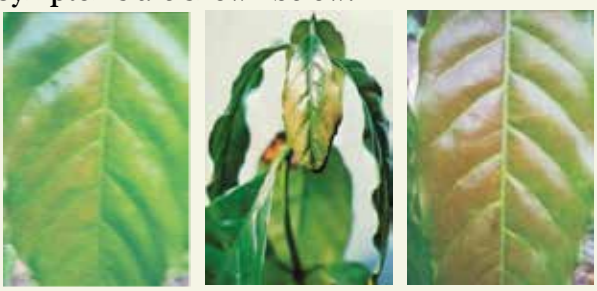
Chlorine helps in photosynthesis, gas exchange and water balance.

A generalized diagram showing the portion of the plant where nutrient deficiency symptoms are first observed are presented in Figure 37.

Figure 37. *Diagram showing levels at which nutrient deficiencies manifest in coffee trees*

The above deficiencies can be corrected by application of fertilizers. Depending on the fertilizer source by which the plant nutrients are extracted, they are classified as either organic or inorganic. A summary of the importance of each micronutrient and their respective deficiency symptoms is given in Tables 14.

Table 14. Micronutrients, their functions and deficiency symptoms in coffee

Micronutrient	Use	Deficiency symptoms
Calcium (Ca)	• Root and leaf development • Fruit ripening and quality • Facilitates uptake of other nutrients • Formation of cell walls • Plant detoxification	• Bronzing, mottling or death of youngest leaves • Die-back of terminal buds • Leaves bronzed along edges, cupped downward • Eventual die-back of shoots • Yellowing of leaves gradually from the centre and outwards **Symptoms are shown below:** 
Magnesium (Mg)	• Chlorophyll formation • Seed germination • Photosynthesis • Produces energy for the plant	• Faint yellowing on leaf edges with sunken, yellow brown to light brown dead spots developing in a wide band along leaf edges • Yellowing between veins evident in affected leaves, particularly along midrib • The main vein turns yellow whereas the leaf veins keep their normal green colour • Brown, bronze discolouration of leaf sections from the centre to the edges **Symptoms are shown below:** 

Micronutrient	Use	Deficiency symptoms
Iron (Fe)	• Catalyst for chlorophyll (green colour) formation • Leaves expanding normally, with vein network remaining green and clearly visible against the light green to yellow green back ground	• Leaves initially develop sharp yellowing between veins of youngest leaves; older leaves unaffected • Background nearly becoming creamy white in acute stages • Severe cases show yellow to bleached white discolouration of green veins **Symptoms are shown below:** 
Zinc (Zn)	• Plant height • Necessary for chlorophyll (green colour) formation • Production of sugars • Component for manufacture of hormones/enzymes	• Leaf deformation starting with young leaves and remain small • 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 • Abnormally short internodes especially in shoots and growing tips • Yellowing/discolouration **Symptoms are shown below:** 

Micronutrient	Use	Deficiency symptoms
Boron (B)	• Development/growth of new shoots and roots • Flowering, fruit settin and development • Germination of pollen • Transport of sugar	• Light green discolouration of youngest leaves, mottled with uneven edges and asymmetric shape • New leaves with dead spots or tips • Stunted growth • Reduced flowering **Symptoms are shown below:**    

Micronutrient	Use	Deficiency symptoms
Manganese (Mn)	• Photosynthesis • Component for manufacture of enzymes	• Yellowing in older and middle leaves • Mottling, striping between veins • Necrotic spotting along main veins **Symptoms are shown below:** 
Sulphur (S)	• Chlorophyll formation • Disease resistance • Seed production • Required to produce energy for the plant • Supports plant transpiration	• Leaves become light green to yellow green with faint yellowing between veins • Leaves become thin; both veins and leave surfaces become yellow Deficient leaves retaining shiny luster Whole plant may show symptoms under severe deficiency **Symptoms are shown below:**  
Copper (Cu)	• Chlorophyll formation • Protein formation	• Young leaves die back • Chlorosis sets in, leaves curl and roll • Shoots are weak and restricted; may be rosseted (Not common if copper based sprays are used in the nursery for controlling *Cercospora* and leaf rust) **Symptoms are shown below;** 

Micronutrient	Use	Deficiency symptoms
Molybdenum (Mo)	• Nitrogen metabolism	• Bright yellow mottling between veins, leaves wither, curl and margins collapse • Leaves get distorted and narrow • Older leaves get affected first • Rare deficiency though **Symptoms are shown below;** 

5.4 Organic Fertilizers

Organic fertilizers are derived from organic plant or animal matter, which comprises of items such as animal droppings e.g. cow dung, chicken droppings/ litter, kitchen compost and plant debris (leaves, grass clippings, vegetable peels). In nature, decomposition of organic matter creates a natural fertilizer. Applying organic compost, animal manure adds nutrient-rich organic material to the soil, improving its quality and texture and reduces dependence on artificial fertilizer products as it improves the physical, chemical and biological composition characteristics of the soil.

Organic fertilizers release nutrients slowly, and only when the soil is warm and moist, which tends to correspond with the plants' times of greatest need. However, they rely on soil organisms to break down organic matter, so nutrients are released more slowly than they are from inorganic fertilizers. This slow-release method reduces the risk of nutrient leaching, but it takes time to supply nutrients to plants. The following organic fertilizers are produced and may be used by smallholder coffee farmers;

5.4.1 Crop residues

Farmers can use crop residues for conserving nutrient stocks by retaining or incorporating crop residues in the field or to use them as livestock fodder and recycle animal manure or to make compost for use in the cropping system. Crop residues as shown in Table 15 contain small amounts of nutrients and as such, the importance of recycling crop residues is to replenish soil organic matter through decomposing mulch. Cycling crop residues through plant residue composting or animals manure improves the availability of nutrients to the plant.

Table 15. Nitrogen, Phosphorus and Potassium concentrations in common crop residues

Nutrient	Dry weight (g/kg)*					
	Millet	Sorghum	Maize	Rice	Soybean	Groundnuts
Nitrogen	4-10	4-9	5-8	4-9	8-13	12-20
Phosphorus	1-1	0-1	0-1	1-2	1-2	1-3
Potassium	15-27	7-15	7-17	13-27	9-18	8-12

**Values do not include leaves, which fall off and are mostly left in the field*

5.4.2 Farmyard manure

Animal or farmyard manures are one of the key sources that increase soil fertility as they are rich in Nitrogen. Chicken or other bird droppings are the best source of stable Nitrogen as presented in Table 16. Additionally, they contain a lot of Phosphate and Calcium. Cattle manure is rich in Nitrogen when it is fresh but when exposed to dry, the Nitrogen evaporates. To avoid Nitrogen evaporation, cow dung manure should be decomposed under covered conditions.

Table 16. Nitrogen, Phosphorus and Potassium values for common Farmyard Manure

Manure	Nitrogen (N) %	Phosphorus (P) %	Potassium (K) (Potash) %
Cow Manure	0.6	0.4	0.5
Horse Manure	0.7	0.3	0.6
Pig Manure	0.8	0.7	0.5
Chicken Manure	1.1	0.8	0.5
Sheep Manure	0.7	0.3	0.9
Rabbit Manure	2.4	1.4	0.6

5.4.3 Compost

Compost is organic matter from plant and farm yard remains that has been decomposed and recycled as a fertilizer. Compost is a key ingredient in organic farming. There are several ways of making compost, based on factors such as availability of organic materials and weather conditions. The process of composting requires making a heap of wet organic matter known as green waste (leaves or food waste) and waiting for the materials to break down into humus after a period of weeks or months. Modern, methodical composting is a multi-step, closely monitored process with measured inputs of water, air and carbon and Nitrogen-rich materials.

The decomposition process is aided by shredding the plant matter, adding water and ensuring proper aeration by regularly turning the mixture. Earth worms, bacteria and fungi further break up the material. Bacteria requiring oxygen to function (aerobic bacteria) and fungi manage the chemical process by converting the inputs into heat, carbon dioxide and ammonium. There are two methods of making compost: Heap composting and pit composting.

Heap composting procedure is outlined below:

- Assemble the first layer of atleast 30cm of rough vegetation such as dry maize stalks or hedge cuttings. Organize the second layer of atleast 10cm thick comprising manure or old compost or slurry and sprinkle some topsoil on top of this layer so that it just covers the material. The next layer of about 15 - 20 cm thick should be made up of green vegetation such as green weeds, grass, hedge cuttings or kitchen waste. If you have wood ash, sprinkle some on top of the green vegetation. If wood ash is not available, use topsoil and use a watering can or any other convenient container to make sure the pit is well watered.

- Repeat the whole process again, starting with rough vegetation then manure or old compost, top soil, green vegetation, ash or soil and finally water again. Repeat this process until the pile is 1-1.5m thick. A well-made pile has almost vertical sides and a flat top. If you have a lot of material to compost, build several smaller piles (about 2m in length). To complete the pile, cover it with a 10cm layer of topsoil. This layer prevents fermentation gases escaping from the pile.

- Ensure enough air circulation, as that would promote rotting rather than composting of the organic material inside the pile. Finally, cover the whole pile with dry vegetation to prevent loss of moisture through evaporation.

- Water the compost occasionally; atleast every 3 days during dry weather conditions (If it is raining there is no need to water). The compost should be kept moist, but not too wet and use a stick to monitor the moisture levels in the pile. To monitor the moisture content, drive a long, pointed stick into the pile. The stick, when removed, will be warm. The stick also helps to check the condition of the pile from time to time. It will show whether the pile is dry or wet.

- After two to three days, decomposition will have started in the pile and this decomposition will start to generate a lot of heat. Use the stick ('thermometer') to ensure that the compost is hot, i.e. the decomposition is in progress by pulling out the stick and checking the lower part for its humidity and warmth (feel with your bare hands). Check the stick regularly, not only for temperature, but also for the presence of a fungus called fire fang. Fire fang destroys the compost pile once the compost becomes dry. Fire fang turns the stick white and if you detect it you should add water immediately. Once there is no more heat generation, the decomposition process is slowing down and it is time to turn the pile.

- Under normal circumstances, the pile should be turned after three weeks. Do not add any fresh material during turning, except water if "fire fang" has developed. Make sure that while turning, the bottom part of the pile ends up on the top. This is necessary because decomposition at the bottom goes slower than at the top. After three more weeks the pile should be turned a second time. The pile should always stay moist but not wet. When the pile has been well looked after and decomposition of all layers has taken place, there is no need for further turning. By now the compost should have a fresh earth smell and no grass, leaves or animal droppings should be visible. Some woody branches or stalks may still be present as they take a long time to decompose. Three weeks after the second turning (six weeks from heaping), the compost should be ready for use. If the planting season is still some time away, leave the pile where it is. Keep it well covered and moist, but not wet.

Figure 38(a) shows the final heap composting product.

Figure 38(a). *A heap composting*

Pit composting procedure on the other hand involves making compost in pits, which have been dug in the ground as outlined below:

1. Dig 3 pits measuring 1.5-2m wide and 1m deep next to each other as shown in Figure 38(b). The best depth for a pit varies according to local soil conditions and the depth of the water table.
2. Compost materials should be placed in the first pit in layers as described below:
   - 10cm of material, which is difficult to decompose (twigs, stalks) at the bottom.
   - Followed by 10cm of material, which is easy to decompose (green and fresh).
   - Followed by 2cm of animal manure (if available).
3. A thin layer of soil from the surface of arable land to obtain the micro-organisms needed for the composting process.
4. Repeat these layers until the heap reaches 1-1.5m high.
5. Cover with grass or leaves (such as banana leaves) to prevent water loss.

6. After 2-3 weeks, all the contents of the pit should be turned over into the second pit and 2 to 3 weeks later, this should be turned into the third pit.

7. As the decomposing material from pit 1 is turned into pit 2, new material, which is ready for composting, can be put into pit 1, thus creating a process of continual compost making.

8. When the compost is ready, but cannot be used straight away, care has to be taken that the compost does not lose its fertility during storage. Compost should never be left uncovered in the rain or in the sun, otherwise the rain can wash out the nutrients and the sun can cause burning and nutrients escape due to evaporation. The compost then loses its fertility. To reduce this loss, the compost should always be covered, with covers such as are banana leaves, intertwined palm leaves or a sheet of plastic.

9. At application, spread the compost to surround the coffee tree atleast 2ft from the plant as shown in Figure 39.

Figure 38(b): *An illustrated procedure for pit composting*

Figure 39. *Fertilizer application around each coffee tree*

5.4.4 Commercial Organic Fertilizers

A wide range of commercial organic fertilizers are currently available to organic farmers. Their use has numerous positive agronomic implications, including the supply of plant macro and micronutrients and organic matter balance.

However, for many available commercial organic fertilizers, the database concerning constituent elements is weak. Commercial organic fertilizers differ widely in nutrient concentration as well as in nutrient spectrum, meaning large differences among the fertilizers in their suitability to complement the nutrient supply by base organic fertilizers like composts, livestock manures or digestates. The advantages and disadvantages of organic fertilizers are highlighted in Table 17.

Table 17. Advantages and disadvantages of organic fertilizers

Advantages
• Can be obtained at a low cost and or easily made by farmers through composting plant and domestic animal wastes available on their farms.
• Organic fertilizers are less likely to burn tender, young plants as they are less concentrated than chemical fertilizers. This partly is because the organic matter contains a lot of water while artificial fertilizers are almost completely dry.
• Organic fertilizers are chemical-free, hence safe, during application and the final commodity (coffee) will be free of noxious chemicals.
• Adding organic fertilizers to the soil increases its ability to hold water and reduces erosion from water and wind
• Nutrients in organic fertilizers are released slowly, which means it is difficult to over fertilize and harm the plants.
• Decreases compaction and crusting of the soil.
• Increases aeration, infiltration, nutrient retention and supplies.
• Stabilizes soil pH and buffers the soil against rapid changes in soil acidity/alkalinity
• Greenhouse gas released into the atmosphere is lower in organic fertilizer production than it is in inorganic fertilizer production.
Disadvantages
• In most organic fertilizers, especially those produced at farm level, there is no indication of the concentration of nutrient(s) and concentrations may vary strongly with the origin of the product and the way it was stored.
• Concentrations of nutrients in organic fertilizers are much less than inorganic fertilizers and do not contain all nutrients required by the coffee trees.
• The release of nutrients is highly variable and reflects the number and degree of microbiological activity, which generally rises and falls with soil temperature.
• Gathering natural materials, such as seaweed, grass clippings and leaves to add to the compost pile is labour-intensive, time-consuming and scarce.
• Organic materials break down at different rates, so the composition and content of organic fertilizers is never consistent.
• Organic fertilizers require very large quantities and are cost prohibitive on a large-scale operation.
• Organic fertilizers can be messy, dirty to handle and may require more labour to apply.

5.5 Inorganic Fertilizers

Inorganic fertilizer usage enables the differentiation between high input and low input coffee farming systems. In a high input system, farmers use optimum levels of inorganic fertilizers to manage soil fertility of their coffee farms to optimise productivity.

Inorganic fertilizer, also referred to as synthetic fertilizer, is manufactured artificially and contains clearly qualified minerals or synthetic chemicals. For example, synthetic Nitrogen fertilizers are typically made from petroleum or natural gas. Phosphorus, potassium, calcium, Magnesium and other trace elements in inorganic fertilizers are often mined from the earth. Inorganic fertilizers can be in form of granular, powder and liquid packaging.

Inorganic fertilizers come in single-nutrient or multi-nutrient formula's. Multi-nutrient formula's include complete and balanced fertilizers, which contain basic nutrients, such as Nitrogen, Phosphorus and Potassium, as well as micronutrients such as calcium, Magnesium, boron and manganese. The percentage of Nitrogen, Phosphorus and Potassium contained in both complete and balanced fertilizers is indicated by three numbers on the package. For example, a 5-10-5 formula is a complete fertilizer, containing 5 percent Nitrogen, 10 percent Phosphorus and 5 percent Potassium. Balanced fertilizers are those that contain equal nutrient amounts, such as a N.P.K 10-10-10 formula.

Balanced inorganic fertilizers, high in all three macronutrients commonly appear in compound fertilizer products of N.P.K 15-15-15. Other compound fertilizer formulations that contain high quantities of one macro nutrient and one micronutrient include ammonium nitrate (carrying N), ammonium sulfate (N and S), potassium chloride/Muriat of Potash (carrying K and Cl), triple super Phosphate (Ca and P) and Magnesium sulfate (Epsom salts) (Mg and S). Compound N.P.K+TE with varying concentrations can also be applied in accordance with deficiency levels to improve levels of both the macro-elements and essential micro-nutrients in the soil.

Inorganic fertilizers provide immediate release of nutrients to plants. However, the concentration of nutrients increases the risk of burning the plant and the rapid release of nutrients may leach them deeply into the soil and water Table where plants cannot access them. The advantages and disadvantages of chemical fertilizers are presented in Table 18. The common inorganic fertilizers and their properties of formulations is presented in Table 19.

Table 18. Advantages and disadvantages of inorganic fertilizers

Advantages
• **They are fast acting:** The nutrients in them dissolve quickly and are immediately available to the coffee plant
• **Predictability and reliability:** Formulations are blended with accuracy and different blends are available for the different phase of the coffee plant i.e. growth/vegetative and reproductive stages
• **The labeling:** amounts of each of the three main ingredients are listed in the order of N-P-K, by percentage, on commercial fertilizer labels as the N-P-K ratio, for instance 12:10:10, 16:6:4, or 10:10:10. Hence commercial formulated fertilizers allow you to know exactly which nutrients you are giving your plants, rather than guessing as the case is with the composition of organic formulae
• Inorganic fertilizers are less bulky, convenient and require less labour to apply compared to organic fertilizers
• Easy to blend to address nutrient deficiency determined through a soil test
Disadvantages
• Most Inorganic fertilizer formulations do not contain micronutrients
• Inorganic fertilizers do not support microbiological life in the soil
• Inorganic fertilizers do not add organic content to the soil
• Inorganic fertilizers are more expensive to access than natural fertilizers
• They may contain ingredients that may be toxic to the skin or respiratory system of labourers doing fertilizer applications. Always use protective wear while applying inorganic fertilizers
• Inorganic fertilizers can build up in the soil, causing long-term imbalances in soil pH and fertility
• They are subject to leaching, a process that occurs when fertilizers are washed away by rain or irrigation water below the level of plant roots
• Inorganic fertilizers can easily be washed away by rain water down the valleys before coffee plants assimilate them

Table 19. The common inorganic fertilizers and their formulations

Fertilizer name	Formulation/content
Urea	46% Nitrogen (N)
Sulphate of Ammonium	21% Nitrogen (N)
Phosphate	16.5% phosphorous (P2 05)
Kali	58% potassium (K2O)
Diammonium Phosphate (DAP)	18% Nitrogen, 46% P2O5(20% is P)
Calcium Ammonium Nitrate (CAN)	21-27% Nitrogen, Nitrate has 13.5% Nitrogen and the Ammoniac group has 13.5 % Nitrogen and 8%Calcium
NPK complete fertilizer	NPK exists in different formulations; 17:17:17, 20:5:5, 10:10:10 and 20:20:20 or can be blended as per soil analysis
ASN	Nitrogen (26%), Sulphur (13%)
ASN with Boron	Nitrogen (26%), Sulphur (13%) and Boron (0.3%)
Single super Phosphate (SSP)	Phosphate (16%), Sulphur and other micronutrients all (12%)
Calcium super Phosphate (CSP)	Phosphate (16%), Calcium and other micronutrients all (12%)
Triple super Phosphate (TSP)	Di-Phosphorus pentoxide P2O5 (46%)

5.5.1 Inorganic Fertilizer Blend for Coffee Trees up to 2 Years

This fertilizer blend has been developed considering the ratio in which the coffee crop takes up nutrients from the soil and it works to replace the same nutrients after every application to ensure the coffee crop receives its "balanced diet" of macro-nutrients of N, P & K as shown in Figure 40(a). This fertilizer blend (indicate the ratios and blend components) is recommended for nursery coffee trees and coffee trees at planting time up to the first 2 years after planting. In addition, farmers are encouraged to apply one basin of organic manure per coffee tree atleast once per year in order to continuously improve the soil structure that will be an enabler for the easier uptake of nutrients by crops. Recommended application rates for this blend are 68 kg for 680 trees per acre for Arabica Coffee (min. 100 grams per tree) per rain season for seedlings in coffee nurseries, coffee trees at planting and up to the first 2 years after planting. This can applied at once or in 2 splits during the rainy season. 10kg bag will cover 100 young trees or seedlings at planting at application rate of minimum 100 grams per tree.

The relevant information on constituent nutrients is usually clearly labelled on the fertilizer pack as shown in Figure 40(b).

5.5.2

This fertilizer blend has been developed, considering the ratio in which the coffee crop takes up nutrients from the soil and it works to replace the same nutrients after every application to ensure the coffee crop receives its "balanced diet" of macro-nutrients of N, P & K. This fertilizer blend 16:2:31 is recommended for coffee trees that are 3 years old and above that are productive. In addition, farmers are encouraged to apply one basin of organic manure atleast once per year in order to continuously improve the soil structure that will be an enabler for the easier uptake of nutrients by the coffee trees. It contains the following basic/straight fertilizers that are blended and packed in 50kg, 25kg & 10kg bags. The recommended application rates are 136 kgs for 680 trees (an acre) for Arabica Coffee (min. 200 grams per tree per rain season). This should be applied atleast in 2 splits during the rainy season. For example, a 10kg bag will cover 50 coffee trees that are 3 years and older (producing coffee) at application rate of minimum 200 grams per tree. A complete fertilizer activity program for Arabica Coffee is presented in Table 20.

Figure 40(a). *Appearance of inorganic fertilizer blend*

Figure 40(b). *Inorganic fertilizer blend label showing formulation of inorganic fertilizers and the packaging*

5.5.3 Foliar Fertilizers

These are formulations of soluble and liquid fertilizers applied on the foliage of the coffee trees to supplement soil-applied fertilizers with the aim of correcting nutrient deficiency and supplementing nutrient availability where soil nutrient uptake is impeded during dry weather or cold spells.

Apply foliar fertilizers when evaporation is low, preferably in the mornings or evenings, when it is not hot.

Table 20. A complete fertilizer activity Program for Arabica Coffee

Application Rate	Fertilizer Type	Application Rate	Role	Amount Required/acre (680 Trees)
100 g/hole	• Lime (if soil pH is <4	100 g/hole	Neutralizing acidity	68Kgs
20L basin well decomposed cattle manure (mix with soil)	• Organic manure	20L basin well decomposed cattle manure (mix with soil)	Improving soil structure	680 basins
60 g/tree	• Single super Phosphate (18-22% P2O5)	60 g/tree	Enhances early root formation and growth, wood and fruit formation	48Kgs
If pH > 5.4 75 g/tree/rain season	• Compound fertilizer: • NPK (25:5:5)	If pH > 5.4 75 g/tree/rain season	Increase vegetative growth	51Kgs
N- deficient 76 g/tree/rain season	• Urea	N- deficient 76 g/tree/rain season	Increase vegetative growth	52Kgs
If pH > 5.4 150 g/tree/rain season	• Compound fertilizer: • NPK (25:5:5	If pH > 5.4 150 g/tree/rain season	Balance vegetative growth and berry production	102Kgs
If Soil PH < 5.4, 250 g/tree/rain season	• Calcium ammonium nitrate (26% N)	If Soil PH < 5.4, 250 g/tree/rain season	1st season (April) for inducing fruit formation & 2nd season for enhancing fruit ripening	170Kgs
Soil PH > 5.4, Use ASN (26 %) at 250 g/tree/rain season	• Ammonium Sulphate nitrate (26% N)	Soil PH > 5.4, Use ASN (26 %) at 250 g/tree/rain season	Increase vegetative growth	170Kgs
250 g/tree/rain season	• Urea	250 g/tree/rain season	Increase vegetative growth	170Kgs
10 Kg/tree/year	• Cattle manure	10 Kg/tree/year	Increase vegetative growth	6.8tons

Application Rate	Fertilizer Type	Application Rate	Role	Amount Required/acre (680 Trees)
A good layer of crop residues be maintained	• Crop residues (maize straw, beans, soya bean)	A good layer of crop residues be maintained	Increase the available food supply for microorganisms resulting in increased biological activity	At least 5 - 15 cm deep is maintained each season
200 g/tree/season	• Murate of potash (62% K2O	200 g/tree/season	For fruit growth & maturation Increased ability to withstand pests & diseases, drought, frost Improves quality (aroma, colour, taste, shelf-life)	136Kgs
250 g/tree/rain season	• NPK 15:2:31	250 g/tree/rain season	Balances vegetative growth and flowering	170Kgs
Soil PH < 5.4, 256g/tree/season	• Calcium ammonium nitrate (26% N)	Soil PH < 5.4, 256g/tree/season	1st season (April) for inducing fruit formation & 2nd season for enhancing fruit ripening	174Kgs
Soil PH > 5.4, 250 g/tree/season ASN	• Ammonium Sulphate nitrate (26% N) OR	Soil PH > 5.4, 250 g/tree/season ASN	Supplies Nitrogen, reduces pH	170Kgs
P -deficient 200 g/tree/year	• Double Super Phosphate (40-49% P2O5)s	P -deficient 200 g/tree/year	Supplies Phosphate Early maturity of berries	136Kgs

5.6 Management and effective use of fertilizer products

There are four best management practices, commonly referred to as the 4Rs or four 'rights' of fertilizer management. These are to apply the right type of nutrient at the right rate, at the right time and in the right place to meet crop demand. These 4Rs help to improve the recovery ratio of fertilizer and therefore contribute to improved agronomic efficiency.

5.6.1 Right fertilizer product

The right fertilizer product means matching the fertilizer and product to the crop's needs and the properties of the soil. Fertilizer can be applied as straight fertilizers that provide one nutrient or compound fertilizers that provide more than one nutrient. It should be noted that compound fertilizers are often more costly than straight fertilizers. The farmer's final choice will therefore be dependant on the local availability and cost of the fertilizer. It is also important to be aware of effect of applying different nutrients to achieve maximum productivity. For example, the application of P and K fertilizer may be required in order to achieve a full response to N fertilizer. Therefore, 'balanced fertilization' is an important aspect in increasing fertilizer usage efficiency.

The choice of fertilizer will further depend on the current and past use of manure, as well as soil properties and climate conditions. For example, where soils have a low buffering capacity (e.g. sandy soils), it would be unwise to use ammonium sulfate as a source of N due to its soil-acidifying potential, while for areas with very heavy rainfall during the cropping season, it is better to avoid nitrate-based fertilizers because they are more prone to leaching than ammonium-based fertilizers such as urea. Before application of any fertilizer, it is important that soil or leaf analysis is undertaken to determine the level of nutrient deficiency.

Not all fertilizer products available on the market are of good quality. If a farmer buys and uses adulterated or poor-quality fertilizer, it will not increase yields as expected because it does not contain the correct amounts of the active ingredients of the required nutrients. For fully soluble fertilizers such as urea, ammonium sulfate, ammonium nitrate, KCl, TSP and DAP, farmers can find out if the fertilizer has been adulterated with sand or brick dust by adding 100g fertilizer to 1 litre of water. Unadulterated fertilizers will dissolve in water, cause a decrease in water temperature and leave only a very small-undissolved carrier residue. Farmers are therefore advised to always buy fertilizers or other agricultural inputs from dealers registered and certified by the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF).

5.6.2 Right fertilizer rate

The right fertilizer rate means matching the amount of fertilizer applied to the crop's needs. Fertilizer rates are site- and crop-system specific and are estimated after considering: the nutrient requirements of the crop; the soil's current capacity to supply the nutrients (measured by carrying out a soil analysis).

A calibrated measure should always be used to apply fertilizer. To apply fertilizers uniformly at the right rate in a large field, uniform measure be used to measure the amount of fertilizer applied to each plant.

Poor responses may be due to fertile soils with large nutrient reserves (often the fields lying close by the farmer's house where fertilizers, animal manures and crop residues have been applied regularly in the past);

Large responses to fertilizer may be obtained on nutrient-deficient but responsive soils (often the fields more distant from the farmer's house where fertilizers, manures and crop residues are not applied).

Very poor responses to fertilizer application may be on degraded soils where fertilizers must be applied in combination with large amounts of organic inputs (crop residues, animal manures) in order to obtain satisfactory responses to mineral fertilizers.

Application of small amounts of fertilizer and/or manure on fertile soils can sustain soil fertility. Resource poor farmers can invest limited cash most effectively by prioritizing fertilizer use in their most responsive fields and using moderate amounts that achieve a large return in yield per kilogram of fertilizer applied. Application of organic resources may be required to rehabilitate non-responsive soils before a response to mineral fertilizer is obtained. In some non-responsive soils the application of organic resources may not result in a response to mineral fertilizers and other techniques may be required (e.g. tillage or application of micronutrients).

Extreme acidic soil pH (below pH5.5) and alkaline soil (above pH 7) can also inhibit the response of the soil to the applied inorganic fertilizers. For extreme acidic soils, calcite or dolomite limes can be used as indicated by the results of soil analysis. And for extreme alkaline soils, fertilizers with acidifying elements such as Ammonia Sulphate, Calcium Ammonium Nitrate should be used to correct the alkalinity levels as recommended from the soil analysis report.

5.6.3 Right fertilizer time

The right time for fertilizer application means making nutrients available when the crop needs them. Nutrients are used most efficiently when their availability is synchronized with crop demand.

Basal fertilizer application is done at or just after planting to supply N, P, K and other nutrients required for early crop growth. Nutrient Nitrogen (N) is highly mobile and easily lost from the soil due to leaching, therefore some fertilizers with Nitrogen (N) should be applied as a 'top dressing' at key stages during crop development, usually when the crop is growing fastest.

Top-dressed fertilizer with Nitrogen (N) can be applied as several split applications to improve fertilizer use efficiency. Top dressings produce good agronomic results;

- If the crop is developing well under favorable climatic conditions and good economic results.
- If high crop prices are expected.

If the crop has developed poorly because of poor rainfall and the price of crop outputs is expected to be low, top dressings can be cancelled and the fertilizer set aside for the next planting season.

5.6.4 Right fertilizer placement

The right placement of fertilizer means applying fertilizer where the crop can optimally access and absorb the nutrients contained in the fertilizer. The choice of application method by the farmer will depend on the estimation of root system area and labour required. But common fertilizer placement methods depend on the form of the fertilizer and they include;

Application of Solid Fertilizers

a). Broadcasting: It refers to spreading fertilizers uniformly all over the coffee field. It is suitable for mature coffee farms because of the dense stand, the roots which permeate the whole volume of the soil area.

Also suitable for applying large doses of fertilizers and when insoluble Phosphate fertilizers such as rock Phosphate are used. Broadcasting of fertilizers in coffee plantations is of two types;

i. Top dressing; It is the broadcasting of fertilizers on the soil surface with the objective of supplying nutrients in readily available form to coffee plants.
ii. Banding of fertilizer around the drip line; It is the broadcasting of the fertilizer in form of a circle on the soil surface below the drip line of the coffee trees/branches.

Disadvantages of broadcasting

i. The weed growth is stimulated all over the field.
ii. Nutrients are wasted in the soil where the root system has not reached.

b). Placement: It refers to the placement of fertilizers in soil at a specific place with reference to the position of the coffee trees and their root system. Placement of fertilizers is normally recommended when the quantity of fertilizers to apply is small, development of the root system is poor, soils have a low level of fertility and when applying Phosphates and potash fertilizers. The most common methods of placement include;

i. Plough placement; In this method, fertilizer is placed at the bottom of the plough furrow in a continuous band during the process of ploughing. Every band is covered as the next furrow is turned. This method is suitable for areas where soil becomes quite dry up to few centimetres below the soil surface and soils having a heavy clay pan just below the plough layer.
ii. Deep placement; It is the placement of inorganic fertilizers in the reduction zone of soil where nutrients remain available to the coffee trees. This method ensures better distribution of fertilizer in the root zone and prevents loss of nutrients by run-off.
iii. Localized placement; It refers to the application of fertilizers into the soil close to the coffee plants in order to supply the nutrients in adequate amounts to the roots of growing plants.

Advantages of placement of fertilizers

i. Utilization of fertilizers by the plants is higher.
ii. Loss of Nitrogen by leaching is reduced.
iii. Being immobile, Phosphates are better utilized when placed.

5.6.5 Nutrient antagonism and competition

This is when excessive amount of one nutrient can suppress the uptake of another, leading to deficiency symptoms of the suppressed nutrient being observed on coffee. For example, excess of potassium can interfere with the uptake of Magnesium. Similarly, excess of manganese or zinc can induce iron deficiency symptoms as presented in Table 21. Farmers therefore need to use results and recommendations from soil analysis to take appropriate corrective action.

Table 21. Nutrient antagonisms

Element in Excess	Nutrient usually affected
Nitrogen	Potassium, Calcium
Potassium	Sodium, Calcium, Magnesium
Phosphorus	Zinc, Iron, Copper
Magnesium	Calcium, Potassium
Iron	Manganese
Manganese	Iron, Molybdenum, Magnesium
Copper	Molybdenum, Iron, Manganese, Zinc
Zinc	Iron, Manganese
Molybdenum	Copper, Iron
Sodium	Potassium, Calcium, Magnesium
Aluminum	Phosphorus
Ammonium	Calcium, Copper
Sulphur	Molybdenum

5.6.6 Soil nutrient availability and limitations to plant growth

It is beneficial for plant growth and health to have all nutrients available in adequate quantities in the soil. However, the overall rate of plant growth and coffee production is dependent on the least available nutrient at a particular time which acts as the immediate constraining factor. This is known as the "Law of the Minimum" and it can be visually explained by the Barrel Analogy shown in Figure 41. The barrel can only hold as much liquid as the shortest plank will allow. In the picture, the shortest plank is Nitrogen showing that the low levels available of this nutrient constrain crop yield even though there are sufficient supplies of other elements such as Sulphur or Magnesium. Should Nitrogen be added, potassium would be the next most limiting factor for production. And when Potassium is added, the next limiting would be Sulphur.

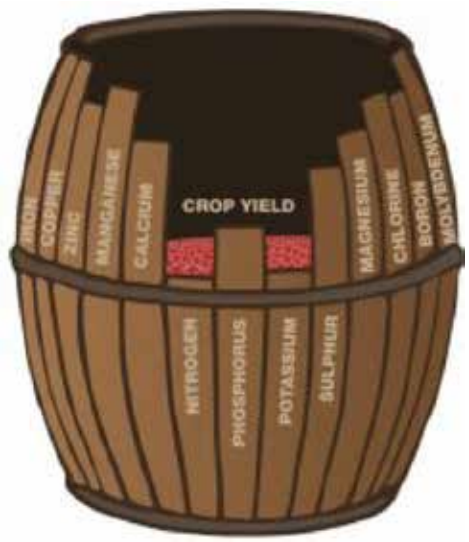


Figure 41. *Barrel analogy*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CHAPTER 6

INSECT PESTS OF ARABICA COFFEE AND THEIR MANAGEMENT

6.0 Introduction

Pests and diseases severely affect the health of Arabica Coffee plants, which further leads into quality deterioration, quantity loss and eventually reduced economic return to the farmer. Successful pest and disease management supplements all other good agricultural practices aimed at growing a healthy crop such as irrigation, fertilization, pruning, soil and water conservation, weed control, shade management. Control strategies against pest and diseases should therefore be based on Integrated Pest Management (IPM). IPM is a coordinated use of pest and environmental information with available pest control methods to prevent unacceptable levels of pest damage by the most economical means and with the least possible hazard to people, property and the environment and the final product (coffee). Insect pests lead to losses either through diminished yield or coffee quality. This chapter provides information and advice on pests of Arabica Coffee and other control.

The major pests in Arabica Coffee growing areas of Uganda include the Coffee stem borers, Antestia bugs, Coffee berry borer, Coffee mealybugs and Coffee lace bugs The minor Arabica Coffee pests include the coffee leaf miners, coffee leaf skeletonisers, tailed caterpillars and scale insects. Although regarded minor, they occasionally cause severe damage.

6.1 Yellow and White coffee stem borers

6.1.1 Description

The yellow stem borer *(Apate monachus)* are wood-boring beetles (Figure 42) measuring 1 – 2cm long and are mainly found in South Western Uganda especially at higher altitude (above 1,500m above sea level). The life cycle of both pests is completed during the rainy season, but often damage is more evident during the dry season. Larvae remain inside the coffee stem and are normally not seen. Usually damage is not economically important, although sometimes individual trees can be lost. There are two species of stem borers present in Uganda i.e. white and yellow-headed stem borer. The white stem borer *(Bixadus sierricola)* is particularly severe on Arabica Coffee at lower altitudes (below 1,500m above sea level..

Figure 42. *Adult white stem borer*

6.1.2 Damage symptoms

The yellow stemborer colonizes a single or group of trees and is capable of doing extensive damage on the coffee

stems by boring or tunneling holes into coffee stems (Figure 43). The presence of wood shavings pushed out of the tunnels is an indicator of attack. They may tunnel down for up to 20 cm into the roots and as much as one meter up into the main stem, causing extensive damage to the lower part of the trunk and the root system including wilting and yellowing of leaves.

Figure 43. *Round tunnel holes in the stem made by stemborers*

Most damage is done by the larvae, which bore into the trunk and roots, exuding woody shavings from its burrows. Attacked stem breaks easily and young trees up to two years old are frequently killed. Older trees wilt and the foliage becomes chlorotic. If they survive, yields are much reduced and the trees are prone to infection by *Fuzarium stilboides*, which causes further wilting of leaves and dead trees or branches. Less damage also occurs under conditions of good shade.

6.1.3 Control

The white stem borer has become particularly hard to control since the withdrawal of Dieldrin and Aldrin in the market. Farmers now use cotton wool dipped in Fenitrothion, Cypermethrin and stuff it the entry holes tunnels to kill larvae. Stem borers can also be controlled culturally by pushing a bicycle spoke or a wire into the tunnel to stab and kill the larvae. Other cultural control efforts include smoothening (covering) tree bark up to 0.5 m with banana fibers or maize cob strands helps to prevent it from laying eggs. Trees may also be banded with a recommended insecticide using a brush from collar to a height of 0.5m to discourage egg laying. Also affected trees may be uprooted and carefully burnt affected trees or branches with borers inside.

6.2 Antestia bugs

6.2.1 Description

Antestia bugs *(Antestiopsis lineaticollis)* are brown or bronze insects with yellow orange patterns (Figure 44). They cause damage through sucking sap from flower buds, flowers, berries, leaves and soft stems. This results into flower and berry abortion, cracking (zebra marks) and rotting of beans, multiple branching and shortening of internodes.

Figure 44. *Antestia bug*

6.2.2 Damage symptoms

Heavily attacked coffee stems show multiple branching (witches broom) with shortening of internodes. A common symptom is flower and berry abortion. In a ripe coffee stand it causes rotting of beans and a good deal of berry shedding. When the fruit is pulped, there is no bean or badly shaped beans. The bugs are so ferocious that two or three on a tree can wipe out the berries. In wet processed coffee zebra black streaks can be seen on the bean parchments.

6.2.3 Control

Cultural control measures can keep Antestia bug populations in check. Coffee bushes should be kept open by regular de-suckering and pruning to make them unsuitable habitats for the pest and suitable for the natural enemy. Farmers can also physically collect the bugs and kill them.

Chemical control should be the last resort when the average population (adults and nymphs) exceed two on a

tree in the drier areas and one per tree in the wetter areas. Therefore, monitor the populations of the pest and when 2 bugs per tree are observed, start chemical spraying. Use Fenitrothion (50%) EC at a rate of 70ml/20 litres water.

6.3 Coffee Berry Borer

6.3.1 Description

The Coffee Berry Borer (CBB) *Hypothenemus hampei* (Ferrari) is one of the most devastating pests of Arabica Coffee causing damage ranging from 50% to 100% yield loss. They are small beetles that borer into coffee berries, damaging the beans thus lowering quality. The adult is a small black beetle (about 2.5 mm long) and covered in thick hairs (Figure 45). The female beetle bores into cherries through the navel region of the green or red berries. Immature berries can shed off when attacked. The beetles in cherries on plant or ground can survive up to 5 months.

Figure 45. *Coffee Berry Borer*

6.3.2 Damage symptoms

The adult female beetle attacks coffee cherries at various stages of development and lays about 15 eggs in the beans. The eggs hatch in about 10 days and the larvae tunnel into the beans to feed causing premature shedding of green cherries. Cherries that do not drop often have defective, damaged beans (Figure 46).

Figure 46. *Coffee berry borer beetle on a bean and damage inflicted*

6.3.3 Control

An integrated pest management strategy is used against the coffee berry borer. The principal tactics are cultural and biological control, use of traps baited with attractants and chemical control with systemic insecticides.

The main cultural control measure includes the pruning of coffee and shade trees to expose the beetle to its natural enemies. Also the regular picking of ripe cherries (atleast every 2 weeks) can be effective in controlling the pest. Hygiene through the keeping coffee field clean and removing dropped cherries – identifying the source of infestation is very important. Farmers are advised to bury all fallen berries in the ground. Overripe cherries on the ground and old berries remaining on the trees are a source of new infection and such infected berries should be stripped and burned. Shaded coffee trees attract a higher number of birds, which have been shown to reduce coffee berry borer levels.

Chemical control of the beetle can be achieved thorough the use of Fenitrothion 50% at a rate of 6ml per litre of water applied at early fruit set (2mm cherry sizes) and later 120-150 days after fruit set if required. Farmers can also use Cypermetrin, Deltametrin, Pyrethroids or Chlorpyrifos at recommended rate as indicated on label and to strictly follow safe chemical use procedures.

The use of certain **biological control** agents such as parasitoids, predators, nematodes and fungal entomo-pathogens where feasible have also been found to be effective.

6.4 Coffee mealybugs

6.4.1 Description

Coffee mealybugs *(Planococcus spp.)* are small sucking insects (about 3mm long) found mainly in Arabica Coffee but also important in Robusta. There are several species similar in appearance to the naked eye. They usually form a mass of many insects identifiable by a white mealy wax cover (Figure 47).

Figure 47. *Large white coffee mealybug*

6.4.2 Damage symptoms

They are generally more of a problem in the dry season when water is lacking. They feed by sucking sap from young shoots and leaves, flower buds, green and red berries as well as roots resulting into yellowing and defoliation of the plants (Figure 48, 49, 50 and 51).

Figure 48. *Coffee mealybug infestation on young shoots/ leaves*

Figure 49. *Coffee mealybug infestation on green coffee cherries*

Figure 50. *Coffee mealybug infestation on ripe coffee cherries*

Figure 51. *Appearance of root mealybug infestation*

Parts of the coffee plant attacked by mealybugs show white waxy colonies usually on the underside of tender leaves and in soft stem areas around cherries. Also, they are found on young roots near the main root, especially where soil is loose around the trunk.

While sucking, they produce honeydew (excreta), which attracts attendant ants that protect them from natural enemies. The honeydew in turn attracts growth of black fungal moulds, which causes unsightly appearance of attacked parts of the coffee (Figure 52). Severe mealybug damage causes ultimately death of the coffee plant.

Figure 52. *The black moulds on coffee leaves following mealybug infestation*

6.4.3 Control

Control of mealybugs can be achieved using cultural control techniques through the pruning of badly damaged suckers and branches or replacing dead trees. This can be an effective solution on a small-scale coffee shamba. Farmers may also apply oils such as vegetable oils, neem oil or mineral oils or soapy solutions (1 to 2%) to kill mealybugs by suffocation. The use of soapy water or oils as a control measure is preferably done during cool and non-sunny periods to prevent discolouration of leaves. Prior extensive application however, it is important to run a test by applying to a branch and after 48 hours check for adverse reactions of the coffee plant.

The use of chemical pesticides however is however fairly effective in prevent ants assessing the bugs and allow natural enemies to control the mealybugs. This can be achieved through tree banding using 20cm wide plastic sheets covered with a sticky substance mixed with insecticides such as Chlorpyrifos, Sumithion and Carbaryl. The farmer can also spray these pesticides on the soil around the tree to kill ants as they disrupt the natural enemies of the mealybugs. It is however important to note that serious infestations of mealybugs have been reported where there has been use of insecticide sprays, especially the highly toxic organoPhosphate sprays which kill almost all insects, including natural enemies of mealybugs. Also care should be taken when mixing pesticides because they are toxic. Apply according to label recommendations and strictly follow safe chemical use procedures.

The use of biological control as a tactic to control mealybugs is feasible and normally sufficient through the action of predator and parasitic insects. The most recognized predator of the mealybug is a ladybird *Cryptolaemus montrouzieri*, a reddish brown beetle about 4mm in length with black wings and which feeds on the mealybugs (Figure 53). The lacewing insect *Oligochrysa lutea* is also an effective predator of the mealybug. Mealybugs are also naturally controlled by parasitic wasps *Leptmastix dactylopii and Anagyrus kivuensis, which lay their eggs in the mealybug resulting in death of the mealybug.*

Figure 53. *Ladybird adult feeding on coffee mealybugs*

6.5 Coffee lacebug

6.5.1 Description

Coffee lacebug (*Habrochila spp*) are small fly-like insects with a light green colour and lacewings (Figure 54) that mainly attacks Arabica Coffee. The bugs suck underside of leaves, leaving shiny black droppings and brown feeding marks.

Figure 54. *Coffee lacebug*

6.5.2 Damage symptoms

Lace bug causes yellowing of leaves that die progressively from margin to mid-rib defoliation, berry abortion and die-back. Attacks are more severe in dry season but disappear with onset of rains.

6.5.3 Control

Ensuring proper plant nutrition such as use of fertilizers or manures can control coffee lacebug infestation. If infestation is heavy, a spray regime with a recommended insecticide is effective.

6.6 Coffee Leaf Miner

6.6.1 Description

Coffee leaf miners *Leucoptera caffeina* (Washbour) are larvae that bore into the leaf and feed on the leaf tissues between the lower and upper surfaces. If the mines are open, the caterpillars can be seen. Feeding causes brown irregular blotches on the leaf leading to premature shedding of leaves.

6.6.2 Damage symptoms

Coffee leaves infested with coffee leaf miner are recognized by the presence of large, irregular, brown spots on the upper surface of the leaf (Figure 55). Rubbing the spot, or bending the leaf across the spot, results in the separation of the upper epidermis and the exposure, in fresh mines, of small white caterpillars. Mined leaves are usually shed prematurely.

Figure 55. *Symptoms of coffee leaf miner*

6.6.3 Control

Leaf miners can be managed by spraying coffee trees with a recommended insecticide. Control is usually achieved by spraying when the caterpillars are still small and are in large numbers, using Fenitrothion 50% E.C. at 70ml/20L water or Pyrinex 1ml/1L water. It is best to spray when population of 30 moths per tree is sited. Strictly follow safe chemical use procedures.

6.7 Coffee Leaf Skeletonizer

6.7.1 Description

Coffee leaf skeletonizer *(Leucoplema dohertyi* warr) is a minor pest in both Arabica and Robusta coffee. Attacks in the field are usually minor but serious outbreaks may occur in coffee nurseries.

6.7.2 Damage symptoms

Coffee leaf skeletonizer larvae feed on leaf upper surface leaving veins and epidermis thereby creating a 'window' (Figure 56). The caterpillars may also feed on the under surfaces of leaves, usually close to the mid-rib. They eat up all the leaf tissues leaving only the naked main veins and upper epidermis, resulting in irregular patches on the leaves.

Figure 56. *Symptoms of coffee leaf skeletoniser*

6.7.3 Control

Coffee leaf skeletonizer larvae can be managed by spraying with a recommended insecticide. Spraying should be done when the caterpillars are still small and are in large numbers, using Fenitrothion 50% E.C. (70ml/20 litres water) or Pyrinex (1ml/litre water).

6.8 Tailed caterpillar

6.8.1 Description

The tailed caterpillar *Epicampoptera andersoni,* as seen in Figure 57, is a minor insect pest of Arabica Coffee whose adult is a small moth. The moth lays eggs, which later become caterpillars.

Figure 57. *Tailed caterpillar damage on coffee leaves*

6.8.2 Damage symptoms

When these caterpillars occur in large numbers especially in coffee nurseries, they cause massive defoliation of coffee leaves. The caterpillars usually feed on leaf lamina, thereby causing serious defoliation as seen in Figure 58.

The caterpillars feed on the under surface of the leaf, about half way between the mid-rib and the edge, leaving the upper surface intact. The older caterpillars, however, feed at the leaf margin, sometimes devouring everything except the mid-rib.

The pest has also been recorded on other plant species like the *Markhamia lutea* (Musambya), Guava fruit trees and *Albizia coriaria* (Mugavu).

Figure 58. *A tailed caterpillar on coffee*

6.8.3 Control

In a small number of plants, the pupae can be collected by hand and destroyed. Spraying should be done when the caterpillars are still small and are in large numbers, using Fenitrothion 50% E.C. (70ml/20 litres water) or Pyrinex (1ml/litre water).

CHAPTER 7

DISEASES OF ARABICA COFFEE AND THEIR MANAGEMENT

7.0 Introduction

Presence of a disease in Arabica Coffee may result in reduced growth, yield and quality. In some cases, diseases may lead to death of plants on a large scale or few plants within the field. Arabica Coffee diseases may be fungal or bacterial nature. Under favourable conditions, such diseases may cause serious damage to the coffee crop. The common diseases affecting Arabica Coffee in Uganda include the Coffee leaf rust; the Coffee berry disease, the Red blister disease and the Root rot disease.

7.1 Coffee Leaf Rust

7.1.1 Description

Coffee leaf rust is a leaf disease caused by the fungus *Hemileia vastatrix*. The disease occurs in Arabica districts in Uganda which are found between 1000 – 1500m above sea level. The severity of coffee leaf rust on Arabica Coffee varies from one cultivar to another. Some Arabica cultivars are more susceptible than others. Wind, rain splash, insects and humans are the main agents of spread of spores. Infected seedlings/cuttings can also spread the disease in new fields or locations. Infected leaves, which remain, on the trees provide sources of infection when the rains begin and the fungus also becomes active. New leaves, which are formed, become infected and the disease cycle is repeated.

7.1.2 Disease symptoms

The first symptoms are pale yellow spots on the lower leaf surfaces. The spots enlarge and produce spores which are orange (rust) in colour as seen in Figure 59. Old parts of the lesions become necrotic and turn brown.

Figure 59. *Coffee leaf rust symptoms on coffee leaves*

Severe attack of the disease results in increased presence of the rust on the leaf, as seen in Figure 60, leading to premature leaf fall, as seen in Figure 61, loss of photosynthetic surfaces and reduced yield.

Figure 60. *A lower side of coffee leaf heavily attacked by coffee leaf rust*

As the disease intensifies, the plant resorts to stored carbohydrates in the roots to sustain developing berries.

This leads to loss of fine feeder roots. Repeated attacks of leaf rust leads to slow decline of the coffee bush as well as reduced yield. Expanding berries fail to fill up due to lack of required nutrients and young berries are shed-off.

Figure 61. *A heavily defoliated coffee tree as a result of coffee leaf rust*

7.1.3 Control

Coffee leaf rust can be managed by good field management practices starting with proper field preparation, use of resistant/tolerant varieties from recommended nurseries, cultural practices such as proper pruning and weeding. It is important to note that well-managed Arabica Coffee does not easily succumb to leaf rust.

However, where coffee leaf rust attacks are evident, it can be managed primarily through application of chemical pesticides or fungicides. A commercial fungicide Orius is an effective pesticide on rust infected Arabica Coffee. Other fungicides especially the copper based fungicides applied weekly starting at beginning of rainy season are very effective. A tank mixture comprising copper (5 kg of 50% WP Copper oxychloride) plus half rate organic fungicide (e.g. 2 kg of Chlorothalonil 75% WP), is also suitable for controlling coffee leaf rust. If however 20% or more of the leaves are affected, the use of a systemic fungicide such as Triazole or Bayleton 25% EC, containing Triademefon, is recommended.

The timing of fungicide application is critical for controlling coffee leaf rust, with maximum effect being achieved through application before the start and during the early period of the rainy season. It is important that the fungicide is re-applied should the previous application be washed off by rainfall. The primary aim of fungicide application is to protect the underside of the leaves, where the fungus is most likely to penetrate the plant at times when conditions are favourable for disease development. Such protection usually requires regular applications throughout the rainy season. Chemical control however may not be economical for small-scale farmers and it may not be recommended in the case of minor infection on Arabica Coffee.

There are no commercial bio-control strategies for controlling coffee leaf rust. However, fungal parasites such as *Verticillium lecanii* and a number of *Darluca species*, occur on coffee leaf rust pustules in coffee fields. Although their effect on disease development is not clear they may be of some benefit. Some insects and mites also feed on the rust spores but again are not used purposefully for coffee leaf rust control.

7.2 Coffee Berry Disease

7.2.1 Description

Coffee berry disease (CBD) *(Colletotrichum kahawae)* is the most important disease in Arabica Coffee grown at higher altitudes in Uganda (over 1,600 m above sea level). Infected berries are the most important sources of inoculum and are most severe during wet seasons. The spores are spread by rain during showers, when spores are washed down from infected berries and bark at the top of the tree to infect berries further down. In addition rain-splash can transmit spores to adjacent trees when droplets fall into small pools of water on the ground or on the plant.

7.2.2 Symptoms

Coffee berry disease attacks the berries, at all stages of the crop from flower to ripe berry. Most damage is inflicted when young, expanding berries are infected, which are mostly shed-off once they become diseased. If the infection reaches the beans, they become black and distorted and are unmarketable. Small dark sunken spots expand to become large sunken lesions as shown in Figure 62. There is also flower and leaf defoliation and berries become mummified.

Figure 62. *Typical dark sunken lesions and 'active' lesions of CBD on green coffee berries.*

7.2.3 Control

The disease can be kept at bay by the use of resistant planting varieties. In case of significant attacks however, the disease can be managed by maintaining healthy coffee plants through pruning or stumping practices. Coffee in shaded stands has also been associated with reduced attacks. Shades moderate temperature and relative humidity, which are the major factors for coffee berry disease development and progression. The use of copper-based fungicides such as Theobendazoles, Tebuconazoles and Copper Nordox 75% EC has been seen to result in effective control of the coffee berry disease.

7.3 Red Blister Disease

7.3.1 Description

Red blister disease, *Cercospora caffeicola* is a serious, widespread and similar to coffee berry disease on the old traditional seedling of Arabica Coffee. The disease has been recorded only in Uganda and Bukoba area in Tanzania. It occurs in both Robusta and Arabica Coffee grown in the low land areas.

7.3.2 Disease symptoms

The disease symptoms include small red and slightly raised spots on both green and ripening cherries. The spots enlarge and join forming unsightly red blisters as seen in Figure 63. The centres of the lesions dry up and turn black. Infected dry cherries do not pulp properly which lead to loss of quality.

Figure 63. *Arabica Coffee berries infected with red blister disease*

7.3.3 Control

Effective control is achieved through the use of tolerant/resistant varieties a*nd* use of good soil fertility management plan by adding NPK or organic manure. Also maintain proper pruning, proper plant spacing and destroy infected coffee debris. Growing coffee under shade, (atleast 50% shade cover) also discourages the disease. Chemical control is not necessary if good management is employed.

7.4 Root Rot or Collar Crack Disease

7.4.1 Description

Root rot or collar crack disease *Armillaria mellea* can be a serious disease in various localities, especially in coffee planted on land cleared from forest. The fungus attacks many forest trees and other tree crops besides coffee. The disease is spread from one tree to another by root contact. Infection of a root system does not immediately result in the appearance of symptoms on the aerial part. These only begin to show when the collar is attacked or when several large roots are destroyed.

7.4.2 Disease Symptoms

The main symptoms are initially, a reduction of shoot growth, changes in foliage characteristics (foliage becomes stunted, chlorotic and sparse). The leaves can wilt (on fruit trees), fall prematurely or show abnormal colourations. (All foliage can turn yellow or sometimes brown). Affected trees slowly decline in production. Leaves turn yellow, followed by wilting and eventual death of leaves, branches and the whole tree. The root, white mycelial growth of the fungus can be seen. At an advanced stage of the disease, the wood of the affected tree is decomposed into a white wet mass with characteristic black lines running through the tissue. Vertical cracks may occur at the base of the stem, hence the name collar crack. The leaves can wilt (on fruit trees), fall prematurely or show abnormal colourations. (All foliage can turn yellow or sometimes brown).

7.4.3 Control

Control can be achieved through ring barking trees prior to felling which is the removal of the bark of the undesired forest coffee trees. This has the effect of depleting the carbohydrate reserves in the root system. The fungus *(Armillaria)* cannot grow in roots deprived of carbohydrates. Ring barking should be done by correctly by completely removing the bark, and letting the tree to dry slowly, at least one year before it is felled down. The removal of the bark prevents downward movement of carbohydrates to the root system. The tree continues to live using the reserves in the roots, which get exhausted - and the tree dies, together with the fungus. The aim of ring barking is to exhaust the reserves in the roots, which may take one to two years. By this time the top of the tree would be dead and felling of the trees can be done. The stump and as much as possible the whole root system should be removed and burnt after the trees have been felled. Replanting on the site should be delayed for atleast 2 years. Chemical control can be achieved by drenching with copper fungicide to reduce infection of future transplants. Copper oxychloride in a mixture of 150gm/ in 20L water may be applied.

CHAPTER 8

ARABICA COFFEE HARVEST AND POST-HARVEST HANDLING PRACTICES

8.0 Introduction

Harvesting is one of the critical steps within the coffee value chain where quality of coffee can be either compromised or maintained. The best quality coffee is obtained from "selective picking of red ripe cherries" and this is recommended for all coffee farmers. Selective picking is the best way to ensure cup quality.

Well-harvested coffee maintains quality and attracts better prices on the market. Selective picking of coffee maximizes the amount of ripe coffee harvested, as the unripe green beans are left to mature and harvested later in the season. Table 22 summarizes factors affecting Arabica Coffee quality and potential problem of at various process stages of handling.

Table 22. Factors affecting quality of Arabica Coffee at harvest and post harvest level

Process step	Factors reducing quality	Potential problem
Harvesting cherry	• Harvesting green cherry	• Green or grassy flavour or woody
	• Harvesting over-ripe cherry	• Fermented or fruity flavor
	• Picking fallen old cherry from the ground	• Fermented or fruity flavors. • Mould contamination producing mouldy or musty flavors
Pulping cherry	• Hold fresh cherry for long periods before pulping	• Fermented or fruity flavors
	• Poor quality pulping equipment or poorly adjusted equipment	• Nipped beans causing stinker beans
Fermentation	• Over-fermentation	• Fermented, fruity, sour or onion flavor
	• Poor hygiene in fermentation tanks leaving a small number of extremely over fermented beans	• Stinker beans producing foul rotted or sour flavors
Washing	• Poor washing leaving mucilage on parchment	• Mould growth producing mouldy or musty flavors
Drying of parchment	• Contaminated by drying on the ground or dirty drying surfaces	• Earthy flavors. Mould contamination producing mouldy or musty flavors
	• Stored partially dry for long periods or rewet during drying	• Mould growth producing mouldy or musty flavors
	• Machine drying too fast, too hot, or uneven	• Poor, mottled or faded colour, dull or bland flavor
	• Coffee is over-dried	• Poor, faded bean colour. Damages easily during hulling

Process step	Factors reducing quality	Potential problem
Storing dried parchment	• Stored dried parchment too wet	• Mould growth producing mouldy or musty flavors
	• Stored near fuels or chemicals	• Contaminated with foul odours
Hulling dry parchment	• Incorrect huller setting	• Bean damage
	• Coffee too dry	• Bean damage
Storing hulled green bean	• Storing too wet	• Mould growth producing and mouldy or musty flavors
	• Stored near fuels or chemicals	• Contaminate with foul odours
	• Stored in jute bags made on machinery lubricated by petroleum oils	• Contaminated with baggy or oily taints
	• Stored in hot humid condition for long periods	• Mould growth producing mouldy or musty flavors. Surface oxidation of beans causing woody flavors. Faded bean colour.
Transport	• Rewetting of coffee due to leaky tarpaulins or containers	• Mould growth producing mouldy or musty flavors
	• Stored near fuels or, chemicals	• Contaminated with foul odours during storage

8.1 Arabica Coffee harvesting best practices

In order to harvest Arabica Coffee properly, farmers must stick to the following harvesting quality controls:

- Selectively pick red ripe cherries in successive picking rounds. Ripe red cherries are selectively picked by hand as shown in Figure 64.
- Clean containers should be used while harvesting in order to avoid contamination and development of moulds.
- Have a clean tarpaulin or hessian square under the coffee tree while harvesting. This will help the farmer to separate qualities of coffee that have found fallen on the ground from that are freshly harvested. Secondly, in case of rain, farmers can gather the harvested coffee quickly.
- Avoid harvesting over- ripe cherries. The delay to harvest is normally done intentionally to have most of the coffee ripen. However in the process some coffee becomes overripe. Therefore, delays between harvesting of cherries and drying must be kept at minimal. When coffee over ripens on the tree, fermentation takes place.
- Avoid picking coffee from the ground and mixing it with freshly harvested coffee. Coffee cherries should not be left to fall on the ground. Cherries picked from the ground may be contaminated with Ochratoxin A (OTA) producing mould.
- Immediately after harvesting, remove leaves, twigs and unripe cherries.
- Do not pick green, immature cherries. Picking green immature cherries leads to quality deterioration and loss of income due to a lot of unripe or underdeveloped beans and poor cup quality of the final product – hence poor prices.

Figure 64. *Selectively hand harvested red ripe Arabica Coffee cherries*

8.2 Why strip picking of coffee is not a recommended harvesting practice

Coffee varieties grown in Uganda do not ripen uniformly, prompting some farmers to harvest it by strip picking as shown in Figure 64. Farmers must avoid strip picking of coffee at all times. In addition to poor quality, the process of stripping coffee results into leaves being broken, coffee bearing loci are destroyed and parts of the primary branches damaged leading to reduced yields in the subsequent season. Strip picking of coffee, therefore, must be avoided due to following reasons:

- Stripping introduces cherries, that are green and still immature, insect damaged or overripe into a coffee sample.
- Over-ripe cherries have a negative impact on the cup quality due to fermentation while unripe and diseased cherries are also main causes of black beans. Black beans have a negative impact on the cup quality.
- Stripping interferes with the development of intrinsic factors of the coffee beans, which affects the coffee quality/density/weight/income.

Figure 65. *Appearance of strip picked Arabica Coffee cherries*

8.4 Arabica Coffee harvest seasons

Two harvest seasons exist in Uganda for Arabica Coffee harvesting. These are the main harvest season and the minor season (fly harvest season). Table 23 shows the Arabica harvest seasons by region in Uganda.

Table 23. Arabica Coffee harvest seasons by region

Region	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep
Bugisu	X	Main crop Arabica			X	X	X	Fly crop Arabica			X	X
Kapchorwa	X	X			X		X	X				
Kasese	Main crop Arabica				X	X	Fly crop Arabica				X	X
West Nile	Main crop Arabica				X	X	Fly crop Arabica				X	X
Kigezi	Main crop Arabica						X	X Fly crop Arabica				

8.3 Arabica Coffee post-harvest handling and processing

Proper Arabica Coffee post-harvest handling and processing is important because it sustains bean quality, adds value and ensures better prices to growers. Two methods for Arabica Coffee processing exist. These are dry processing and wet processing. The major difference between wet and dry processing is how the fresh cherry is treated.

8.4.1 Wet processing

Wet processing is more complex than dry processing, requiring specific equipment and the availability of large quantities of clean water. Green coffee produced in this way is usually of better quality and commands higher prices. Two methods exist and they include a) Full wash and b) Semi-wash process (Figure 66).

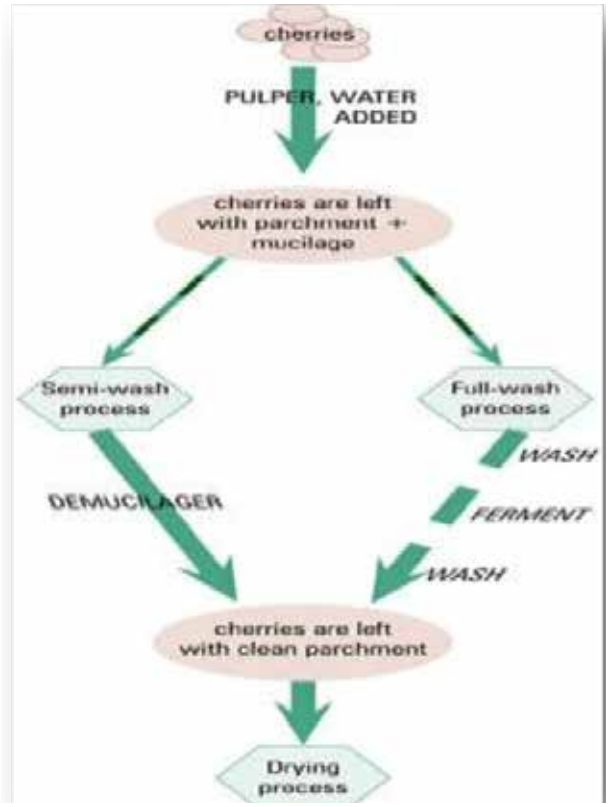

Figure 66. *Diagrammatic presentation of the wet processing methods*

In the full wash process the skin of fresh cherry is physically removed using a manual or powered pulping machine with addition of water as shown in Figure 67. The sugar coating (mucilage) on the resultant parchment is allowed to ferment over one to two days and then the parchment is washed thoroughly to remove all traces of fermented mucilage. The parchment is dried until the bean inside reaches 12%-13% moisture content. This process can produce high quality coffee, but requires large quantities of water - between 2-10L water/kg of fresh cherry and good management of the fermentation and washing process to ensure the coffee flavor is not compromised in the process.

Figure 67. *A manual pulper for removing the skins off fresh cherries*

The drying of parchment coffee takes between 7 - 10 days. Parchment coffee must be properly dried to avoid mould growth and achieve/maintain good quality. It is advisable that parchment coffee be dried under shade during the full sun to avoid cracking of the parchment skin during drying. The drying should be on clean surface, preferably raised tables or trays with a mesh base as shown in Figures 68(a) and 68(b). Parchment Coffee should not be dried directly on bare ground/ soil or dirty surface as this leads to contamination and poor cup quality such as earthy flavors in the finished coffee. Also, during drying, parchment coffee should not be spread out too thick on the drying surface/areas as this prolongs drying and may lead to development of mould. The coffee should be continuously turned until the moisture content has reached 12%-13%.

Figure 68(a). *Trays with a mesh base recommended drying of parchment coffee*

Figure 68(b). *Dry parchment coffee awaiting bagging*

In the semi-wash process, the mucilage is removed immediately after pulping using a mucilage remover, the Parchment washed straight away and dried. Notably, this process does not ferment the mucilage with the coffee parchment as it is mechanically removed during the pulping process by use of mucilage remover and the clean parchment, ready for drying. Recent technological advancements have shown that wet pulpers combined with mucilage removers are cost efficient and are effective in consistently producing high quality coffee without the need for fermentation. These units also save on water costs as they typically use only about 0.5L of water per kg of fresh cherry, in addition to reducing the risk of over-fermentation and quality problems in the final coffee product. While there is an initial capital cost to purchase the pulper and demucilager units, there is no need for fermentation tanks, washing systems and waste water lagoons. This provides a big saving to the farmer.

8.4.2 Dry processing

Dry processing of Arabica Coffee also known Drugar involves the drying of fresh cherries the cherries immediately after harvesting without removing the pulp to produce what is commonly referred to as Kiboko coffee. The dry Kiboko Coffee is dried as FAQ and exported as Drugar (Dry Uganda Arabic)

The process of drying Kiboko coffee may take 14 - 30 days depending on weather conditions. Dried Kiboko coffee must have moisture content of 13-14% before undergoing processing at a primary dry processing mill into FAQ. When fully dried, Kiboko coffee should be black in colour, rattles in the shell, must have no smell and free of mould and extraneous matter such as stones.

Out-turn ranging between 50-60 % is common for Kiboko Coffee. However, majority of Arabica Coffee is washed except for Kasese and South Western Uganda where it is dried as Kiboko and eventually sold at export level as Dry Ugandan Arabica (Drugar).

Proper drying leads to good quality of coffee and better price for the product. Always dry coffee on tarpaulins as shown in Figure 69, clean mats, trays with a mesh base, concrete floors or cemented floor. Cherry must be turned with a rake to allow uniform drying and should be covered at night and during rainfall. During the first two or three days of drying ensure that the layer is as thin as possible (not more than 4 cm or 1.5 "thick) to facilitate uniform drying of the cherries.

Figure 69. *The dry Kiboko Arabica Coffee being dried on tarpaulin*

Figure 70(a). *Large scale solar drier*

Figure 70(b). *Small scale solar drier*

To quicken the drying time, farmers are now shifting to the use of large or small scale solar dryers as shown in Figures 70(a) and 70(b) respectively.

8.5 Arabica Coffee best storage practices

Even where coffee has been dried well, it can still grow moulds during storage, leading to musty flavors if it is not properly stored. The best practices for coffee storage described below should be adhered to:

- Coffee must be properly cooled first before storage. This prevents condensation and therefore re-wetting of the coffee.
- After cooling, the dry coffee should preferably be packed in clean sisal/jute gunny bags as shown in Figure 71. The bags should be covered to prevent the coffee from absorbing moisture and growing moulds.
- Coffee storage in polythene bags, as shown in Figure 72, is prohibited and should not be used.
- Packed parchment or dry cherry coffee should be stored in stores, silos or warehouse dedicated for coffee storage.
- The store/silo or warehouse should have cemented floor, plastered walls, leak proof roof and well-ventilated with a relative humidity of less than 65%.
- The coffee bags in the store/silo/warehouse should be placed on pallets raised to atleast 15cm as seen in Figure 73 to avoid re-wetting by ground moisture. Stacked bags should be placed atleast 30cm away from the walls.

- The coffee warehouse should not be used to store any contaminant product such as strong smelling liquids such as petrol or paraffin, diesel, or agricultural fertilizers and chemicals. This is because stored coffee quickly absorbs and retains foreign odours, which are eventually detected in the final cup and thereby spoiling its quality.
- The coffee warehouse should also not be used as store for other farm produce such as beans, maize, ginger, to avoid pest infection and contamination.
- The environment around the coffee store should be kept clean to maintain hygiene and prevent rodents from making entry into the store. A proper procedure for receiving coffee into storage should be maintained on a First In First Out (FIFO).

Figure 71. *Sisal gunny bags*

Figure 72. *Woven polybags should not be used for holding green beans*

Figure 73. *Coffee bags placed on pallets in a warehouse*


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CHAPTER 9

ARABICA COFFEE VALUE ADDITION

9.0 Introduction

Value addition involves activities that add value to the coffee product prior to sale on the market. Value addition starts with the selective picking and harvesting, wet pulping of the cherries, hulling of the dry parchment and grading the clean coffee known as Fair Average Quality (FAQ) before sale. To achieve good quality FAQ or clean coffee, the wet mill or huller at a later stage should be well calibrated to properly process the coffee. The hulling process is carried out using a hulling machine shown in Figure 74.

Figure 74. *A sample Coffee Huller machine*

9.1 Sorting dry coffee

A machine may be used to clean and sort hulled coffee by colour, size, density and aerodynamic. However, ultimately, the human hand may be needed to carefully "hand-sort" the coffee ready for export as shown in Figure 75.

Figure 75. *Appearance of sorted coffee beans with parchment and without parchment*

9.2 Grading of green coffee beans

Coffee beans are an agricultural product and like any agricultural produce, there is variance in the *size, colour and shape*. Assessing the quality of green coffee beans and finding out its attributes is important in coffee export business. This process involves two steps: (a) Grading and (b) Cupping. Grading is the first part in the assessment of the physical attributes of the green beans while cupping involves tasting and assessing the inner flavours of a coffee cup.

Before grading coffee, a sample is first obtained to determine:

- Moisture content
- Screen size of the beans
- Quantity of defects and foreign matter

The size of the bean/coffee is measured using screen (SCR) size trays with screen numbers ranging from sizes 10-20 as shown in Figure 76.

These are replaceable metal sheets that have round holes in them that retain beans of a certain size and allow smaller beans to pass through. It is a way of analyzing the physical quality of green coffee beans or clean coffee popularly known as Fair Average Quality (FAQ).

Figure 76. *Screen size trays for grading green coffee beans*

The SCR size or bean size is particularly important for roasters who require more or less the same screen size for the following reasons:

- Small and light beans will over roast during the roasting process if they are mixed with larger, heavier beans.
- Coffee standards provide for strict permissible limits within screen size grades.
- Based on screen size, the bigger the coffee bean the better the quality and the higher the price. Size of the beans is influenced by genotype (variety, management practices and the environment). However, cup quality may not necessarily follow the same trend.

A reliable moisture meter, as shown in Figure 77, should be used to determine moisture content of the coffee.

Figure 77. *A moisture meter for determine moisture level in the coffee*

9.3 Arabica Coffee grading and compliance safeguards

The grading of Arabica Coffee follows a strict code determined mainly by screen size and total percentage defects. Above all, all coffee grades (except under grades) should comply with the following safeguards.

- **Moisture:** Keep moisture content within the confines of the agreed standards and coffee law, 13-14% at primary level and 11-12.5% at export level. Moisture is one single factor that can spoil the coffee grade substantially.
- **Defects:** Coffee should be free of defects or atleast within the permissible defect counts. A defected bean is one is not considered to be a regular coffee bean e.g. a bean that is broken or insect damages. Defects can affect both the appearance of the green bean (its uniformity) and the final cup profile. Defects should be avoided as much as possible.
- **Foreign matter:** Foreign matter (anything else other than coffee) in the coffee should be avoided as much as possible as it lowers the grade of coffee.
- Coffee should be of a good physical appearance, free from all traces of fermentation, mustiness and other undesirable smells and taints. Table 24, 25 and 26 shows different Ugandan export grades for Arabica Coffee.

Table 24. Ugandan export grades for Arabica Coffee

Grade	Screen retention	Total defects (by count)	Remarks
Bugisu Aa	17 = 90% 16 = 8 % 15 = 2%	5%	
Bugisu A	16 = 90% 15 = 8% 12 = 2%	7%	Tolerance of up to 3% retained by screen 17
Bugisu A+	17- 60% 16- 30 % 15- 8% 12- 2%	5%	A mixture of AA&A of coffee from Bugisu and Kapchorwa areas.
Bugisu B	15 = 90% 14 = 8% 12 = 2%	10%	
Bugisu Pb	15- 80% 14- 15% 12- 5%	10%	Tolerance of A = 0-2%
Bugisu Ab	17-8% 16-60% 15-30% 14-2%	7%	It is a mixture of A and B
Bugisu Cpb	15-60% 14-38% 12-2%	12 %	Should have zero tolerance of A and AA
Bugisu Ug	Consists of defects sorted out of the export grades by hand or colour sorters.	Sound bean tolerance = 10%; Extraneous matter = 2%; Stones & metals =0%	Exportable under grade.

Table 25. Export grades for washed Uganda Arabica, Mt. Elgon

Grade	Screen Retention	Total Defects[1]	Remarks/Recommendations
Mt Elgon Aa	17- 90% 16- 8% 15- 2%	5%	• Only for coffee from Bugisu and Sebei area around the Mt Elgon. • No primary defects • 5-8 secondary defects • 0-3 quakers in 100gms roasted coffee • Minimum score 80 points on the SCAA cupping scale.
Mt Elgon A+	17- 60% 16- 30 % 15- 8% 12- 2%	5%	• Mixture of AA&A of coffee from Mt Elgon • No primary defects • 5-8 secondary defects • 0-3 quakers in 100gms roasted coffee • Minimum score 80 points on the SCAA cupping scale.

Grade	Screen Retention	Total Defects[1]	Remarks/Recommendations
Mt Elgon A	16- 90% 15- 8% 12- 2%	7%	• Only for coffee from Bugisu and Sebei area around the Mt Elgon. • No primary defects • 5-8 secondary defects • 0-3 quakers in 100gms roasted coffee • Minimum score 80 points on the SCAA cupping scale. • Tolerance of up to 3% screen 17.

Table 26. Export grades for other Arabica's

Grade	Screen Retention	Total Defects	Remarks/Recommendations
AA	17- 90% 16- 8% 15- 2%	5%	• Applicable to both washed and unwashed
A	16- 90% 15- 8% 12- 2%	7%	• Applicable to both washed and unwashed • Tolerance of up to 3% retained by screen 17
B	15 -90% 14- 8%	10%	• Applicable to both washed and unwashed
PB	15- 80% 14- 15% 12- 5%	10%	• Applicable to both washed and unwashed
AB	17-8% 16-60% 15-30% 14-2%	7%	• Applicable to both washed and unwashed
CPB	15-60% 14-38% 12-2%	10 %	• Applicable to both washed and unwashed should Zero tolerance of A and AA
TRIAGE	Light & broken beans from the processing lines/ gravity table.	Sound bean tolerance = 10%. Extraneous matter = 2% Stones & metals =0%	• Exportable to emerging markets.
MIXED ARABICA	Natural and Washed Arabica defect beans from gravity table, sweepings and sorting.	Sound bean tolerance = 10%. Extraneous matter = 2% Stones & metals =0%	• Exportable to emerging markets.

9.4 Transporting of green coffee beans

Storage and transport pose similar risks to coffee quality. The re-wetting of coffee beans due to leaky tarpaulins, or high humidity inside hot containers standing for long periods in tropical ports can result in the coffee developing moulds or musty flavors. Special techniques for handling bulk or bagged green beans for container shipping are now well developed and in place. Coffee should be packed well and transported intact to avoid re-wetting and any quality deterioration. The mode of transport therefore must be reliable and in good mechanical condition. Coffee harvesting, drying and marketing normally coincide with rain seasons and the transporting trucks must have sound tarpaulins or be in leak-proof box body model to avoid re-wetting of the coffee. Always transport coffee alone and avoid carrying substances which may contaminate the coffee e.g. fuels and agrochemicals. Where possible, ensure that transit time is as short as possible from the source to the consignee.


PROBAT

CHAPTER 10

COFFEE FARMING AS A BUSINESS

10.0 Introduction

Coffee is the second most traded tropical commodity in the world after oil. In Uganda, it is one of the most traded due to availability of a fully functional liberalised marketing system. In order to obtain full benefits from coffee, growers must carry out coffee farming as a business in order to maximize profit. It should be driven by standard production and manufacturing practices aimed at sustaining economic output and product quality in order to maximize profit. The practices should be undertaken timely, accurately and efficient in resource utilization. Maintenance of financial and operational records is therefore crucial in monitoring of the performance of the coffee business enterprise. Factors that affect profitability of coffee farming include:

1. **Productivity** – in terms of yield (kg) per tree, acre/hectare
2. **Market price** – influenced by quality, demand and supply
3. **Exchange rate** - fluctuates depending on market forces
4. **Milling loss** - depends on Kiboko/parchment quality. The higher the quality, the lower the milling loss

10.1 Objectives of coffee farming as a business

The coffee farming community should aim at the following objectives in undertaking coffee farming as a business:

Understanding that coffee, is money and therefore,

1. Maximizing coffee output
2. Enhancing quality of coffee
3. Maximizing profits by reducing costs and increasing revenue
4. Maximizing sales
5. Making savings and investments for growth

Therefore, the following principles must be followed in doing coffee as business:

- Start by having a proper registration of the coffee business with the Uganda Registration Services Bureau (URSB) and Uganda Revenue Authority (URA)
- Ensure good management practices at levels of the coffee value chain
- Undertake planning, proper record keeping to track all expenditures and incomes
- Ensure proper financial management
- Undertake regular monitoring of the coffee fields to assess performance and early detection of any pest or disease
- Seek expert advice when in doubt. Uncertainties must be addressed by professional people
- Obtain and use weather forecast data for proper planning
- Obtain and use real-time market information
- Practice enterprises diversification along with coffee business to increase returns
- Understand the needs of the consumer or your client
- Test and choose best options that maximize return per unit area, including bargaining for the minimum costs for inputs and maximum prices for sales depending on quality of your coffee

10.2 Types of coffee farming businesses

10.3.1 Sole proprietor

A sole proprietorship is a type of business where one individual or married couple is in business alone. The owners have day-to-day responsibility for running the coffee farm as a business. They own all the assets and the profits generated. The advantage of this type of business is that it is the easiest and least expensive form of ownership to organize. Secondly, the owners are in complete control and within the parametres of the law, may make decisions as they see fit.

10.3.2 Partnership

A general partnership is a type of business where two or more persons (usually not a married couple) agree to contribute money, labour, or skill to a business through formal process usually contained in a written partnership agreement where each partner shares the profits, losses and management of the business and is personally and equally liable for debts of the partnership. The advantages of partnerships are that they are relatively easy to establish. However, time should be invested in developing the partnership agreement. Also with more than one owner, the ability to raise funds may be increased. The profits from the business flow directly through to the partners' personal tax returns. A prospective employee may be attracted to the business if given the incentive to become a partner. The business usually will benefit from partners who have complementary skills.

10.3.3 Corporation

Forming and operating a corporation or Limited Liability Company (LLC) is a bit more complicated and costly, but well worth the trouble for some small businesses. Corporations and LLCs make sense for business owners who either 1) run a risk of being sued by customers or of piling up a lot of business debts, or 2) have substantial personal assets they want to protect from business creditors. What sets the corporation apart from all other types of businesses is that a corporation is an independent legal and tax entity, separate from the people who own, control and manage it. Because of this separate status, the owners of a corporation don't use their personal tax returns to pay tax on corporate profits - the corporation itself pays these taxes. Owners pay personal income tax only on money they draw from the corporation in the form of salaries, bonuses and dividends.

10.3.4 Cooperatives

A cooperative is a type of business entity owned, controlled and operated by a group of users for their own common benefit. Each member contributes equity capital and shares in the control of the cooperative on the basis of one-member, one-vote. It is a business of true equals -- an organization owned and operated democratically by its members. These grassroots business organizers often refer to their businesses as a "group," "collective," or "co-operative"

There are specific laws dealing with the set-up of cooperatives. Farmers may contact Uganda Cooperative Alliance or Ministry of Trade, Industry and Cooperatives, or the local agricultural office or District Commercial Officer for more information. The following principles are important for success of a cooperative:

1. **Voluntary and open membership** - Co-operatives are voluntary organizations, open to all persons able to use their services and willing to accept the responsibilities of membership, without gender, social, racial, political or religious discrimination.

2. **Democratic member control -** Co-operatives are democratic organizations controlled by their members, who actively participate in setting their policies and making decisions. Men and women serving as elected representatives are accountable to the membership. In primary co-operatives members have equal voting rights (one member, one vote) and co-operatives at other levels are also organized in a similar democratic manner.

3. **Member economic participation** - Members

contribute equitably to the capital of their co-operative. At least part of that capital is usually the common property of the co-operative. Members usually receive limited compensation, if any, on capital subscribed as a condition of membership. Members allocate surpluses for any or all of the following purposes:

- Developing their co-operative, possibly by setting up reserves, part of which atleast would be indivisible;
- Benefiting members in proportion to their transactions with the co-operative; and
- Supporting other activities approved by the membership.

4. **Autonomy and independence -** Co-operatives are autonomous, self-help organizations controlled by their members. If they enter to agreements with other organizations, including governments, or raise capital from external sources, they do so on terms that ensure democratic control by their members and maintain their co-operative autonomy.

5. **Education, training and information -** Co-operatives provide education, training and capacity building for their members, elected representatives, managers and employees so that they can contribute effectively to the development of their co-operatives. They inform the general public - particularly young people and opinion leaders - about the nature and benefits of co-operation.

6. **Concern for community -** Co-operatives serve their members most effectively and strengthen the co-operative movement by working together through local, national, regional and international structures. Co-operatives work for the sustainable development of their communities through policies approved by their members.

7. **Horizontal and vertical integration** - Producer groups need to integrate both horizontally (many producer groups operating at the same level) and vertically (carrying out value addition processes).

10.3 Farm records and accounts

A commercial/business farmer needs both farm records and accounts for proper management of the coffee business enterprise. A farm record is a document (in most cases a book) that is used to keep account of different activities, events and financial undertakings regarding the farm operations.

10.3.1 Farm business records

Some of the common farm business records include:

- Income and expenditure or receipts and payment or cash record
- Farm inventory or tools and properties record
- Profit and loss account
- Yield or production record
- Labor records
- Farm input utilization record
- Sales record
- Purchase record
- Crop record book

Type of record by description and use and its use is given in samples Tables 27-35.

Table 27. Sample income and expenditure record (Receipts and payment/cash record)

Receipts	Amount	Payment	Amount
Total		Total	

Table 28. Sample farm inventory record (Tools and properties record)

Serial #	Description	Purchase Date	Purchase Cost	Repairs	Current Worth	Sale Price

Table 29. Sample profit and loss record

Revenue	2017	2016
Sales revenue		
Service revenue		
Interest revenue		
Other revenue		
Total Revenues		
Expenses		
Advertising		
Bad debt		
Commissions		
Cost of goods sold		
Depreciation		
etc		
Total Expenses		
Net Income Before Taxes		
Income Tax Expense		
Net Income		

Table 30. Sample yield record (Production record)

Date	Kg/Debes of Cherry	Cumulative Total	Comments

Table 31. Sample labour record

Start Date	Activity/ operation	Man days	Cost/Man day	Total Cost (Ushs)	Cumulative Total (Ushs)

Table 32. Sample stores record

Date	Received (Quantity)	Taken out (Quantity)	Balance (Quantity)	Comments

Table 33. Sample sales record

Date	Coffee Product	Retail Price/Kg (Ushs)	Amount sold (Kg)	Total Sales (Ushs)

10.3.2 Farm accounts

Farm accounts, on the other hand, deal only with the financial aspects of all farm operations that mainly include farm expenditures and income in order to help the farmer calculate how the business is doing Tables 35 and 36.

Table 34. Differences between farm records and farm accounts

SN	Farm Accounts	Farm Records
1	Farmers can monitor the changes in price of product bought or sold by the farm.	• It gives the history of what happens in the farm from beginning to the end of the farm business
2	It enables the farmers to carry out the necessary planning required for the smooth running of the farm	• Provides the necessary facts and figures for farm planning and budgeting
3	It shows the financial weakness/strength of the farm	• It helps to determine the level of profit or loss made by the farm
4	It helps to show the value of assets and liabilities of the farm	• It enables the farmer to obtain loans from the bank
5	Fraudulent practices on the farm can be detected	• Creates room for farm evaluation in order to determine the farmers management skill
6	Certain management decision like whether to continue or discontinue with a section of the farm can be made	
7	Shows credit worthiness of the business	
8	Helps the business in tax assessment	

Table 35. Type of record by description and use

Type of Record	Description	Use
Farm Inventory records	• Type of asset/equipment, quantity, date of purchase.	• Complete listing of all assets, verifying their weighed values, measurements and numbers, including valuing of physical assets e.g. tractors and farm implements; and calculation of depreciation due to wear and tear.
Production records	• There is a weekly, a monthly and annual record of everything produced on farm.	• They help the farmer to keep track of how well the farm is doing.
Labor use records	• Family labour. • Hired labour, man hours; • Piecework schedule rates.	• Measurement of labour, work etc. • Rates of work/wages and salaries.

Type of Record	Description	Use
Weather records	• Rainfall/temperature on daily basis	• Planning of activities
Financial records including income and expenditures records.	• Sales amounts/value • Costs • Expenditures and income from crop production and sales, fertilizer application amounts and rates and costs, seedling amounts and costs, weeding costs and costs of pest and disease control; plus yield records.	• Enables the farmer access bank loans. • Compilation of mandatory returns to URA/NSSF

10.5 Profitability indicators

Profitability indicators form one group of financial analysis, which are used to evaluate profitability and efficiency of the farm management, that is, the farm's ability to produce maximum output (margin or profit), ideally with minimal inputs. These include Gross Margins, Return on Investment and Payback period.

10.5.1 Gross Margins

The Gross Margin (GM) of a farm activity is the difference between the gross income earned and the variable costs incurred. For a farm to break-even, the total gross margin should not be less than the total overheads. The gross margin per unit area is widely used for comparative analysis of crop activities of different farms and between farms of similar environments. Valid comparisons can be made in terms of a common production unit e.g. per acre or hectare. It could also be per unit of labour. Gross margins are useful in deciding the best combinations of activities on a farm. The guiding principle is to select the highest GM per unit of the most limiting resource.

Gross Margin for various Arabica Coffee value chain business can be found in Annex 2

10.5.2 Return on Investment

Return on investment (ROI) measures the gain or loss generated on an investment relative to the amount of money invested. It is expressed as a percentage. It is used for personal financial decisions, to compare a company's profitability or compare the efficiency of different investments. The return on investment formula is:

ROI = (Net Profit /Cost of Investment) x 100

10.5.3 Payback period

Simply defined as the year, which the cumulative cash flow becomes positive. Payback period indicates the period within which expended funds are recouped. It is useful to quickly assess the profitability of several investment options. Its limitation is that it does not consider benefits and costs after payback

10.6 Coffee marketing

Arabica Coffee can either be sold as Kiboko (for Drugar areas), Parchment, FAQ and graded coffee, roasted beans or as a beverage/coffee cup. Coffee marketing options for the Arabica Coffee farmer include:

- Trading in cherry at farm gate – to wet processing mills
- Trading in Kiboko (as for Drugar) or parchment at the local primary markets
- Trading in FAQ at national markets
- Trading in graded coffee for export markets

10.6.1. Scenario 1. Selling parchment coffee at local primary markets

This scenario generates more money for the farmer than selling cherries at farm gate. The indicative costs for doing so are shown in Table 36.

Table 36. Trading parchment Arabica Coffee at local primary markets

Selling parchment at local primary markets				
	Rate/kg	%	Kg	Ushs
Weight			1,000	
Loading to pulping centre	10			10,000
Transport to pulping centre per kg	20			20,000
Off-loading	10			10,000
Out-turn		20%		
Total kg parchment			200	
Pulping cost per kg	150			30,000
Drying	25			5,000
Loading dry parchment	10			2,000
Transport to market	40			8,000
Commission per kg	50			10,000
Total cost				85,000
Price per kg (parchment) local market				5,200
Total income for FAQ				1,040,000
Margin				955,000
Additional income case 1				55,000
Additional income case 2				172,000
Additional income C1 %		6		
Additional income C2%		22		

10.6.2. Scenario 3. Selling FAQ at national markets

Arabica Coffee farmers have an opportunity to add value and trade in FAQ (clean coffee) at the major national markets that include Kampala, Mbale, Kasese, Mbarara. Table 37 shows indicative costs for doing so.

Table 37. Trading FAQ at national markets

FAQ costs	Rate/kg	%	Kg	Ushs
Weight			1,000	
Loading to parchment centre	10			10,000
Transport to parchment per kg	20			20,000
Off-loading	10			10,000
Out-turn		20%		
Total kg parchment			200	
Pulping cost per kg	150			30,000
Transport to Kampala (parchment)	30			6,000
Hulling out-turn (FAQ)		90%		
Volume FAQ (kg)			180	
Hulling cost	80			14,400
Commission per kg (Group level)	50			9,000

FAQ costs	Rate/kg	%	Kg	Ushs
Commission per kg (Association level)	50			9,000
Total cost				98,400
Price per kg (FAQ) local market				6,000
Total income for FAQ				1,200,000
Margin				1,101,600
Additional income case 1				201,600
Additional income case 2				318,600
Additional income case 1%		22		
Additional income case 2%		41		
Additional income case 3				146,600
Additional income case 3%		15.4		

10.6.3. Scenario 4. Selling FAQ in Export Markets

A scenario of selling FAQ coffee in export markets. Table 38 shows indicative costs for doing so.

Table 38. Trading graded (FAQ) coffee in export markets

FAQ costs	Rate/kg	%	Kg	Ushs
Weight			1,000	
Loading fresh cherry to parchment centre	10			10,000
Transport to parchment per kg	20			20,000
Off-loading	10			10,000
Out-turn		20%		
Total kg parchment			200	
Pulping cost per kg	150			30,000
Transport to Kampala (parchment)	30			6,000
Hulling out-turn (FAQ)		90%		
Volume FAQ (kg)			180	
Hulling cost	80			14,400
Grading out-turn rate		92.5%		
Graded volume			166.5	
Grading cost (kg)	150			24,975
Commission per kg (group level)	50			9,000
Commission per kg (Association level)	50			9,000
Total cost				123,375
Price per kg (FAQ) local market				6,700
Total income for graded FAQ				1,340,000
Margin				1,216,625
Additional income case 1				316,625
Additional income case 2				433,625
Additional income case 1%		35		
Additional income case 2%		55		
Additional income case 3				115,025
Additional income case 3%		10.4		

10.7 Access to finance

Farmers need money to meet their daily demands. This may force them to sell their coffee prematurely at very low prices. Framers need to be able to borrow money on affordable terms (low interest rates and long gestation and loan recovery periods) linked to the coffee harvesting seasons.

Farmers can overcome these challenges by forming Village Savings And Loan Associations (VSLAs) or joining Savings and Credit Cooperative Organisations (SACCOs). These can serve as savings and loan schemes or can link farmers together to apply for farm loans from the larger banks..

10.8 Enterprise diversification to support coffee business

Farmers should not rely exclusively on coffee for their income. Uncertainties like low yield and low prices can affect their income unexpectedly. Coffee farmers are advised to keep cattle, goats, poultry and apiary (Figure 78) as well as grow other food and cash crops to protect themselves from food insecurity and income shortages. Animals can also provide manure for the coffee farm. Farmers can intercrop coffee with vanilla, bananas, beans, groundnuts, passion fruit and/or avocado to provide food and additional income. However, it is important to seek guidance from your extension officer before intercropping coffee with other crops.

Heavy feeder crops such as maize, cassava and sweet potatoes should be grown on a separate piece of land for food and cash and not intercropped with coffee. Farmers may also be engaged in non-farm alternatives enterprises such owning retail or wholesale shops, making crafts and/or having formal employment.

Figure 78. *Apiary as a form of enterprise diversification on a farmers coffee farm*

10.9 Family decision making

Successful coffee farming has many stages such as planning, production, processing, marketing and utilization of profits to cater for family needs and to expand the coffee business. At all these stages, key decisions should be equitable, encourage participation of all family members (Head of family, spouse and adult children) and ensure that the farm benefits all. For example, if the head of the household takes all decisions on the use of coffee earnings, the spouse and/or children may sell coffee secretly to cater for their needs.

Coffee earnings may be used for school fees, health care, investment in the farm, home care, food security and savings. A farm enterprise should clearly communicate roles and responsibilities, expectations, capabilities and entitlements for everyone involved. For example, children of school going age should not work in coffee farms during school time and all wages and working hours must comply with national employment policies.

CHAPTER 11

CLIMATE SMART ARABICA COFFEE PRODUCTION

11.0 Introduction

Climate change is a phenomena caused by the warming of the earth due to the emission of greenhouse gases. As a result of climate change, Uganda is witnessing ecosystem instability in the form of extreme weather conditions such as prolonged drought, floods, increased temperatures, erratic/irregular rainfall patterns, hailstorms, landslidesb and thunderstorms. Such changes and instability in the ecosystem has disrupted agricultural productivity.

It is a fact that the major coffee production areas of Uganda have become drier and hotter over the past three decades. Annual temperatures have risen across the country, potential evapotranspiration increased and the distribution of precipitation has become more variable. Whereas the extent of these developments varied across the country, global climate models project annual mean temperature to increase by 1.7°C-1.8°C until mid-century. In line with the current trend, the increase is projected to be higher in the Southwest, than in the Eastern of Uganda. Projected increases in total annual precipitation were substantial and range from +6.8 % (Southwest) to +11.5% (South-East) averaged over all projections.

Figure 79. *Effect of prolonged drought on Coffee*

The contradiction that East Africa recently experienced a series of devastating droughts, while the majority of climate models predict increasing rainfall for the coming decades has been termed the East African climate paradox. Whether or not the future climate in the region will indeed become wetter or not should be considered an open option but planning for mitigating measures in either way should commence.

Arabica Coffee production can seriously be affected by climate change causing massive economic losses to the farmer and possible invasion of higher altitude forested areas of Mt. Elgon, Rwenzori and Kigezi Highlands. In Uganda, sporadic dry spells of weather have been observed to cause wilting of coffee plants in many parts of the country as seen in Figure 79.

11.1 Climate change models and projections for Arabica Coffee production

Climate Change Impact Zoning for Arabica Coffee is as shown in Figure 80.

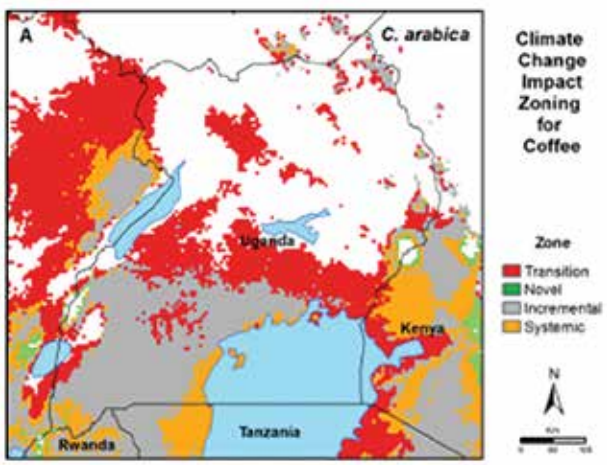


Figure 80. *Map showing future climate change impact zoning for Arabica Coffee by 2050*

The models and projections show that there will be eminent changes for Arabica Coffee growing in Uganda that may take place by 2050. The changes will create new map of Arabica Coffee growing zones if the current trend is upheld are depicted as follows:

1. **Transition zone:** These are the areas shown in red on the map. Here farmers can opt to switch crops from Arabica to Robusta or from Robusta to Cocoa or farmers can altogether opt out of agriculture.
2. **Novel zone:** These are the areas shown in green on the map. These are areas that will be suitable for coffee but are currently not under coffee. Such areas will include, forested areas of Mt. Elgon National Park. This means that Arabica Coffee production will be moving to new areas including the protected reserves.
3. **Incremental zone:** These are the areas shown in grey on the map. Such areas will need crop improvements and better management and a supportive policy framework to protect the environment.
4. **Systemic zone:** These are the areas shown in orange on the map. Here adaptation will need to be put in place (shade systems, improved varieties, etc.)

11.2 Implications of climate change for Arabica Coffee production

Increasing temperatures shall demand replanting with drought/disease resistant varieties or varieties that are particularly suited to yield in certain climatic conditions. The future climate change suitability for Arabica Coffee in 2050 is presented in Figure 81.

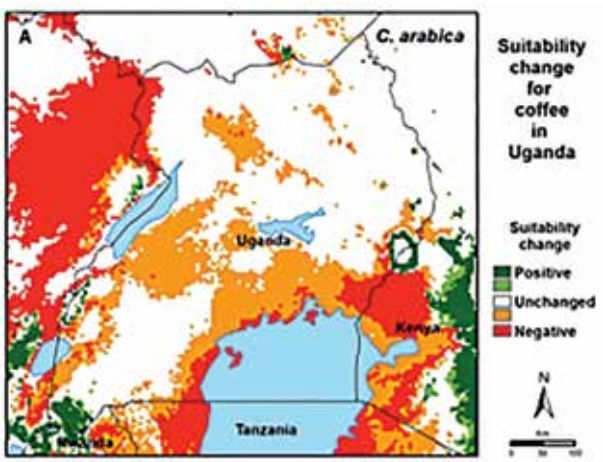


Figure 81. Future climate change suitability for Arabica Coffee by 2050

According to Figure 81, it is predicted that by the year 2050:

- **Negative** (Red areas): Areas currently suitable for Arabica will no longer be so in 2050. They will be negative, implying it will not be possible to grow Arabica or it will only be grown with heavy investment with climate smart agricultural practices.
- **Positive** (green areas: These areas will still be suitable for Arabica Coffee production in the future scenario (2050).
- **Unchanged:** This indicates areas that are currently not growing coffee and will continue to be so.

11.3 Climate change adaptation and mitigation strategies for Coffee growing

Adaptation and mitigation strategies are becoming increasingly important in order to sustain Uganda's coffee production growth. Given that smallholders dominate coffee production in Uganda, these strategies need to be low-cost and hence affordable, acceptable and efficient. Adaptation involves actions that minimize the negative impacts of climate change. It is aimed at lowering the risks posed by the changing climate.

Mitigation involves activities that reduce, prevent, or remove greenhouse gas emissions and therefore limit the magnitude of long-term climate change. Both adaptation and mitigation are aimed at enhancing resilience of coffee. Training to help farmers implement good agricultural practices is an important step in climate adaption and mitigation. Table 39 gives a summary of climate hazards on production and adaptation/mitigation measures to prevent impacts and Table 40 gives a summary of climate hazards on post-harvest and measures to prevent impacts..

Table 39. Climate hazards on production and adaptation/mitigation Measures to Prevent Negative Impacts

Climate hazard on Production	Direct-impact on coffee tree/ Vulnerabilities	Adaptation/Mitigation measures
High temperature	• Physiological effects • Increased pests like coffee berry borer • Increased disease incidences like coffee leaf rust	• More shade • Enhanced pest and disease control • More resistant varieties
Heavy rain hail strong winds	• Increased tree damage • Increased fruit fall • Increased mould growth • Increased soil erosion • Landslides	• Windbreaks • Cover crops • Mulching • Trenching
Intermittent drought	• Increased non-uniformity flowering and ripening • Increased disease incidence • Irregular bean development	• Agro-forestry • Enhanced pest and disease control • Cover crop • Improve soil/water management • Change/improve fertilizer plan

Climate hazard on Production	Direct-impact on coffee tree/ Vulnerabilities	Adaptation/Mitigation measures
Prolonged rain	• Delaying flowering • Extended vegetative phase • Delayed ripening of fruits • Lowers photosynthesis • Favours fungal diseases	• Enhanced disease control • Shade regulation
Prolonged drought/ insufficient rain	• Weaker trees wilting increased mortality of young coffee trees • Increased pest incidence • Poor quality fruits/bearing of small sized fruits/low density	• Increased soil mulches and plants • Increased irrigation • Increased water harvesting • Better infiltration techniques • Pruning • Stumping • Establish cover crops • Plant trees- agro-forestry systems

Table 40. Climate Hazards on post-harvest and adaptation/mitigation measures to prevent negative Impacts

Climate hazard on post-harvest	Direct-impact on post-harvest	Adaptation/mitigation options
Prolonged or unseasonal rain, Winds, Hailstorms	• Poor/difficulty in drying coffee	• Proper Harvest and Post Harvest Handling
Winds, hailstorms	• Increased foreign matter in dried cherry/Kiboko	• Proper Harvest and Post Harvest Handling
Reduced productivity, incomes	• Low market access and income • Low credit worthiness • Low standard of living • Gender inequity	• Diversify income sources both on and off-farm • Improve business/investment planning • Engendered planning and implementation

11.4 Stepwise Climate Smart Investment Pathways tools

The stepwise Climate Smart Investment Pathway (CSIPs) is a tool that helps farmers to apply at low cost, the recommended coffee farming best practices. The tool encourages an incremental investment into recommended practices step-by-step. Farmers can implement according to both, the resources they have and the most limiting factor specific to their area, until he/she is able to reach the final level of investment, ideally resulting in increased productivity and hence improved livelihoods.

The limiting factors may vary among growing areas, therefore, the steps may also vary among sites. The approach involves a 2-step process, consisting of developing (1) a general national and (2) a regional specific stepwise climate smart investment pathway. The national CSIP is established by seeking expert opinions, including those of representatives from the national coffee board, coffee specialists, coffee agronomists and coffee research institutes among others. The findings from the national CSIP are validated and adapted with stakeholders at regional level (comprising representatives from the local government, farmer representatives and input dealers), resulting in a site-specific regional CSIP.

CHAPTER 12

COFFEE SUSTAINABILITY FARMING PRACTICES

12.0 Introduction

Sustainability has three main pillars, referred to as people, planet and profits. The three elements are captured in the following categories:

1. **Economic:** Whereby farmers have improved market access and receive a fair price for their coffee.
2. **Social:** Which entails improving the quality of life of farm employees and those that they support.
3. **Environmental:** which uses production methods that have a reduced impact on biodiversity and environmental degradation.

12.1 Economic Sustainability

The economic pillar of sustainability is where the coffee businesses feel they are on firm ground. To be sustainable, a coffee business must be profitable. However, profit cannot justify the over dominance by the other two pillars. In fact, profit at any cost is not at all what the economic pillar is about. Activities that fit under the economic pillar include compliance, proper governance and risk management. Farmers need to sustain productivity and quality at farm level by keeping good records. This helps them to evaluate the impact of different good agricultural and post-harvest practices.

One important economic consideration of sustainability is the role of gender and youths in coffee farming. Sustainable business of the coffee sector, especially in smallholder dominated production systems, is often hampered by unequal distribution of information, labour, skills and other resources and benefits across gender and youth within coffee-farming families. In many coffee-producing countries, young boys and girls do not find an attractive future in the coffee farms of their parents.

Coffee businesses will increase their efficiency, profitability and sustainability if they promote gender and youth equity due to the following:

- Women are an important source of labour in coffee production yet they have limited access to resources and benefits in the coffee value chain. This results in many missed business opportunities for this category. Productivity and quality can easily be improved in the coffee value chain by providing more support and opportunities to women than they are currently.

- Youths form the majority of the population in Uganda. Integrating and attracting the youths in coffee value chains will ensure continued productivity and business sustainability.

The strategies outlined in Table 41 help businesses and the entire coffee sector players to address gender and youth economic participation in the coffee value chains. The strategies link the broader goals of the coffee industry, including maximizing productivity, growing the supply base, strengthening resilience to climate change and improving the livelihood of farmer households. Therefore, since the youths form the majority of the population in Uganda, integrating and attracting them into coffee value chains will ensure continued productivity and coffee business sustainability.

Table 41. Business strategies for enhancing gender and youth equity

Gender	Gender Dimension
Women	• Create an enabling environment - Ensure that policies and actions are gender responsive at all levels of the coffee value chain. • Promote participatory intra household decision-making in which spouses consult each other and decide together on resource utilization. • Support equitable distribution of household and productive activities within coffee farming families and promote labour and time saving technologies. • Increase women's membership and participation in farmer groups through introduction of quotas and develop leadership capacity of women. • Build the capacity of extension agents to equitably provide services to men and women farmers. Men and women's roles ought to be put into consideration in the delivery of extension and advisory services. If possible recruit more women as extension agents and lead farmers. • Provide opportunities for women to benefit from standard-related training programs; and ensure that any extra labour demand on women is assessed, managed and that equal premiums go to both women and men. • Support associations of women in coffee by providing services, business linkages and build their capacity and confidence. • Work with financial service providers to develop products with alternative collateral requirements that meet women needs. • Disseminate climate change related information via communication channels accessible and frequently used by women. • Combine technical trainings with reproductive health, nutrition for coffee farming households. • Create a work environment that is healthy, safe and free from discrimination. • Businesses should pay equal remuneration, including benefits, to women and men for work of equal value. • Providing gender disaggregated facilities, amenities to serve the different interests of both women and men.

Gender	Gender Dimension
Youth	• Capacity building: provide appropriate training and exposure through education, mentoring, coaching to motivate young farmers and create awareness on importance of family farming • .Develop models on production and business for rural youth. • Develop groups on youth extension and clubs on young creativeness. • Organize savings associations among the youth • Help youth coffee farmers to access loans for agri-business. • Expose the youth to new and advanced technologies. • Support farmer organizations to give space to young farmers. • Support youth business organizations and offer a voice to young farmers. • Strengthen cooperation amongst youth groups and help youth realize their potential. • Provide other opportunities in coffee value chain for the youths other than farming e.g. as coffee baristas, cuppers and ICT application developers. • Develop financial products tailored to the needs of youth. • Equip young coffee farmers with business skills and life skills and conduct Policy advocacy focusing on youth.

12.2 Social Sustainability

The social sustainability includes giving appropriate respect and care to workers and families involved in coffee production and the supply chain. A sustainable coffee business should have the support and approval of its employee's stakeholders and the community it operates in. Approaches to securing and maintaining social sustainability are various, but it comes down to treating employees fairly and being a good neighbor and community member, both locally and globally.

As a rule of thumb, all children should go to school. Outside school hours, they may do light work on the coffee farm under adult supervision. This helps the children to learn about the farm and they can help with practices such as record keeping. Children should not participate in hazardous activities such as spraying chemicals or carrying heavy loads.

On the employee side, the coffee businesses should focus on retention and engagement strategies, including more responsive benefits such as better maternity and paternity benefits, flexible scheduling and learning and development opportunities. For community engagement, the coffee business should come up with many ways to give back, including fundraising, sponsorship, scholarships and investment in local public projects.

Coffee workers should be treated with respect. A fair rate for jobs should be agreed and paid when work is completed or as agreed. All payments should be recorded. Workers should have access to clean and safe drinking water, clean toilets and protective gear.

12.3 Environmental Sustainability

The environmental pillar ensures that adequate attention is given to the protection of the natural environment. A coffee farmer should think about the environment around his/her land and the long-term impact of his/her farming methods. The farmer should also think about packaging wastewater management, waste management, water usage and their overall effect on the environment, energy conservation and safe storage and application of agro-chemicals and disposal of packaging material.

Prevention of water and environment pollution is of critical concern and serves many purposes. For example, if a farmer washes pulped parchment Coffee in the river, water for all the neighbors down stream will be contaminated. Therefore, pulped coffee should be

washed in a container away from the water source. Also chemical sprays should be used away from the water sources.

In terms of waste management, it is important for the farmer to separate organic and inorganic waste so that compost can be made from the organic waste to improve the soil. All chemical containers should be punctured to prevent reuse and disposed of safely. All plastic and metal waste should be kept safely until the time for their safe disposal.

Agro chemicals may be dangerous if not properly stored and used safely. In case of disposal, the Uganda National Bureau of Standards agents or National Environment Authority (NEMA) officers should be consulted for advice. The following guidelines should be adhered to when using chemicals:

- Always wear a full protective gear, such as head cap, nose and mouth masks, overalls, gumboots, eye goggles, gloves and gum boots when handling or spraying chemicals as illustrated in Figure 82.
- Do not spray near other people, livestock or water sources.
- Do not spray when it is windy. Do not spray against the direction of the wind.
- Make sure that you warn other people before and after spraying.
- Banned chemicals such as Endosulfan, Paraquat, Actellic Super, Ambush, among others, should not be used.
- Chemicals should be kept in a locked place out of the reach of children and away from food and stored crops. Always possible, keep them in a separate store.

Energy and water are precious resources that need to be harnessed and used with care. A farmer should plant multipurpose trees for shade and fuel supply. Always use energy saving stoves and solar energy appliances where possible. Explore the possibility of biogas from livestock manure and other sources. Roof tops and runoff rain water should be collected in water tanks and trenches or ponds for irrigation and moisture retention during dry spells.

Figure 82. *Recommended protective gear while spraying chemicals*

Crop residues grown alongside coffee should be used for mulching, composting or feeding livestock. Avoid burning the crop residues in the field as burning causes loss of nutrients and the fire may spread to the coffee field.

12.4 Coffee certification programs

The basic rationale behind certification for coffee growing is that consumers are willing to pay more (a premium) for coffee that is of a higher quality standard or is farmed using practices that are more sustainable and traceable. The process of accreditation should be pursued if farmers stand to make a commercial gain from it. Therefore each individual farm/farmer group (depending on the standard) must consider independently whether the benefits achieved from certification outweigh the costs involved with implementing the desired standard.

Certifications based on the production and processing standards employed along the supply chain are monitored and communicated to consumers through the use of "marks"/"seals" which can be used on product packaging/advertising. However, certification is usually a lengthy process and is very expensive as producers must pay fees for the assessments as well as bearing the costs associated with certification compliance monitoring. Therefore many producers find it difficult to afford being accredited with more than one scheme. Knowing which certifications to prioritize because they are most applicable and brings the most benefit is therefore of vital importance.

Considering that there is a multitude of different standards offered worldwide, it is prudent for producers to choose a certification scheme that is specific to their target market. For example, if all of the coffee grown from a farm is sold into the US market, then being certified under USA Organic Regulation (the USDA National Organic Programme) would be of considerable benefit. Organic operators certified in accordance with any of the standards in the family can apply for use of the mark on their products and therefore use the mark identifiable to a specific region or the more general International Federation of Organic Agricultural movement (IFOAM) mark. Farmers in Uganda can choose to practice and adhere to any of the following Coffee Certification Programs (1) Organic Certification (2) Fairtrade Certification (3) Rainforest Alliance Certification (4) Smithsonian Bird Friendly Certification (5) 4C Common Trade for Coffee Commodities Certification and (6) Starbucks C.A.F.E Practices. The relevant practices under each of these certification schemes are described below.

12.4.1 Organic certification

This is a sustainable agriculture system that produces coffee in harmony with nature, supports biodiversity and enhances soil and environmental health. The International Federation of Organic Agriculture Movements (IFOAM) provides a standard (the IFOAM Standard) that is considered a good baseline for organic producers. The IFOAM "Family of standards" are organic standards that have been officially endorsed by the Organic Movement as part of the IFOAM Organic Guarantee System. Areas of the IFOAM standard that are relevant to coffee production include:

- A good ecosystem management
- Soil and water conservation
- Appropriate choice of crops and technologies, pest/disease management
- Processing and packaging/labeling.

The opportunities and challenges for the organic certification are detailed in Table 42. Farmers growing organic certified coffee must conform to prescribed ware housing facility standards. (Figure 83).

Figure 83. *Organic certification label in a coffee warehouse*

Table 42. Opportunities and challenges of organic certification

Opportunities
• Accounts for organic coffee sales up to about 29%
• Opportunities are particularly strong in more developed countries (specifically the US, Canada, EU, Russia and Japan where a good premium is attached
• Average price differential paid to producers from USDA certified produce was US$0.255 per pound.
• Where the cooperative is sizable then producers must develop an Internal Control System (ICS) where the group demonstrates through training and internal inspection that the organic standards are met.
• The certification auditor checks the system rather than the individual farmers.
Challenges
• Organic certification only focuses on small-scale farms even though large-scale coffee estates are influential in promoting ethical supply chains.
• Smallholders must be organized into a cooperative with more than 15 members. This is a barrier for isolated famers or farmers located where the governance structures/skills are not present for farmers to form cooperatives.
• Transition period to sustainable practices may be lengthy (up to 3 years) depending on what chemicals were used on the land previously. This makes it economically difficult for farmers to make the transition because the main costs come during the transition while the produce must still be sold at the conventional prices.
• Many small farms are organic by necessity because they cannot afford chemical inputs. However, they also cannot afford to pay for certification and therefore cannot achieve the price premium.
• Annual re-certification is required.

12.4.2 Fairtrade certification

The Fairtrade mark gives assurance to retailers and consumers that Fairtrade producers in the producing country are getting a fair deal for their work. Fairtrade certification overseen by "Flo-cert" also ensures adherence to strict social standards that foster healthy working conditions and prohibit child labour. Their environmental standards ensure that natural ecosystems are not degraded and cultivated land is used sustainably." Flo-cert is an international certification company owned by Fairtrade International but independently operational. It is responsible for the inspection of producers against FT standards on an annual basis. The standards specific to coffee can be accessed online. The opportunities and challenges for the organic certification are detailed in Table 43.

Farmers growing Fairtrade certified coffee must conform to prescribed production, processing and ware housing standards. (Figure 84).

Figure 84. *Fairtrade certification label in a coffee warehouse*

Table 43. Opportunities and challenges of Fairtrade certification

Opportunities
• Benefits of marketing/awareness campaigns carried out by Fairtrade International. • If assessors decide that standards are no longer being met, producers are given the support and time to enable them to rectify the problems. • Producers receive atleast the Fairtrade minimum price (varies by coffee type, origin and if it is grown organically) and additionally the Fairtrade Premium. The premium is an additional amount that is utilized to improve living conditions following guidelines set out by Fairtrade standard. • Producers can apply for financial assistance to cover fees of inspection and audit from the Producer Certification Fund. Many groups also receive assistance in paying certification fees from commercial partners or from NGOs/other partners.
Challenges
• All actors in the chain must be certified. Therefore producers must find out if there are Fairtrade buyers willing to buy their coffee in the countries they want to target. Simply getting certified themselves does not guarantee that they will be able to sell their product on Fairtrade terms to the desired consumers. • Continuous improvement by producers is required. • Small holders must be organised into a cooperative with more than 15 members. This is a barrier for isolated farmers or farmers located where the governance structures/skills are not present for farmers to form co-operatives. • FLO Cert Focuses on small-scale farms even though large-scale coffee estates are influential in promoting ethical supply chains. • The application process is expensive, costing about €500 plus the cost of the visit (the overall cost will vary depending on the number of days required). • Annual re-certification is required.

12.4.3 Rainforest alliance certification

"By promoting sustainable land-use practices, the Rainforest Alliance helps protect the environment and ensure the well-being of workers and their communities. The Rainforest Alliance certification is granted based upon compliance with standards compiled by the Sustainable Agriculture Network. (SAN) They promote human workers' rights, community relations, protection of biodiversity/ wildlife, conservation of natural resources, integration of crop/waste management and prohibition of hazardous chemicals. Businesses that source products grown on certified farms and farms that meet the Sustainable Agriculture Network (SAN) standard may apply to use the Rainforest Alliance Certified seal. RA-Cert is the Rainforest Alliance's auditing division, which provides independent and transparent verification, validation and certification services based on the standards. Full Rain Forest Alliance criteria can be found on the website; *www.rainforest-alliance.org/*. The percentage of certified content used in a product determines how the seal may be used on the final product. The opportunities and challenges for the Rain Forest system are detailed in Table 44.

Table 44. Opportunities and challenges of rainforest certification

Opportunities
• In 2017, 557,911metric tons of coffee, representing 9.4% growth compared to 2016. • International brands (including McDonalds, Kenco, Costa and Nespresso) stocking coffee which is Rainforest Alliance Certified has helped to boost public awareness. • Support is provided to certified producers and those in the process of achieving certification through aiding them in identifying their financial requirements, providing business advice, advising on how to use the mark to their best advantage and linking them with supporting institutions. • By implementing the Sustainable Alliance Network's (the Rainforest Alliance partners sustainable farm management system, farmers can control costs, gain efficiencies and improve crop quality. • SAN standards are available both for producer groups and for farms.
Challenges
• All businesses in the chain (buying, trading, mixing) products from certified farms must achieve SAN/ Rainforest Alliance Chain of Custody certification in order to call their product certified. • Annual re-certification is required.

12.4.4 Smithsonian Bird Friendly certification

The Smithsonian Migratory Bird Center (SMBC) gives this certification to farmers in order to promote shade-grown organic coffee plantations that can play a key role in the conservation of the global environment and of migratory birds that find sanctuary in these forest-like plantations." The criteria applied in the field for Bird Friendly coffee are designed to provide additional accreditation for those farms whose interaction with the environment exceeds organic practices. The aim is to sensitively integrate coffee cultivation to agroforestry systems for maximum benefit to the ecosystem. Additionally, some socio-economic criteria include that healthy environment for workers is created, pollution at the processing stage is avoided, community benefits are encouraged and, farmers are guaranteed fair and stable prices, access to markets and access to credit.

The shade criteria under the Smithsonian Bird Friendly standard are more stringent than those of the Rainforest Alliance standard. It requires atleast 11 species of canopy trees per hectare and the main canopy must be over 40 feet in height. Furthermore, the coffee must have more than 40% foliage cover provided by three forest layers. Full shade criteria can be found on the website; *www.qcsinfo.org/*. The opportunities and challenges for the Smithsonian system are detailed in Table 45.

Table 45. Opportunities and challenges for the Smithsonian bird friendly certification

Opportunities
• Potential benefits of using shade trees (e.g. better tasting coffee, recycling organic matter saves money). • Although no minimum price is set, producers can use the certification to negotiate a better price for their coffee. As much as 18% more than organic coffee can be achieved in the long term. • Eco-tourism possibilities for birdwatchers, nature lovers and agricultural tourists is possible. • Inspections can be done at the same time as the organic inspection to save time and money. • Audits are only once every 3years because shade cover does not change very much on an annual basis and this saves money for producers. • The organic inspector who visits the site in the intermediary years only need to visually assess the shade practices. • Provides a completely traceable product to the consumer – could be valuable instrument for market purposes.
Challenges
• All certified Bird Friendly coffee must also be certified organic. • Producers must pay for initial periodic audits. • Affects all of the actors along the chain: Importers pay a fee of US$100/yr and roasters pay 25cents/lb to be registered. These fees are used to support bird conservation research. • Many other plants besides the coffee plants require management. • Relatively new compared to other certifications and currently only sold in certain markets (e.g. US, UK, Canada, Japan and the Netherlands). • Few certified farms in Africa.

12.4.5 4C Common trade certification

The 4C Association is a global platform for stakeholders in the coffee sector to come together and collectively work to improve the economic, social and environmental conditions of those working in the industry. The code of conduct has four main pillars:

1. Rules of participation for trade and industry
2. Support mechanisms for farmers
3. A verification system, and
4. Participatory governance structure

The Code encompasses 10 Unacceptable Practices and a 4C Code Matrix presenting 28 principles for guidance on good sustainability practices. A traffic-light system acts as the indicator for how effectively the organization aligns itself with the 28 principles. To achieve certification the producer (or "unit") must have reached an "average yellow" level on the traffic light system as well as having excluded the 10 Unacceptable Practices. "Average yellow" means that within each dimension (economic, social, environmental) there may be some "red" practices so long as there is equal number of "green" to balance them out. The full details of these criteria can be found online on; *www.4c-coffeeassociation.org*

The certification system starts with a self-assessment and mapping exercise of all the business partners/ organizational structure. Then a third party completes an independent verification. Collective consultations are used for making revisions to the code. The opportunities and challenges for the 4C system are detailed in Table 46.

Table 46. Opportunities and challenges for the 4C common trade certification

Opportunities
• A 4C License is valid for three years. • Open to coffee producers at all levels. Seen as an improvement tool. To aid this, producers can get increasingly efficient by being trained in better agricultural practices, access to new technologies/materials, applying integrated pest management systems, record keeping and enhancing management capacity. • Freely available online information. • Seen as a first step/baseline in reaching other certifications. • Benchmarking partnership held with Rainforest Alliance for a 4C license without any additional cost or verification procedures. Be part of the international community to share new thinking/ideas and co-produce the standards. • Continuous improvement approach.
Challenges
• All actors in chain face a fee for membership (which increases along the chain). Must pay for verification on services (cost will depend on different factors e.g. the daily rate of the verifier, travelling expenses). The average cost per external verification is thought to be approximately €2,800. • During the 3 year interim period between audits the producers must conduct self- assessments on a yearly basis and send their results to the 4C Secretariat. • If they are expanding to include more farmers, 4C Units may need to be visited annually. • 4C verifiers may conduct additional unannounced random verification visits. • No on-product seal or labeling as promotion is mainly used business-to-business. • No minimum price but free to negotiate price based on high quality and sustainable production methods.

12.4.6 Starbucks C.A.F.E. practices

Starbucks CAFÉ (Coffee and Farm Equity) Practices is the company's green coffee sourcing program, started in 2004. The standards were developed in partnership with Conservation International and an independent third-party company, Scientific Certification Systems (SCS). Points are awarded in four categories to producers that supply Starbucks coffee. These are:

- Product quality
- Economic accountability
- Social responsibility and
- Environmental leadership

Certain criteria are mandatory for all suppliers. Reaching a certain point level confers preferred supplier status; a higher level is awarded strategic supplier status. These suppliers get enhanced pricing and contract terms. Although CAFÉ Practices is a proprietary set of sourcing guidelines and not a certification, their criteria are available to the public, much like those of various coffee certifications. There are some "Zero Tolerance" criteria (e.g. payment of minimum wage, no child labour and traceability), which must be complied within order to be part of the program. For the other criteria, however, the program establishes a quantitative scoring system. So even if farmers start with a low score, they can be part of the program and then gradually improve their performance in the course of the following years. Essential criteria of the standard include:

1. **Financial transparency-** including traceability of the coffee proceeds back to the farmer

2. **Social Responsibility**
   - Payment of minimum wage, compliance with national laws on overtime payment.
   - Freedom of association and collective bargaining

- Vacation and sick leave program for workers
- No child labour, discrimination, forced labour
- Decent housing conditions for workers living onsite
- Access to education, medical care
- Safe pesticide handling

3. Environmental Leadership on Farm

- Watercourse and water quality protection
- Controlling soil erosion
- Improving soil fertility
- Shade cover
- Wildlife conservation, natural conservation areas
- Ecological pest and disease management
- Management and monitoring practices

4. Environmental Leadership at Processing

- Minimize water consumption (wet mill)
- Minimize water pollution
- Waste recycling
- Minimize energy use

The following steps are only a selection of essential requirements of the standard, meant as an introduction. These are:

1. Application to Starbucks Coffee Company, including submission of a coffee sample
2. Application to a verifier approved by SCS
3. Quotation, Contract with the verifier
4. Pre-payment (50%)
5. Self evaluation

Onsite verification (all farms larger than 50 ha, all wet and dry mills have to be verified. From farms smaller than 50 ha, only sample needs to be verified)

1. Report submitted to supplier for approval or comments
2. Final payment to verifier
3. Report submitted to Starbucks Coffee Company (Farmer Support Center)
4. Final approval as "verified", "preferred" or "strategic supplier" by Starbucks

Annex 1: Health benefits of drinking coffee

A lot of recent research done on coffee suggests that coffee offers a host of potential health benefits. This incredibly complex beverage contains more than 1,000 compounds that can affect the body. The most commonly studied are caffeine (a nervous-system stimulant that's known to have positive cognitive effects) and polyphenols (antioxidants that can help slow or prevent cell damage). Though researchers don't always know exactly which of coffee's ingredients are responsible for producing their studies' health-boosting results, there's evidence that drinking coffee does help in the following:

1. Improves overall health

An analysis of nearly 220 studies on coffee, published in the "British Medical Journal" in 2017, found that coffee drinkers may enjoy more overall health benefits than people who don't drink coffee. The analysis found that during the study period, coffee drinkers were 17 percent less likely to die early from any cause, 19 percent less likely to die of heart disease and 18 percent less likely to develop cancer than those who don't drink coffee.

2. Protects against Type 2 Diabetes

A 2014 study by Harvard researchers published in the journal *"Diabetologica"* tracked nearly 124,000 people for 16–20 years. Those who increased their coffee intake by more than a cup a day over a four-year period had an 11 percent lower risk of developing Type 2 diabetes; those who decreased their intake by one cup per day had a 17 percent higher risk of developing the disease.

3. Controls Parkinson's Disease Symptoms

A number of studies have suggested that consuming caffeine can reduce your risk of developing Parkinson's disease — and research published in 2012 in the journal of the "American Academy of Neurology" showed that a daily dose of caffeine equivalent to that found in two eight-ounce cups of black coffee can help to control the involuntary movements of people who already have the disease. (You'd have to drink nearly eight cups of brewed black tea to get the same amount of caffeine.)

4. Slows the progress of Dementia

In a 2012 study published in the *"Journal of Alzheimer's Disease"*, Florida researchers tested the blood levels of caffeine in older adults with mild cognitive impairments, which can be a precursor to severe dementia, including Alzheimer's disease. When the researchers re-evaluated the subjects two to four years later, those whose blood levels contained caffeine amounts equivalent to about three cups of coffee were far less likely to have progressed to full-blown dementia than those who had consumed little or no caffeine.

5. Safeguards the Liver

Several studies published in respected journals have found that coffee drinking has beneficial effects on the liver, including reducing the risk of death from liver cirrhosis, decreasing harmful liver enzyme levels and limiting liver scarring in people who have hepatitis C.

6. Promotes Heart Health

In 2013, the journal "Epidemiology and Prevention" published a review of studies analyzing the correlation between coffee consumption and cardiovascular disease. Data from 36 different studies showed that people who drink three to five cups of coffee per day had a lower risk of heart disease than those who drink no coffee or more than five cups per day. While the reason isn't clear, one possibility is that coffee helps to improve blood vessels' control over blood flow and blood pressure.

7. Reduces Melanoma Risk

A recent study appearing in the "Journal of the National Cancer Institute" looked at the coffee-drinking habits of more than 447,000 people over 10 years. The researchers found that those who drank four or more cups of caffeinated coffee each day had a 20 percent lower risk of developing melanoma than people who drank decaffeinated coffee or no coffee.

Annex 2: Arabica Coffee gross margin per hectare (Ushs)

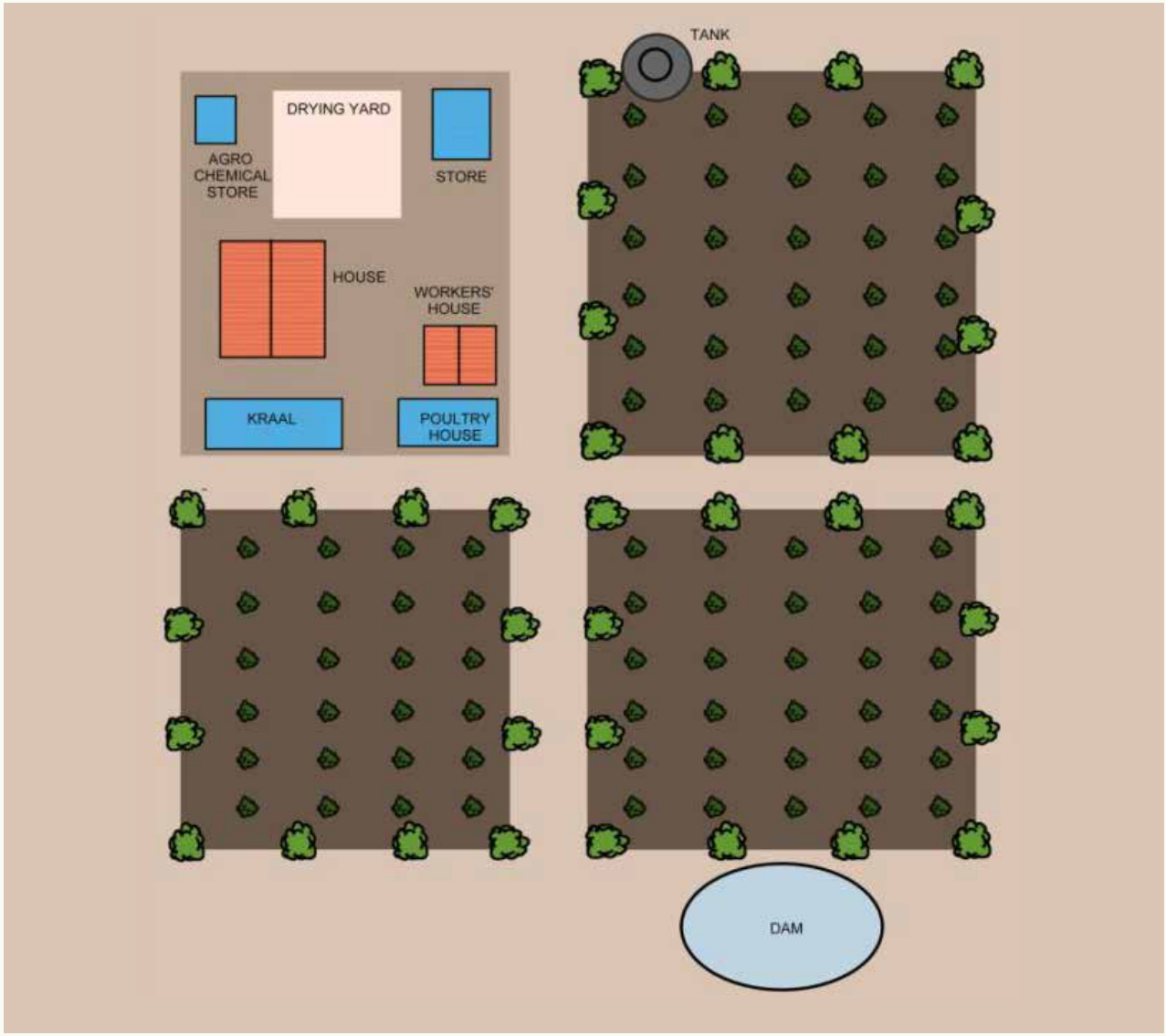
Activity	Physical Measure And Costing (Ushs)	Quantity	Rate	Year 1	Year 2	Year 3	Year 4	Year 5
Bush clearing	375,000 @ha	1	375,000	375,000				
Land opening 1st & 2nd	500,000 @ha	1	500,000	500,000				
Field establishment labour: I ha								
Well fermented cow dung manure	2 Truckloads @150,000		300,000	300,000			300,000	
Field marking	1,640 holes marking	1,640	50	82,000				
Digging planting holes	1,640 holes digging	1640	500	820,000				
Refilling the holes with soil and manure	1,640 holes refilling	1,640	200	328,000				
Shade trees planting				200,000				
Recommended Arabica seedlings	1,640 plantlets (clones)	1,640	1200	1,968,000				
Planting seedlings into holes	1,640 seedling planting	1,640	100	164,000				
Field acclimatization (first month)				250,000				
Provision for gap filling					50,000			
Purchase of banana suckers	275 suckers	275	2000	550,000				
Coffee/banana intercrop 4:1	275 banana holes digging and planting	275	1500	412,500				
Beans intercrop seed cost	40 kg per year	40	6000	240,000	240,000			
Beans intercrop seed cost				50,000	50,000			
Mulching	Bundles of straw			400,000	400,000		400,000	
Erosion controls e.g. fertigation trenches	40 Man days	40	8000	320,000	250,000	60,000	60,000	60,000
Sub-Total				6,959,500	990,000	460,000	760,000	60,000
Inputs								
Fertilizer: CAN, NPK 25-5-5, 500 g per tree per year	@140,000	2	140000		2,296,000	2,296,000	2,296,000	2,296,000
Fertilizer and chemical applications	12.5 man days	12.5	8000		100,000	150,000	50,000	50,000

Activity	Physical Measure And Costing (Ushs)	Quantity	Rate	Year 1	Year 2	Year 3	Year 4	Year 5
Farm tools and equipment	Hoes, pangas, secateurs etc.			60,000	60,000	60,000	100,000	100,000
Pests and disease controls	5 litres @Ushs 40,000				200,000	200,000	200,000	200,000
Herbicides and application	A litre@ Ushs 30,000					150,000	150,000	150,000
Tarpaulins	6 pieces @60,000				60,000	360,000	360,000	360,000
Gum boots				40 000				
Farm overall				50,000				
Watercan, jerrycan, spade, garden fork slasher				50,000				
Wheelbarrow				120,000				
Gunny bags	bags@3000				12,000	64,000	100,000	100,000
Sub-Total				280,000	2,728,000	3,280,000	3,256,000	3,256,000
Field maintenance:								
Training of coffee (pegging)				100,000				
Coffee weeding	200,000 per weeding	4	200,000	800,000	800,000	400,000	400,000	400,000
Thinning and pruning of banana	200,000 per year				200,000	200,000	200,000	200,000
Sub-Total				**900,000**	**1,000,000**	**600,000**	**600,000**	**600,000**
Harvesting of coffee and beans								
Harvesting	150 Ushs/kg of fresh cherry				450,000	1,200,000	1,875,000	1,875,000
Drying process	500kg of parchment dried at Ushs 35,000				35,000	112,000	175,000	175,000
Post-harvest handling of beans costs	200,000 per year			200,000	200,000			
Transport expenses: home & market	Truck hire @50,000/ trip				50,000	400,000	500,000	500,000
Sub-Total					735,000	1,712,000	2,550,000	2,550,000

Activity	Physical Measure And Costing (Ushs)	Quantity	Rate	Year 1	Year 2	Year 3	Year 4	Year 5
Provision for 5% Contingency costs	Contingency 5%			100,000	100,000	100,000	100,000	100,000
Amortized cost (Ushs/ha)1				0	0	0	0	0
Depreciation of equipment (Ushs/ha)				0	0	0	0	0
Total Variable Costs (TVC)				8,439,500	5,553,000	6,152,000	7,266,000	6,566,000
Expected income								
Annual yield (kg/ha) of dry cherry or parchment (5kgs of cherry=1 kg of parchment					600	1,600	2,500	2,500
Unit cost of production (Ushs/kg)	Unit cost=TVC/total output					3845	2906.4	2626.4
Farm gate price (Ushs/kg parchment)					7000	7,000	7,000	7,000
Gross income from beans	1200 kgs@Ushs 1800			2,160,000	2,160,000			
Gross income from banana yield (Ushs/ha)	156 bunches @Ushs 10,000			1,560,000	1,560,000	1,560,000	1,560,000	1,560,000
Gross income-coffee					**4,200,000**	**11,200,000**	**17,500,000**	**17,500,000**
Overall gross income				**3,720,000**	**7,920,000**	**12,760,000**	**19,060,000**	**19,060,000**
Gross margin	**Gross income- Total variable cost**			**(4,719,50)**	**2,367,000**	**6,608,000**	**11,794,000**	**12,494,000**
	Cumulated net income/Hectare			(4,719,50)	(2,352,50)	4,255,500	16,049,500	28,543,500
	Cumulated net income/Acre			(1,910,72)	(952,429)	1,722,874	6,497,773	11,556,030
Assumptions of Recommended Coffee practices farmer								
1. He/she adopts most of the GAPs								
2. He/she applies recommended amounts of fertilizers and/or manures								
3. He/she carries out proper canopy management								
4. He/she carries out pest and disease management								

Annex 3: Farm layout

It requires advance planning before any field operation. It includes the following whose relative positions/ locations on the farm are important.



1. The Farm household.
2. Farm blocks, or divisions.
3. Coffee drying yard (this is usually near the Farm household and up slope in relation to other structures like the Kraal).
4. The Coffee store.
5. The agro-chemicals store.
6. The workers house.
7. The farm road
8. Other farm structures like the irrigation structures (the water source, irrigation pipes, Tanks) etc. (the water sources for irrigation/Dams are usually sited at the low altitude positions of the farm).
9. Other enterprises/farm structures at the farm like poultry/cattle etc.

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