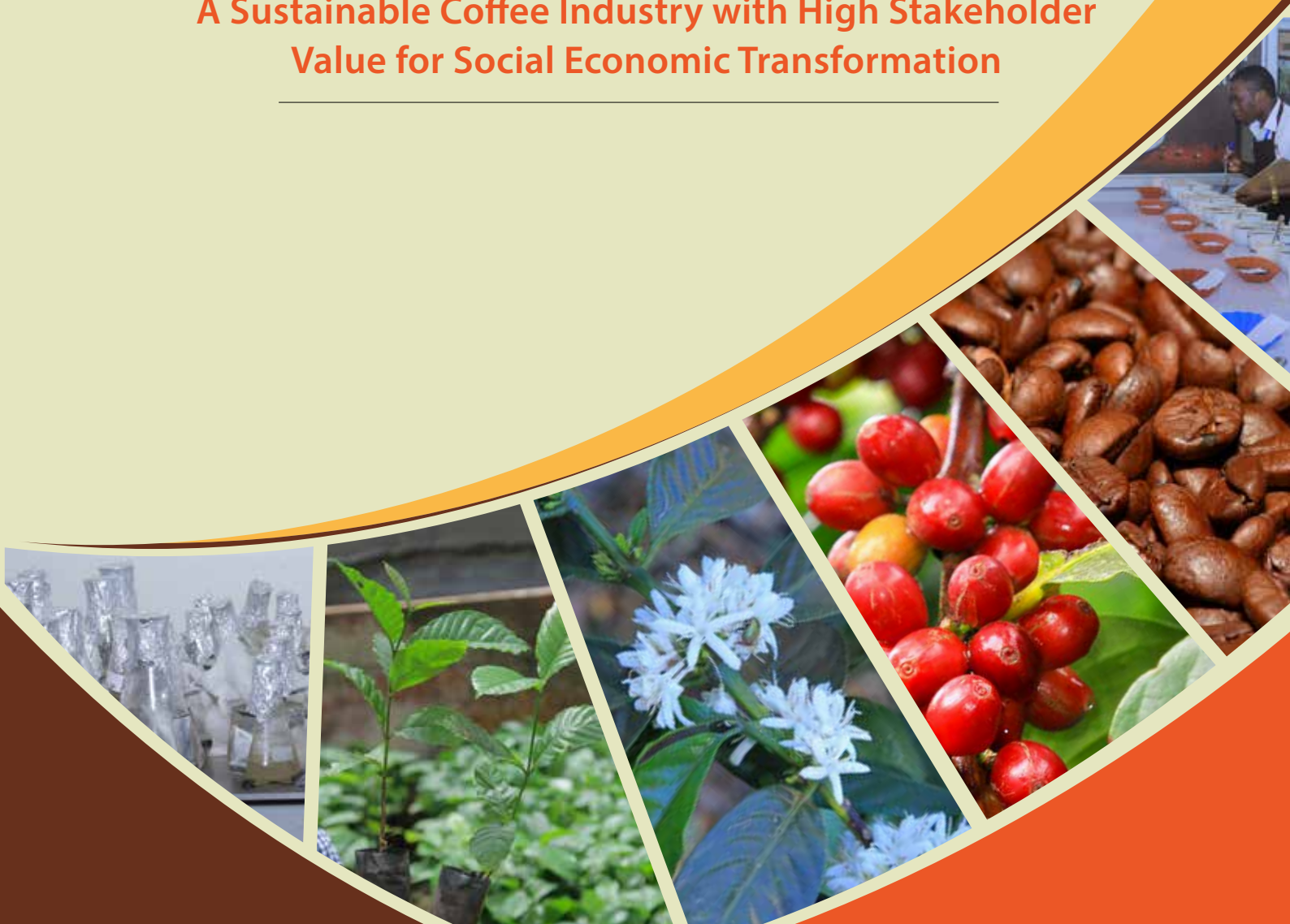
THE MINISTRY OF AGRICULTURE,
ANIMAL INDUSTRY & FISHARIES

Uganda Coffee
Development Authority

ROBUSTA COFFEE HANDBOOK

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



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Uganda

THE BIRTHPLACE OF ROBUSTA COFFEE

Uganda Coffee
Development Authority

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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.

This handbook has therefore been prepared to guide Robusta 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, the 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

ROBUSTA COFFEE GROWING IN UGANDA

1.0 Background

Coffee is the second most traded tropical commodity (in value) in the world after oil. Coffee is the major cash crop of Uganda, 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 the coffee value chain related activities.

1.1 Government policy and strategy on 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 of 1994. Coffee research is centralized and done under National Agricultural Research Organisation (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 Uganda Coffee Development Authority (UCDA) 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.

Coffee can grow in most districts of Uganda. In fulfillment of the Government's policy and strategy, coffee production is being strengthened in old traditional zones but also being encouraged in new areas. Rapid replacement of the old low productive coffee with high yielding, quick maturing and disease tolerant improved Robusta varieties is encouraged. Farmers are being sensitized to grow the high yielding clonal coffee, employ good husbandry practices and participate in marketing through their Farm Level Organizations (FLOs) or cooperatives.

The coffee roadmap targets a five-fold increase in production of quality coffee from the current figure of about 4.6 million bags to 20 million bags by the year 2025, 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 strategy 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 envisaged to drive this undertaking.

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 are employed by all categories of value chain players and most particularly, the coffee farmers, traders and processors. Therefore, acquiring good planting material, employing proper husbandry practices, ensuring that good pest and disease control

methods are undertaken, carrying out good post harvest handling and engaging in coffee production as a business is crucial. By joining and producing through farmer organizations too would enhance the achievement of economic benefits from coffee production through pooling resources, commodity bulking, increasing bargaining power and chances of directly dealing with exporters. This Robusta Coffee Production Handbook acts as a guide in all these aspects.

1.2 Characteristics of Robusta Coffee and its importance

Robusta Coffee *(Coffea canephora)* is grown in the low altitude areas of Uganda, ranging from about 900 metres to 1,200 metres above sea level. It has a shallow root system and grows as a robust tree or shrub to about 10 m tall. It flowers irregularly, taking about 10–11 months for cherries to ripen depending on rainfall distribution, producing oval-shaped beans. Robusta Coffee has a greater crop yield per tree than that of Arabica, contains more caffeine (2.7% compared to Arabica's 1.5% and contains less sugar (3–7% compared to Arabica's 6–9%). It is less susceptible to pests and disease, thus, needs less fungicides and pesticides than Arabica.

Commercial production of Robusta Coffee began in the early 1920's and an extensive production program was undertaken in the 1950s. By 1960, coffee production had risen to about 2 million 60Kg bags and reached its first peak of 3.7 million in the 1972/73 coffee year and 4.2 million bags in 1996/97. However, due market imperfections, old age of coffee trees and poor agronomic practices, production had again declined to as low as 2.1 million bags by 1991. After coffee liberalization in 1991, production has been improving despite the Coffee Wilt Disease (CWD) that has destroyed about 56% of Robusta trees since its detection in 1993, causing a big constraint to Robusta Coffee production. However, through research and extension, coffee wilt disease resistant and high yielding varieties are currently available and being distributed to farmers thereby boosting production. Currently, out of 104 districts growing coffee, 60 growing only Robusta Coffee while 13 grow only Arabica. 38 districts grows both Robusta and Arabica Coffee. Robusta Coffee production stands at about 3.3 million bags.

Benefits of growing Robusta Coffee include:

- Provides an assured income.
- Uganda's high altitude Robusta is of a better cupping quality and fetches a higher price (premium).
- Can be well integrated with other crops on the farm hence increasing returns per unit area to the farmer.
- It is a beverage with well-documented health benefits.
- Source of employment.
- It is perennial, remaining productive for up to 40-50 years without replanting.

1.3 Robusta Coffee growing zones in Uganda

Robusta is the major type of coffee grown in Uganda, accounting for about 80% of production. It grows in most low altitude areas of Uganda, covering Central, Eastern, Mid North, West Nile, Western and South Western Uganda that are within 900 - 1,500m above sea level. Robusta has Lake Victoria Crescent as its native habitat. Wild Robusta still grows in natural forests around the Lake Victoria Basin and in the Kibaale and Zooka-Adjumani forest reserves where it is estimated that between 150-400 hectares are still under wild Robusta Coffee as shown in Figure 1.

1.4 Robusta Coffee varieties in Uganda

Since 2009, the National Agricultural Research Organization (NARO) has released 10 varieties of coffee that are high yielding and resistant to Coffee Wilt Disease. These varieties with their description, year of release and major attributes are presented in Table 1.

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

Table 1. Recommended Robusta Coffee varieties

Robusta Coffee Variety	Description	Year of release	Current status	Major attributes	Remarks
Elite	Mixture of open pollinated seed above Robusta clones	First recommended in 1995		Yield 2000kg/ha/yr, susceptible to rust, red blister and CWD	Being phased out
6 old clones (1s/2, 1s/3, 1s/6, 223/32, 257/53, 258s/24 (0))	Cuttings raised from bare roots initially cut from a mother garden.			Yield 2,500kg/ha/year, susceptible to leaf rust, red blister and CWD	Are susceptible to CWD.
KR1 (NARO-Kituza Robusta1)	Ugandan clone	2009	Contemporary variety	Yield 2200kg/ha/cc/yr; resistant to leaf rust, tolerant to RBD resistant to CWD, has big beans, good cup quality	Recommended
KR2 (NARO-Kituza Robusta 2)	Ugandan clone	2009	Contemporary variety	Yield 2600kg/ha/cc/yr; resistant to leaf rust, tolerant to RBD, resistant to CWD, has big beans, good cup quality	Recommended
KR3 (NARO-Kituza Robusta 3)	Ugandan clone	2009	Contemporary variety	Yield 4900kg/ha/cc/yr; resistant to leaf rust, tolerant to RBD, resistant to CWD, has big beans, good cup quality	Recommended
KR4 (NARO-Kituza Robusta 4)	Ugandan clone	2009	Contemporary variety	Yield 2300kg/ha/cc/yr; resistant to leaf rust, tolerant to RBD, resistant to CWD, has big beans, good cup quality	Recommended
KR5 (NARO-Kituza Robusta 5)	Ugandan clone	2009	Contemporary variety	Yield 2900kg/ha/cc/yr; resistant to leaf rust, tolerant to RBD, resistant to CWD, has big beans, good cup quality	Recommended.
KR6 (NARO-Kituza Robusta 6)	Ugandan clone	2009	Contemporary variety	Yield 2600kg/ha/cc/yr; resistant to leaf rust, tolerant to RBD, resistant to CWD, has big beans, good cup quality	Recommended.
KR7 (NARO-Kituza Robusta 7)	Ugandan clone	2009	Contemporary variety	Yield 3000kg/ha/cc/yr; resistant to leaf rust, tolerant to RBD, resistant to CWD, has big beans, good cup quality	Recommended.
KR8 (NARO-Kituza Robusta 8)	Ugandan clone	2017	Contemporary variety	Yield 3100kg/ha/cc/yr; resistant to leaf rust, tolerant to RBD, resistant to CWD, has big beans, good cup quality	Recommended. NaCORI is still building plant stock to distribute to nursery operators
KR9 (NARO-Kituza Robusta 9)	Ugandan clone	2017	Contemporary variety	Yield 3900kg/ha/cc/yr; resistant to leaf rust, tolerant to RBD, resistant to CWD, has big beans, good cup quality	Recommended. NaCORI is still building plant stock to distribute to nursery operators
KR10 (NARO-Kituza Robusta 10)	Ugandan clone	2017	Contemporary variety	Yield 4800kg/ha/cc/yr; resistant to leaf rust, tolerant to RBD, resistant to CWD, has big beans, good cup quality	Recommended. NaCORI is still building plant stock to distribute to nursery operators

1.5 Objectives of the Handbook

Coffee is a strategic commodity whose development is being accelerated across the country to enable the sector to continue playing a leading role to income generation for coffee value chain stakeholders. To achieve this, it is critical that Ugandan coffee farmers enhance their production and productivity at farm level in a sustainable way that addresses social, ecological and economic dimensions. The Government approved and launched the National Coffee Policy in 2013 and the National Agricultural Extension Policy in 2017, both of which 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 knowledge and skills to help build the human resource capacity.
- Assist in building an efficient and effective public and private extension service for Robusta Coffee production and marketing.
- Increase awareness on the part of the general public on benefits of growing Robusta Coffee.
- Facilitate the growth of Robusta 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 in the medium term.

CHAPTER 2

ROBUSTA COFFEE AGRO-ECOLOGICAL REQUIREMENTS AND PRODUCTION SYSTEMS

2.0 Introduction

Robusta Coffee is more tolerant to pest infestation and is well adapted to warm and humid equatorial climates. And when handled and processed properly, it can be a product for specialty markets, fetching premium prices on the international market.

2.1 Soil and Land Requirements

Robusta Coffee can grow on different soil types. But for best root establishment and high yields, it requires a fertile, well aerated, free draining, slightly acidic, deep soil with reasonable humus content and a minimum depth of 1-1.5m in well moist and 3m in drier areas. Robusta does 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. A pH level below 5.5 will limit crop performance and at this level, adequate liming must be done to correct the pH levels back to a suitable range.

2.2 Altitude

Robusta Coffee production requires an altitude range of 900-1500 metres above sea level. Different altitudes produce different cup profiles. Robusta Coffee grown at higher altitude tends to be more acidic and complex while that grown at lower elevation tends to be more intensely flavored. Uganda is a classic case showing differences in elevation. It produces relatively high altitude Robusta Coffee at an average of 1200m above sea level.

2.3 Temperature

Robusta Coffee requires warmer temperatures ranging from 22° - 28°C (71 - 82°F). It is much more tolerant to hot conditions compared to Arabica Coffee. Temperatures higher than 30^0C can cause a range of physiological problems, including flower abortion poor fruit setting, development and premature ripening. At this relatively high temperature, photosynthesis is also reduced. On the other hand, frost damage can occur if temperatures fall around 0^0C or below.

2.4 Rainfall and Humidity

Robusta requires a rainfall range of 1,200 mm to 1,800 mm, 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 seedlings should be irrigated (or hand watered) atleast twice a week to ensure that the seedlings get established. Also, where there is inadequate rainfall during growth, supplementary watering/irrigation to sustain continuous growth, induce uniform flowering and good fruit formation should be carried out.

A fairly regular/frequent rainfall pattern throughout the cherry development stage is required. A good soaking of 25 mm every 14 days or approximately 20-litres (1 jerrycan) of water per plant is required to stimulate flowering and sustain fruit formation. Rainfall triggers the flowering and fruit filling process. Without adequate and sustained rainfall/ moisture, flowering may extend over many months making harvesting uneven, more difficult to achieve

good quality of harvested berries and becomes costly to the farmer.

Excessive droughts can cause the coffee tree to become dehydrated and thus lead to its defoliation and or increased attacks of pests such as the red spider mite, leaf miner, twig borer and the coffee berry borer or even death through wilting.

Excessive continuous rainfall can, on the other hand cause excessive vegetative growth and inhibit the flowering of the coffee tree or destroying it altogether. Thus, locating coffee plantation near a water supply for possible irrigation as well as for processing of cherry is desirable.

2.5 Wind Effects

Strong winds have an adverse effect on coffee growth because they can cause excessive water evaporation and tree breakage and increase the demand for irrigation. Therefore in especially windy areas it is desirable to establish windbreakers along borders of the coffee plantation.

2.6 Robusta Coffee Production Systems

The farmer needs to know the kind of system he/she needs in order to plan for field activities accordingly. Two types exist i.e. mono cropping (pure stand) and intercropping (mixed stand).

2.6.1 Monocropping System

Monocropping is an agricultural practice of growing coffee as a single crop or pure stand on one piece of farmland as shown in Figures 2(a) and 2(b). The advantages and disadvantages of coffee monocropping are highlighted in Table 2.

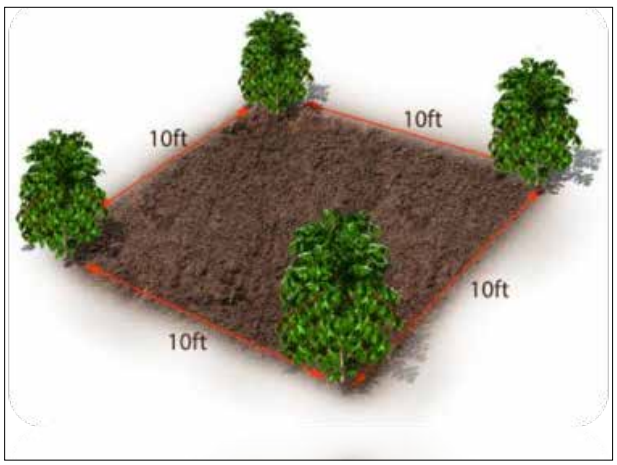


Figure 2(a). *An illustration of Robusta Coffee monocrop at a spacing of 10 x 10ft*

Figure 2(b). *Robusta Coffee monocrop at a spacing of 10 x 10ft*

Table 2. Advantages and disadvantages of Coffee monocropping

Advantages	Disadvantages
• The coffee growing requirements, planting, maintenance including pest control and harvesting are the same across the farmed land. This lowers specific operational costs and enhances optimization of those operations. • 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.	• Food Insecurity: While increased coffee yields may be attained, it can potentially reduce the food available to feed the households. • Growing the same coffee crop year-after-year depletes valuable soil nutrients that plants rely on and hence this deficiency must be compensated for by using increasing amounts of appropriate fertilizers. • High income risk in case of crop failure. • Monoculture is highly susceptible to pests and diseases, requires intensive use of chemicals to control pests, diseases and weeds. • Limits optimum utilization of land and the resultant farm revenue.

2.6.2 Intercropping

Intercropping also known as mixed cropping or co-cultivation is a type of agriculture that involves planting coffee plus one or more 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 in young coffee include bananas, green pepper, cabbages, tomatoes, soya-beans, groundnuts and the non-climbing *Phaseolus* beans. 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 is important to note however, that growing beans on the same plots continuously, particularly in the humid areas, may result in serious problems of aphids. This practice therefore, must be avoided. Maize, millet, rice and root tubers such as potatoes and cassava are high nutrient demand crops and therefore not recommended.

The coffee-banana intercropping, as shown in Figures 3(a) and 3(b), is a major type of coffee system in Uganda. 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. 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. In this combination, each banana plant would shade four coffee bushes and each coffee bush would be shaded by only one banana plant. Advantages and disadvantages of the Robusta Coffee intercropping are highlighted in Table 3.

Table 3. Advantages and disadvantages of the Coffee-Banana intercrop system

Advantages	Disadvantages
• 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 risks faced by farmers when cultivating monocrops. • Return to labour is often higher in banana–coffee systems. It increases total revenue/inflow per unit area by over 50% 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 root development in both banana and coffee and improves availability of potassium (K) in the topsoil, due to the large biomass turnover. • The permanent canopy and root systems of banana reduce soil losses due to erosion by reducing the impact of rainfall drops and run offs on the topsoil. • Reduces greenhouse gas (GHG) emissions by increasing above and below-ground carbon stocks.	• It increases competition for water, nutrients and light. Bananas generally suffer more. • It is labour intensive and requires a lot of management and care. • If shade is too dense, the yield potential of coffee may be reduced due to competition of the coffee and the intercrop.

"Coffee banana intercrop is a good multipurpose practice that displays diversification and soil and water conservation benefits. It is a climate change adaptation measure"

The following practices/requirements help farmers to attain maximum yields in intercropped coffee:

- Establish the production system where rainfall is more than 900 mm/year.
- Establish production on fertile soil where Nitrogen, Phosphorous, Potassium and Magnesium are not limiting nutrients. Poor soil fertility limits production of banana and coffee in most cases.
- Select deep, well-drained fertile soil with good water holding capacity and a pH that is between 5.5 and 6.5. Deeper soils (1 m or more) allow plants to develop a taproot and a more extensive root system.
- Apply mineral fertilizers to supply the right nutrients. Do not add fertilizers to coffee that is heavily shaded because the increase in coffee yield may not be sufficient to cover the extra investment in fertilizers.
- Carry out proper canopy management to ensure the required balance between banana and coffee plants which in turn maximises benefits from fertilizer application. This is achieved by properly pruning of coffee trees and also properly de-suckering banana plants.
- Grow quick maturing annual crops such as tomatoes and bush beans between banana and coffee for one to two years to obtain income before the bananas and coffee are ready for harvesting. Coffee benefits when tomatoes are sprayed with fungicides while legume crops such as bush beans provide nitrogen–rich crop residues that benefit coffee and banana plants.
- Establish proper spacing for both banana and coffee. Spacing of 10x10ft. (Coffee) and 20x20ft (Banana) is appropriate. However, do not intercrop young banana and coffee plants with climbing crops e.g. climbing beans.
- Use carefully selected good quality and disease free materials for coffee and all the intercrops.
- Carry out proper mulching by using crop residues. Mulch from banana pseudo-stems and leaves and coffee pruning residues, is particularly valuable in areas with marginal rainfall.
- Carry out good pest and disease control measures, practice proper weeding and establish proper drainage effectively.
- Set up soil conservation measures, such as terraces and grass strips, on land with a slope.

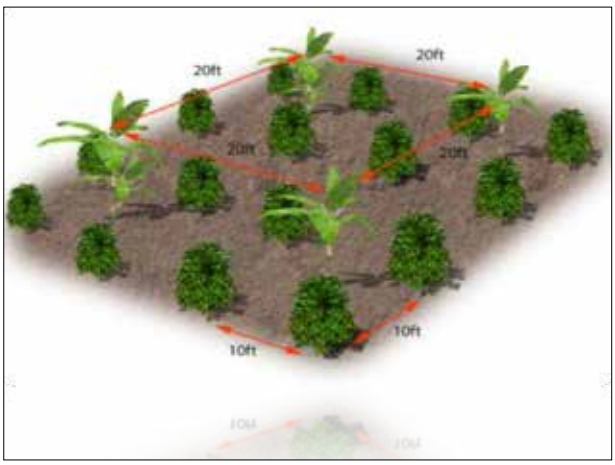


Figure 3(a). *An illustration of Robusta Coffee-Banana intercrop paced at 10 x 10ft for coffee and 20 x 20ft for Banana*

Figure 3(b). *Coffee-Banana intercrop spaced at 10 x 10ft for coffee and 20 x 20ft for Banana*

CHAPTER 3

ROBUSTA COFFEE FARM ESTABLISHMENT AND FIELD MANAGEMENT PRACTICES

3.0 Introduction

Robusta Coffee farm establishment starts with land preparation whose objectives is to facilitate maximum water infiltration and minimal soil movement, safe disposal of surplus water and simplification of irrigation works. Land preparation also facilitates the establishment of a good road system within the plantation. Once land is cleared and coffee is planted, attention shifts to good management practices. Poor field management significantly contributes to low productivity in coffee and should be avoided. For maximum benefits, farmers should therefore make adequate investments in the Coffee farm establishment and its field management practices.

3.1 Coffee Farm Establishment

The area to be planted with coffee must be prepared atleast 1 year before the coffee seedlings are planted out. There are 9 distinct steps to follow:

1. Clear the site
2. Plant Windbreakers
3. Mark out the rows
4. Establish shade trees
5. Set up water delivery systems
6. Dig holes
7. Select good planting materials
8. Plant seedlings
9. Put temporary shade and water the seedlings

3.1.1 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. The roots of old tree stumps are frequently a source of infection of 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 20x20m. This gives a good shade cover, while avoiding competition for water and nutrients.
- Fallow land in Uganda is commonly infested with couch grass (Lumbugu), usually the worst enemy of coffee. This must therefore be completely eradicated either by digging and handpicking 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 cover crops should be planted to avoid erosion.
- For sloped terrain, establish terraces using a wooden frame tool, as shown in Figures 4(a) and 4(b).
- With land up to 15% slope, run the rows across the slope making sure there is a fall of 1 to 2% for drainage.
- When land is greater than 15% slope, contour planting must be undertaken.
- Practice water conservation measures such as contour trenches, contour terraces, vegetative barriers, bands, grass strips and cut-off drains to avoid soil, water and nutrient loss.

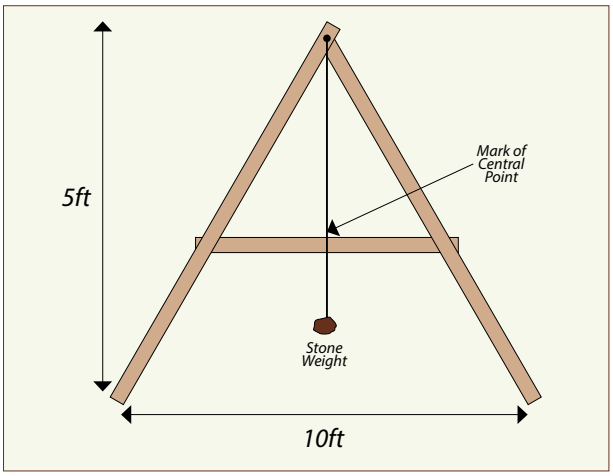


Figure 4(a). *An A- frame for establishing contours to mark terraces in the coffee garden*

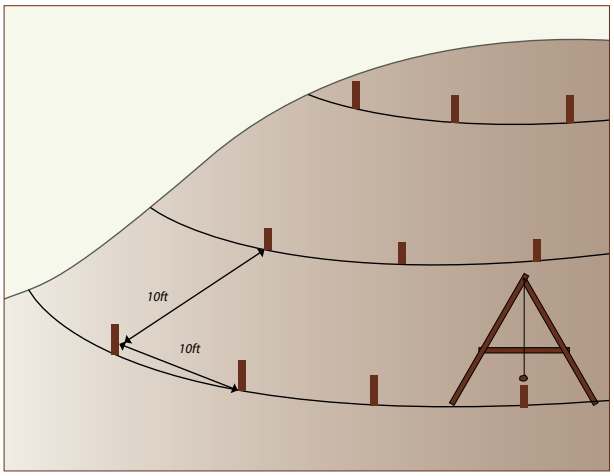


Figure 4(b)*. Using an A- frame to find the contours and mark out the planting holes in the garden*

3.1.2. Plant Windbreakers

Windbreakers are usually located along boundaries of the coffee plantation as shown in Figures 5(a) and 5(b). They should be established before planting the coffee. Preferred trees include avocados, jackfruit and mangoes. Other useful trees used include *Ficus natalensis*, which is preferably planted at a spacing of 60ftx60ft. The spacing between windbreakers on sloping land however should be closer. Windbreakers are useful in many ways. They help to:

- 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 limits erosion
- Increase biodiversity and may provide farmer with alternative source of income.

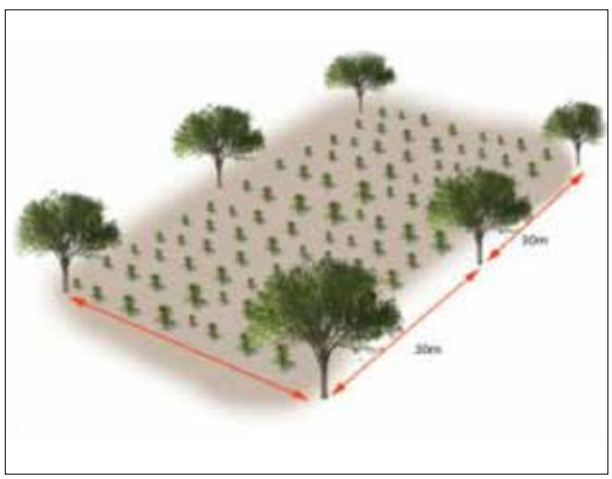


Figure 5(a). *Windbreakers planted at a spacing of 30m on flat gradient*

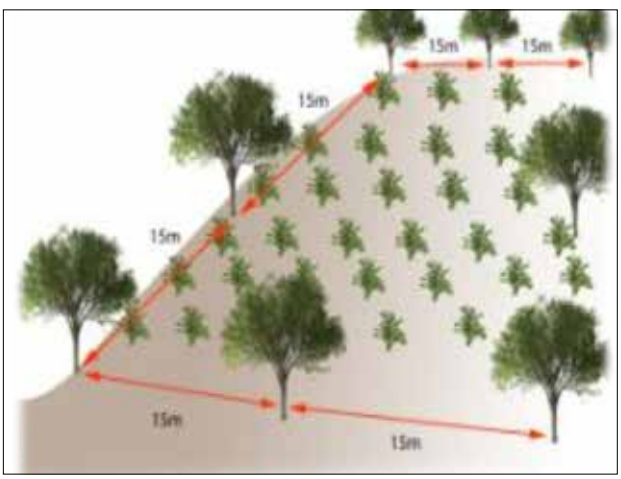


Figure 5(b). *Windbreakers planted at a spacing of 15m on a slope*

"Windbreakers are a climate change mitigation and adaptation measure"

3.1.3 Mark out the Rows

Marking rows for planting coffee is important in establishing a coffee farm. The recommended row-direction is east/west direction because it makes most use of sunlight. The recommended spacing of Robusta Coffee by NaCORI is 10ft x10 ft. (3mx3m). This should result in about 450 plants per acre. However, trials are being done at NaCORI, Kituza, aiming at increasing tree density per acre. Results should be availed in the short to medium term, with attendant GAPs recommendations to guide farmers.

3.1.4 Establish Shade Trees

Given this era of climatic change (weather extremes), shade trees are very important in coffee farming as shown in Figures 6(a), 6(b) and 6(c). Farmers should establish shade trees atleast one year before coffee is planted out. 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 in addition to over-shading the coffee trees. It is recommended that the spacing of the shade trees be approximately 20-40m apart depending on the tree species and expected canopy profile. In warmer and drier areas such as the mid-north of Uganda, shade tree spacing should be planted at shorter distances, but after recommendation from the field extension officer, while on site. Once shade trees are 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 garden - a condition favorable to disease and pest development such as coffee leaf rust and/or black coffee twig borer. Shade trees should be pruned at the beginning of the rainy season. Keep the trees at a maximum height of 4-5m to facilitate easier management. Advantages and disadvantages of shade trees are listed in Table 4.

Table 4. Advantages and disadvantages of Shade Trees

Advantages	Disadvantages
• Shade trees protect the coffee bushes from heavy rainstorms and hailstorms. • Shade trees reduce the intensity of wind speeds and soil erosion and act as windbreakers. • Shade trees protect coffee plants from high solar radiation and limit evapotranspiration • Shade trees limit weed growth. • Reduces decay rate of organic matter in soil. • Increases biodiversity by promoting higher populations of birds, predators of coffee pests and pollinators of coffee plants thereby improving fruit formation. • Reduces plant metabolism and encourages more regular flowering. • Helps to stabilize the soil, reduce soil erosion and water runoff. • Shade trees is a requirement for sustainable coffee farming.	• Shade trees may compete with coffee for nutrients and water. • Requires regular loping and thinning which is labour intensive. • Shade if poorly managed 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 shade trees.

Advantages	Disadvantages
• Shade trees slows down coffee cherry ripening, thereby improving bean density and cup flavour. • Shade trees play a role in efficient utilization of nutrients by taking up leached nutrients that are outside the reach of the coffee tree root zone and returning these nutrients to the top soil through litter fall which acts as mulch. • When leguminous trees are used as shade trees, they fix nitrogen from the air to restore soil fertility and structure. • Shade trees provide diversified income from products like firewood and also the pruned shade tree branches provide fuel for farm activities like the drying furnace and cooking	

Figure 6(a), (b) and (c). *A Robusta Coffee plantation intercropped with shade trees*

The following tree species are recommended for growing in different regions of Uganda as seen in Figure 7.

1. Central Region
- *Ficus natalensis* (Mutuba);
- *Albizia coriaria* (Mugavu, Musisiya)
- *Ficus mucuso* (Mukunyu, Kabalira)

2. Mid-Northern Sub-Region
- *Ficus natalensis* (Annar, Ananga),
- *Albizia coriaria* (Litek, Ober, Bata, Latoligo, Omogi, Ayekayek)
- *Cordia africana* (Akoiyi)
- *Ficus ovata* (kwoyo, pwoyo)

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

4. Busoga Sub-Region
- *Ficus natalensis* (Mugaire, Kiryanyonyi),
- *Ficus mucuso* (Mukunyu)
- *Ficus ovata* (Kookowe)

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

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

- Trees that are alternate host to the black coffee twig borer e.g. Avocado and *Albizia chinensis*;
- Hardwood trees that attract pit sawyers e.g. *Grevillea Robusta* and *Maesopsis eminii* (Musizi);
- Trees that take very long to grow e.g. *Milicia excelsa* (Mvule);
- Trees that can only provide a conical shaped shade e.g. Eucalyptus, Jack fruit trees.
- Trees that have leaves, which take very long to decompose.
- Trees that produce thorns as these are very difficult to tame e.g. *Erythrina abyssinica* (Ejjiriki
- Poisonous trees.

"Planting shade trees is a climate change mitigation and adaptation measure"

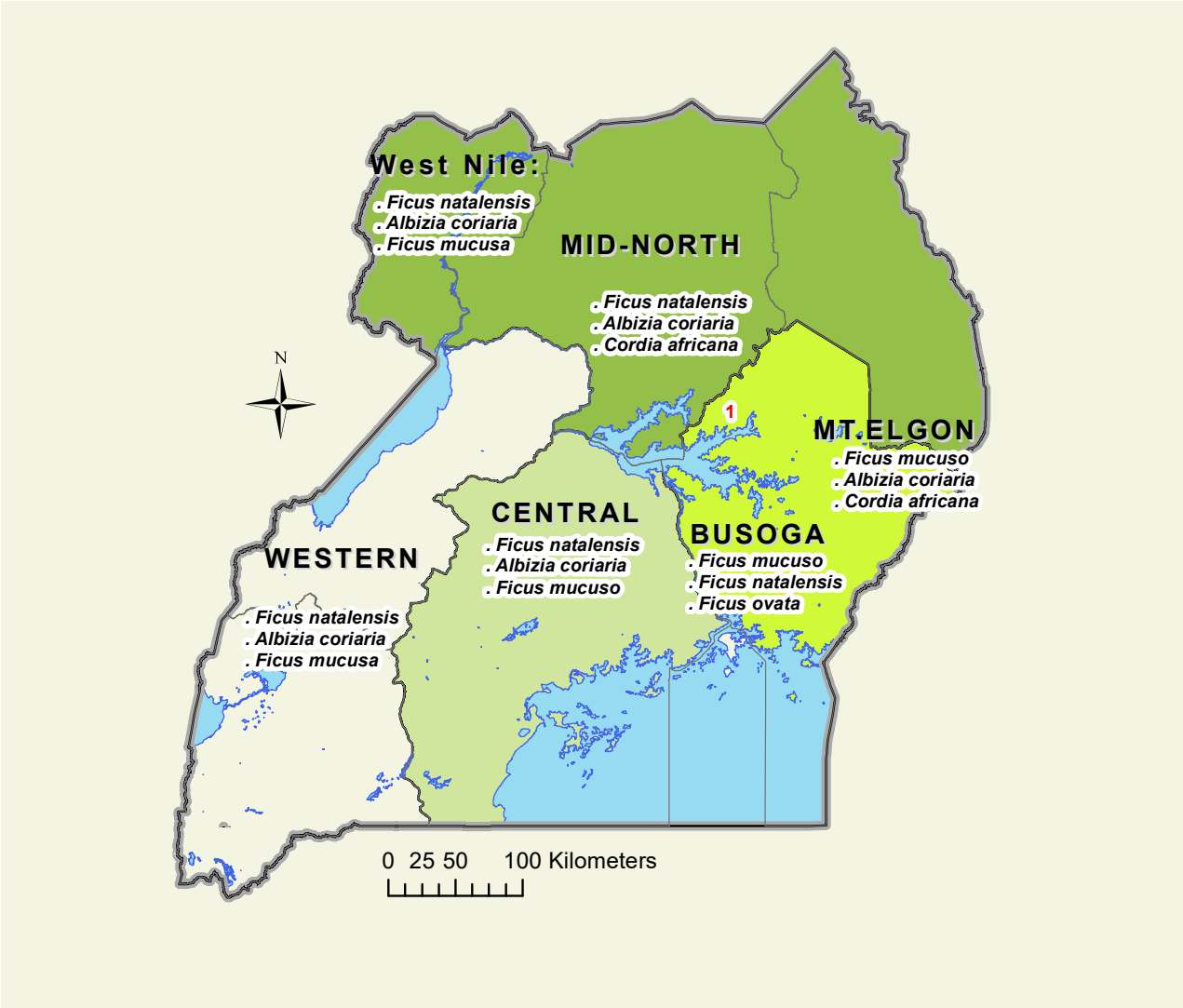


Figure 7. *Map of Uganda showing recommended shade trees by region*

3.1.5 Set-up Water Delivery Systems

Planning for water conservation and future availability is important while preparing the coffee field. The importance of water delivery systems cannot be over-emphasized today given climate change effects. Irrigation or water delivery systems should be installed prior to the planting of coffee. 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 lakes, rivers and springs. Pumping systems can be motorized, solar powered or manual. Farmers can also use or dig water channels to distribute rainwater. There are different options of setting up water delivery systems depending on a farmer's income and technical advice from water experts and these may include surface, drip and/or overhead, as shown in Figure 8.

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"

3.1.6 Dig holes and backfill

Preparing holes before the planting season helps the farmer to be ready for planting at the first rains. Hole preparation process, as shown in Figure 9, is as follows:

- Marking of positions, with pegs, where the coffee plants will be planted, arranged in regular patterns to facilitate management, a processes known as pegging.
- 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. When digging the holes, keep the fertile topsoil separate from the subsoil. On sloping surfaces, the topsoil is placed on the upper side of the slope to allow it get into the hole first, in case it rains before backfilling. The sub soil is placed on the lower side of the hole to prevent it from getting back to the hole.
- Refill the holes with well 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. The decomposed manure should be placed in the top 20cm zone of the hole to enable the tender plant with a shallow root system to benefit from the manure.

Put a peg at the center of a half filled hole before completing the backfilling. This helps to identify the center of the hole while planting. The steps taken to prepare good coffee holes are illustrated in Figure 10.

Figure 9. *A newly dug planting hole*

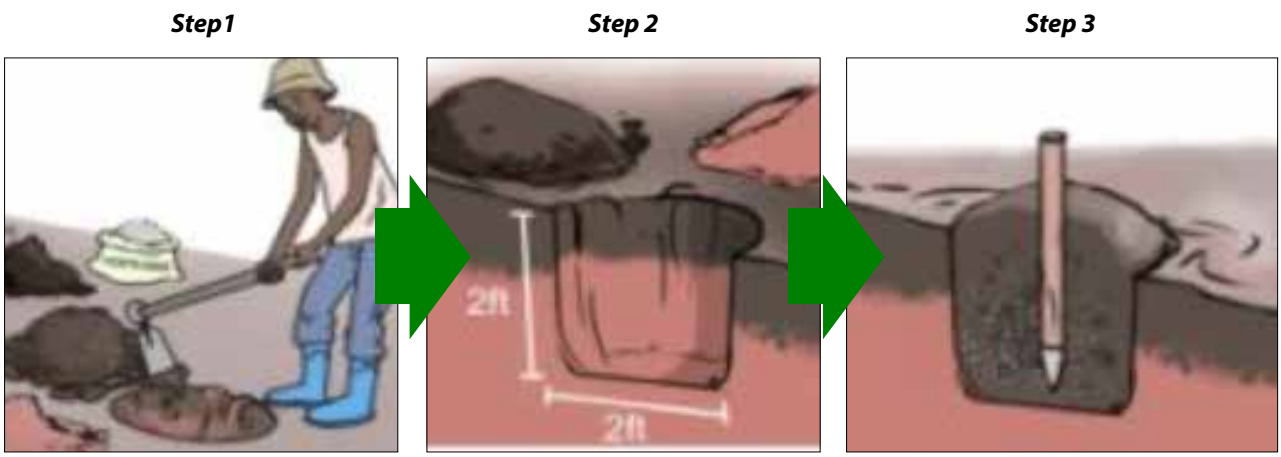


Figure 10. *An illustrated process for preparing coffee-planting holes*

3.1.7 Select Planting Materials

It is important to buy good clean planting material in order to expect a good yield. Start by seeking guidance from Uganda Coffee Development Authority (UCDA), your district agricultural office, the National Coffee Research Institute (NaCORI) or your nearest local government extension officer for guidance on certified nurseries. The process of selecting good clean planting materials is elabourated below:

- Get coffee plants with 3 – 4 pairs of true leaves for clonal coffee cuttings or 4 – 5 pairs of true leaves for elite Robusta seedlings at the onset of the rainy season as seen in Figure 11.
- Always use seedlings or cuttings from a certified nursery.
- Check all seedlings for signs of pests and diseases, especially root mealybugs, aphids, sucking insects and brown eye leaf spot. 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.
- The choice of the coffee variety matters. Generally, productivity of elite seed as shown in Figure 10 is lower than that of the clones. Some clonal coffee varieties can give an average yield of 3000kg of clean (FAQ) coffee per hectare. Clones are also suitable for areas with adequate rainfall but can also be planted in areas receiving marginal rainfall if rains are supplemented with irrigation and good field management.

Figure 11. *Mature and ready to plant Robusta Seedlings*

Figure 12. *Coffee seedling with unsuitable J- root system*

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

3.1.8 Planting out

- Prior to the actual planting of coffee plantlets in the prepared holes, wet the soil by irrigation to a depth of 60cm (2ft).
- In absence of irrigation, it is advisable to plant at the beginning of the rainy season of March to May and September to October for traditional coffee districts in regions of Central, Western, Rwenzori, South Western and Eastern (Busoga) or April to August for Northern and Elgon Regions. Plant coffee plantlets within the first 2 to 3 weeks after the onset of the rainy season. Plant in the early morning or late afternoon and cloudy days to minimize effect of sun damage at planting.
- Use water buckets or basins to soak well the entire seedlings before planting.
- Ensure that roots protruding beyond the polythene pots are trimmed off before planting. Then open up the center of the back-filled holes sufficiently to fit the size of the potted plant (accommodate the taproot and other roots). Remove the polybag/polythene pots before planting by gently inverting the fully soaked seedling in your hands and gently pull off the polybag. Place the seedling in the hole with the collar at level with the surrounding soil or slightly higher to allow for some sinking when the soil settles. Ensure that no depression or heap of soil is made around the plant. If inorganic fertilizer is available, apply one handful of Triple super phosphate (TSP), Single Super Phosphate (SSP) or Diammonium Phosphate (DAP) within the root zone of the seedling but avoid the fertilizer touching the stem. Phosphorus stimulates root growth.

Maintain the roots of the seedling in the rooting zone of the soil to avoid either deep or shallow planting. Fill in the soil and press the soil firmly around the newly planted seedling using your hands. Protect each seedling from sunshine by providing temporary shade (tree branch/ split banana pseudo-stems) and also provide cover at the base of the planted seedling. Mulching the entire row reduces erosion and conserves moisture immediately after planting. However, where mulch is not sufficient, place a ring of mulch around the plant and this mulch must not be in contact with the stem of the plant. Avoid planting out coffee seedlings when conditions are windy or hot and dry or during the hottest part of the day. The quality of cuttings/seedling should conform to 3-4 pairs of true leaves for clonal and 4-6 pairs of leaves for elite Robusta seedlings. Plantlets must be strong and healthy with no sign of pests and diseases.

Regularly inspect the planted field to identify dead plants and replace them as soon as possible to have a full-stand plantation as seen in Figure 13.

During dry period continuously water the young seedlings until they get well established. Bottle drip irrigation have been seen to be effective for survival of newly planted seedlings.

Figure 13. *A full planted Robusta Coffee garden with no gaps*

3.1.9 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 periods. 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 crop water requirements and irrigation frequency for the different growth stages of Robusta Coffee. With supplementary rains, the frequency may be reduced to twice a week and once a week for occasional irrigation. Resource constrained farmers are advised to use bottle irrigation as shown in Figure 14.

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

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

Coffee growth stage	Amount of water required (L)	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

"Watering is an important climate change mitigation measure"

3.1.10 Training or Bending of Coffee Stem

To maximise benefits from Robusta Coffee (especially the tall varieties) it is recommended that production be based on the multiple stem system (preferably 3 stems) through training/bending. Training/bending is done 5-6 months after planting or when the coffee tree reaches a height of about 60cm (2ft). It involves bending the coffee trees along the tree line in an *East to West* direction and pegged down at about 45 degrees to allow suckers to develop. Training/bending leads to breaking dormancy of multiple buds at the base resulting in growth of numerous suckers. If the older bent stem is vigorous, a farmer should select a total of 3 stems including the already existing one and where the older bent stem is weak, 3 vigorous suckers should be selected and the weak mother stem cut in order to have a total of 3 stems per bush as future bearing stems. The procedure for training coffee is outlined below:

- Bend the original seedling in an East-West direction after it has attained about 2 ft height.
- Select two suckers (where you prefer to maintain the bent/trained stem) or three suckers (where you prefer cutting of the trained/bent stem later on). This is done in order to have 3 stems.
- Suckers should be selected from as low as possible along the base of the trained coffee tree and should be groomed/maintained to allow them develop/grow into full stems. These suckers form the future bearing stems.

- The selected suckers should be at about 15cm from the ground level and well positioned from each other.
- When the suckers are about 30cm tall, the peg is removed and the end of the main stem turns upwards once again.
- All the coffee plants are bent in the same direction towards the west and along the row.
- Alternatively, newly planted coffee plants of 4-6 months are capped at a height of 15–30 cm (6–16 inches) above the ground. This is done by removing the tips to encourage development of multiple stems, which are then selected as described above. The training procedure is illustrated in Figure 15 while a trained Robusta Coffee plant is shown in Figure 16.

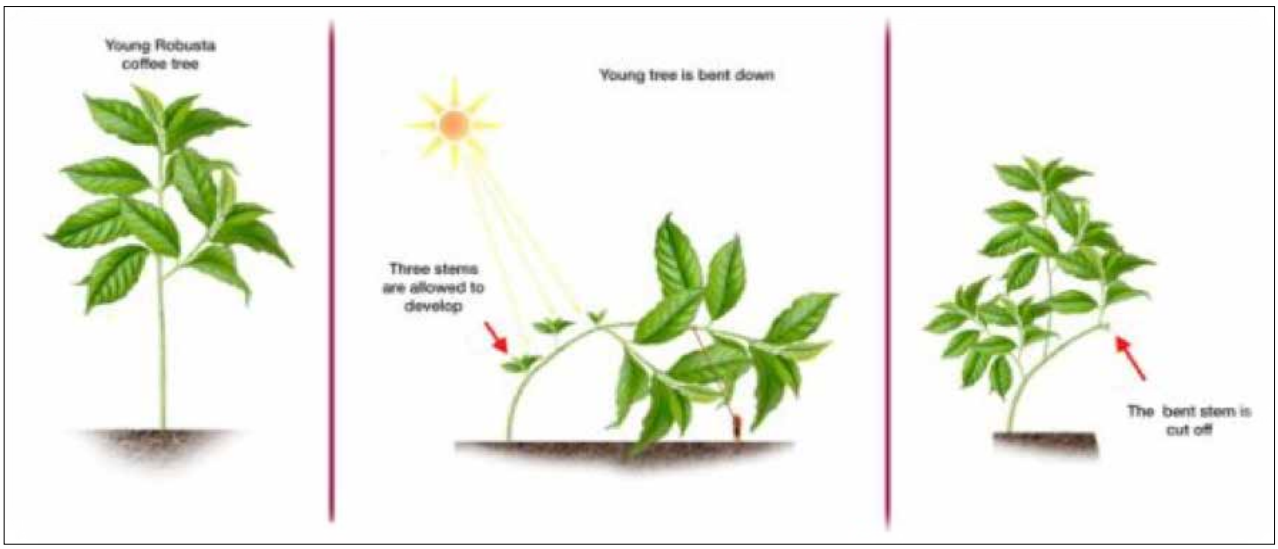


Figure 15. *An illustration of the training procedure in coffee*

Figure 16. *A trained coffee plant*

3.2 Field Management Practices

Robusta Coffee under recommended management practices should produce atleast 1,500kg of clean coffee (FAQ) per hectare per year, but clonal coffee can attain 3,000-4,000 kg FAQ per hectare per year under same good management. This can be achieved with minimum maintenance cost, if the farmer undertakes proper 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 that always ensure water and/or moisture availability in the soil. The good coffee management practices include among others:

- Weed control
- Mulching
- Irrigation
- Soil and water conservation
- Use of cover crops
- Training or bending
- Pruning and De-suckering

3.2.1 Weed Control

A weed is any undesired plant growing within the coffee field. Control of weeds should be done before they produce seed (fourth leaf stage), applying fertilizers or mulching. Weeds compete with coffee plants for water and nutrients and eventually lead to reduced crop growth, low yields, poor quality coffee beans and loss of income. 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 - 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 17. Do not weed using a hoe in the rainy season as it increases the risk of soil erosion. Further more, use a regular hoe for weeding young coffee and a forked hoe for opening up hard soil pans in mature coffee to avoid injuring the root system of the coffee plants.

Figure 17. *Motorized weeding equipment*

Chemical weed control is the use of herbicides in the management and control of weeds and should be used as a last resort. It is advisable to slash the weeds first and then spray the re-growth with herbicides while they are still tender and soft and before they flower and become hard. Use recommended herbicides with active ingredient of glyphosate such as Round-up for grass weeds. Round-up works best on tender and soft weeds and most especially *graminae* family like couch grass (*Lumbugu).*

Use the rates recommended by manufactures on the labels of the containers or consult your nearest extension worker. Good timing of herbicide application where the weed re-growths are still very tender and soft (about two or three pairs of leaves after their slashing and before flowering) enables effective herbicide performance by killing all weeds at even lower application rates thus reducing chemical costs. 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. Care should be taken to avoid accidental spraying of the young coffee with the chemical to avoid killing or damaging them. Cover the plants with non-suffocating materials like

boxes, ring weed half a metre radius around the base of the plantlets before application to avoid accidental spraying of the young coffee plants.

It is safer to avoid herbicide use until the coffee is atleast two years old. During spraying, use of a set of protective gear including overalls, helmets, eye goggles, gumboots, hand gloves, nose and mouth masks is recommended to protect workers against chemical exposure. Use of protective clothing prevents physical contact and inhaling of chemical mist or fumes, which is a health hazard. Immediately after, the with water and soap to wash off any chemicals that might have come in contact with the body during spraying.

3.2.2 Mulching

Mulching is the covering of the topsoil between crop rows and columns and around coffee trees with dried or rotten plant residues e.g. dried grass, maize stalks, bean haulms, coffee husks, straws and compost manure. Maize stalks (Figure 14) are recommended because they contain a lot of Potassium, which is important in coffee crop establishment.

The marginal value of the mulch products arises from their decomposition to release nutrients. Any organic material can be used as mulch and should be well spread over the ground between coffee trees in the entire field. In young coffee, the most important area to mulch is within the spread of a canopy of the branches since the roots of the tree have 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. Mulching is very useful in many ways but it also has a few drawbacks as outlined in Table 6.

Table 6. Advantages and disadvantages of mulching

Advantages	Disadvantages
• Mulching improves the yield by facilitating better regulation of moisture levels in the soil, thereby increasing soil moisture retention and improving surface water infiltration into the soil. • Mulching reduces the watering requirements –thereby minimising costs of irrigation. • Protects the soil surface from erosion. • Encourages more vigorous top growth and 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. • Mulch reduces temperature variation in the soil and can protect young plants from frost damage. • When used for prolonged periods mulch controls weeds thereby suppressing the cost of labour and herbicides in managing weeds.	• May be a costly process especially with regard to the additional labour required. • May increase incidences of certain pests e.g. leaf miner, termites and dusty surface beetle. • Pesticides need to be applied to avoid spread of pests that have come in with mulch. • May increase the fire hazard. Some firebreaks, by not mulching certain rows, are advisable. • Mulches may lead to a deficiency in or total unavailability of zinc and magnesium. • Prolonged use of Elephant grass and swamp straw as mulching material can in the long run cause yellowing and death of the coffee plants. Therefore, interchange mulching material regularly. • If mulch touches the stem of the young tree, the tree may develop collar rot or may attract ants and other pests.

Advantages	Disadvantages
• Mulch builds up topsoil fertility and improves uptake of nutrients through the general amelioration of soil structure and improved microbial activity. • Mulching limits the excessive uptake of manganese, which may build up rapidly to high levels in acid soils. It also increases the potassium level in the soil.	

"Mulching is an important climate adaptation and mitigation measure"

3.2.3 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.
- Allows effective fertilizer application.
- 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 for the proposed acreage and consider the potential for drought periods. To supply water through the irrigation system, it is important to consider the dam storage capacity and application rate (cubic meters 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.

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. 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 (7th week from fruit set) and the rains fail.
- The rains are insufficient during bean filling.
- The rains fail during the ripening stage.
- The 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 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 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 micro-irrigation system that allows water to drip slowly 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 and minimize evaporation. It is the most preferred type of irrigation since it is economical 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 benefits and disadvantages of drip irrigation are indicated in table 7.

Table 7. Advantages and disadvantages of drip irrigation

Advantages	Disadvantages
• Low evaporation and runoff water losses compared to overhead and basin systems • Increased efficiency of water use • Low energy and labour costs • Efficient fertilizer applications • Cost of weed control is reduced • It is easier to use in fields with irregular levels and shapes. • Avoids unnecessarily wetting of the inter-rows. • Its labour costs are lower than other irrigation methods. • It enables combining fertilizer application with irrigation (fertigation) thereby saving fertilizer application costs and increasing fertilizer efficiency. • It delivers highly uniform water distribution to coffee trees. • Coffee foliage is not wetted thus no risks of washing down protective fungicides.	• 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. • High risks of water salinity. • 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.

Overhead/Sprinkler Irrigation

This 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. Advantages and disadvantages of overhead irrigation are indicated in table 8.

Table 8. Advantages and disadvantages of overhead irrigation

Advantages	Disadvantages
• 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 • It triggers flowering	• It requires high initial investment capital. • It 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 is 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 causes uneven distribution of water.

Basin Irrigation

This type of irrigation involves holes being dug in form of basins between coffee trees and water is 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. Advantages and disadvantages of basin irrigation are in table 9.

Table 9. Advantages and disadvantages of basin irrigation

Advantages	Disadvantages
• It requires little initial investment costs compared to drip system or overhead systems. • It uses less water (almost a half) compared to overhead system, thus enhances sustainable water use. • No losses due to wind which are large on windy days with overhead • 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.	• 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. • It requires intense supervision to ensure that labourers apply the right quantities of water. • 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 given in Table 10.

Table 10. Advantages and disadvantages of under tree irrigation system

Advantages	Disadvantages
• 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.	• 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 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 gives advantages and disadvantages of bottle irrigation.

Table 11. Advantages and disadvantages of bottle irrigation

Advantages	Disadvantages
• 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.	• 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.

3.2.4 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:

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

Rainwater harvesting pits

Rainwater-harvesting pits as shown in Figure 18 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, construction material requirements/availability and labour.

The pit can be constructed using bricks, which are coated with cement or lined with polythene sheet. The pit has a 'one-way' silt trap where water can only enter.

Figure 18. *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. A popular method known as *"Fanya Juu"* involves placement of soil on the upslope side of the contour trench (throw the soil up) and a *"Fanya Chini"* involving the placement of soil on the lower side of the contour trench. The terraces are laid in an alternate order starting with a *"Fanya Juu"* structure followed by a *"Fanya chini"*. The spacing of *"Fanya Juu"* terrace depends on the slope of the land. On a gentle sloping land spacing of 10m apart may be used and on a steep slope spacing of 8m apart may be used (Figure 19).

Figure 19. *An illustration of "Fanya juu" and "Fanya chini" terrace*

Construction of water retention bands

Construction of water retention bands such as digging pits/troughs at some points of the terrace conserves rainwater and facilitates its availability to the neighbouring coffee trees by way of gravity flow thereby nourishing the trees during the dry period as illustrated in Figure 20. A small amount of oil may be added to the trapped water to prevent breeding of mosquitoes.

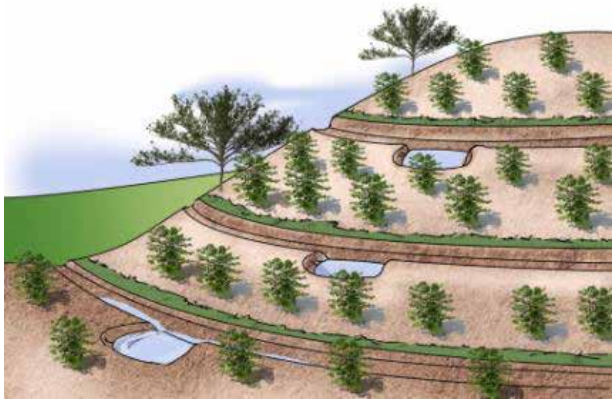


Figure 20. *An illustration of water/soil retention bands*

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. Use *of Indigofera spicata* (Figure 21) plant spp in the third year is recommended when intercropping of the annual crops has stopped or from the first year where monocropping is practiced.

Figure 21. *Indigofera spicata as a cover crop in a coffee shamba*

Planting Grass and Vegetation

Grasses such as vetiver grass, *Paspalum spp* and leguminous plants such as *Tithonia diversifolia* should be done 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.

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.

Mulching

Mulching, as shown in Figure 22, is a proven way of conserving soil water and moisture and should be put to good use by farmers.

Figure 22. *A well mulched Robusta Coffee garden as a water conservation measure to reduce soil erosion*

3.2.5 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 change smart agricultural practice. Figure 23 show different crops that may be used as cover crops.

Lablab planted as a cover crop in a coffee shamba

Desmodium spp. as a cover crop in a coffee shamba

Figure 23. *A cover crop to prevent soil erosion in a coffee shamba*

"Coffee cover crops are a climate change adaptation measure"

3.2.6 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 that will not bear again or only produce minimal and small coffee cherries. This is the right time to remove such branches.
- Use a pruning bow saw, sharp secateurs or a pruning saw for removing unwanted shoots of coffee trees. The pruning tools are illustrated in Figure 24. Ensure that the tools are cleaned using 75% ethanol, spirit or 25% dilution of Jik before, during and after use to prevent spreading disease from tree to tree. Keep the metallic tools oiled to prevent rusting.
- The number of stems should be kept to the optimal 3 stems or a maximum of 4 to maintain optimum productivity.
- Remove all suckers that are not well positioned, secondary and tertiary branches that are not healthy/ strong or vibrant to enough give good crop yields.
- When there are many suckers, the coffee plant will not be able to feed all of them sufficiently. Remove the weaker and senescent lower primaries and keep the vigorous upper primaries.
- Removing suckers (de-suckering) can be done several times during the year depending on the amount and distribution of rainfall. 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 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 Wilt Disease (CWD). Figure 25 shows well-pruned coffee trees.

De-suckering is a type of pruning where numerous

Figure 24. *Pruning tools(pruning saw, bow saw and secateurs)*

A properly pruned coffee tree changed

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 25. *An illustration of well-pruned coffee*

shoots that grow from the laterals, verticals and tertiaries are removed from coffee trees. These "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 check excessive growth to avoid competition from many suckers, open up the canopy, enhance productivity and to achieve less disease and pest incidences.

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

CHAPTER 4

REHABILITATION AND RENOVATION OF OLD ROBUSTA COFFEE TREES

4.0 Introduction

The majority of coffee farms in Uganda are well over 50 years and are producing coffee below their potential. The yield potentials of such farms are far below average. 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. The coffee tree in Figure 26 is such an example of a coffee tree 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, where young high yielding seedlings are planted to replace the old unproductive coffee trees.

Figure 26. *An old coffee tree that is over-due for stumping*

Rehabilitation, therefore, refers to pruning or stumping of coffee trees to rejuvenate and improve their productivity by increasing the amount of coffee produced by each tree because of bringing it back to its youthful, productive cycle. It 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 enable maintaining a 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 and introducing shade trees in the coffee farm. 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 trees and renovation is the only option.
- Superior 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.

- Old tree age: Over a long period of time (40 years or above), trees produce less and small coffee berries and 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 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 several cycles.
- 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 making use of 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. In this case, farmers can reduce the total number of bearing stems per bush to save some fraction of the expected crop yield to prevent total yield losses.

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 plot may be completely damaged and require renovation, whereas another area of the plot requires rehabilitation only.

4.2 Coffee Stumping Practices

Stumping coffee is a practice of selecting and cutting down elderly and unproductive stems existing on a 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 cherries 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 Robusta 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 nurse the developing suckers until they are mature enough to be on their own as seen in Figure 27.

Figure 27. *Rejuvenation process using a sucker*

4.2.1 Purpose of Coffee Stumping

- Remove unproductive 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 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 28). 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 pathogenic agents from 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 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. Suckers arising from the side of the prevailing wind are usually less likely to be broken off by wind.

vii. When suckers are approximately 20cm (8inches), 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 and may easily break off with heavy crop.

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 tree stump. In such a 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 as seen in Figure 29.

Figure 28. *Angle at which the pruning saw is set on the stem to be stumped*

Figure 29. *Stumped old coffee tree (full stumping) showing re-growth of suckers*

In a good coffee management system, it is recommended that stumping, also referred to as a "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 may not want to lose all their income by stumping the entire garden at once. In this case, it is advisable for the farmer to phase the stumping and aim at completing the entire garden over a period of 1-4 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 parts around year 7 of the stems on the trees and in the first phase, 50% of the field is systematically stumped. After the first year when the stumped portion starts to bear crop, the second 50% of the farm is also systematically 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. 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 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. 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 bushes 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.

The different types of stumping are summarized in Table 13

Table 13: 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 10 or 7 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 farm.
- Later this breather stem is also cut off/removed after 1 – 2 years (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 if the farmer has alternative income. Stumped coffee fields can be intercropped with cover crops like beans, groundnuts and peas to earn alternative 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 soil.
- 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 disadvantages are that the field will be out of production for one or two years, 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 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 tree.

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. After stumping, an abundant number of suckers will grow from the stump as seen in Figure 30. The majority of these suckers should be quickly 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 31. 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. Ensure that the branches on the breather stem do not shade the underneath suckers to avoid etiolated and poor quality suckers as seen in Figure 32.

Figure 30. *A stumped coffee tree with rejuvenating suckers maintained for multiple stem system after 3-6 months*

Figure 31. *A stumped coffee tree with new (rejuvenating) suckers after 9 months*

Figure 32. *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 or mother stem. 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 fusarium spores from one tree to the next. The selected stem to be left (the breather) should be well positioned on the stump to give space/room for suckers (shoots) to develop and grow without direct shading. The choice should be for the most out positioned stem at the base of the tree, which will also be removed with ease later without damaging the developed suckers. The breathers' must be stripped of all primary branches anticipated to shade the suckers by cut lifting, an operation commonly known as skirt lifting. A number of suckers will develop on each of the cut stems within 2-3 months. When these suckers develop, carry out a frequent and vigorous sucker selection operation for the next six months to 1 year as illustrated in Figure 33.

Figure 33. *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 34. During this period the production is mainly from the breather stem. 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 34. *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 2 from the time of stumping as illustrated in Figure 35. Suckers will thereafter stand-alone reaching a height of more than 1.5m.

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 weak and unproductive and should be progressively striped off (cut) from the stems as they become unproductive. These Robusta 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 diverted to more productive branches for optimum utilization and improved yields.

Figure 35. *Status and appearance at the end of year 2 after cutting off the two stems*

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 and the numerous suckers that will develop on each of the cut stems are trimmed. It is important to select three suckers of the same height, good health and those that are well positioned around the stump to act as your next future bearing stems as illustrated in Figure 36.

Figure 36. *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 at an angle of about 45 degrees slanting downwards and facing outside the stump with a smooth cut, 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 not to stump more than 1/3rd of your trees at one time. Look at all coffee bushes and identify those, which are giving less than 1 kg per tree/bush. These are old and it is time to stump them.
- After stumping, there will be renewed/fresh growth and many more leaves, leading to many more big cherries that are easier to pick.
- After stumping, the critical time is between 3-6 months from the time of stumping and by end of year 1, the farmer should have decided on the preferred future bearing stems by continuously removing the re-growths that continue appearing in favour of the preferred suckers. This minimizes competition and enables the farmer to grow only the 3 vigorous future productive stems.

CHAPTER 5

SOIL FERTILITY MANAGEMENT FOR ROBUSTA 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 s1ch 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 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 are referred to as macronutrients. Other elements are required in very small (micro) quantities but are essential for plant growth. These micro nutrients include Zinc, Copper, Magnesium, Calcium, Boron, Iron, Manganese, Molybdenum, Sulphur and Chlorine.

There are 16 natural elements (nutrients) that are essential for plant growth. Three elements (Carbon, Hydrogen and Oxygen) make up 94% of the plant tissues and are obtained from air and water. The other 13 elements are obtained from the soil and are divided into two broad categories - 'macro' and 'micro' nutrients. These terms do not refer to the importance but the quantity requirements of the elements by the plants. 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 mineral analysis. Three samples per two to four 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 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 37. 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 37. *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 and pest damage. For proper diagnosis, a farmer is advised to consult an extension worker.

5.3 Coffee Nutrition

5.3.1 Benefits of fertilizing coffee

Coffee quantity produced per unit area improves significantly when soils are well managed for optimum fertility. Fertilizer application can increase yields of Robusta Coffee from the average current 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 management practices. Plant nutrients are classified into two categories as macronutrients and micronutrients.

5.4.2 Importance of Macronutrients

Macronutrients are nutrients required by the plant in large quantities. They mainly include Nitrogen, Phosphorus and Potassium.

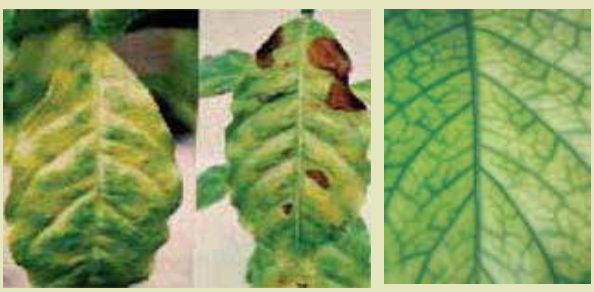
Nitrogen is necessary for vegetative growth. It increases tree-bearing capacity and enhances coffee bean size.

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 given in Table 12.

Table 12. 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 • 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 • 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 and pest damage. For proper diagnosis, farmers are advised to consult their extension workers.

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 set 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 facilitating pollen germination through the stigma to the ovary. Consequently, it facilitates optimal flowering and fruit set, 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, which enhances bean colour (the bluish green colour of the 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 works in form of a chloride, it 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 shown in Figure 38.

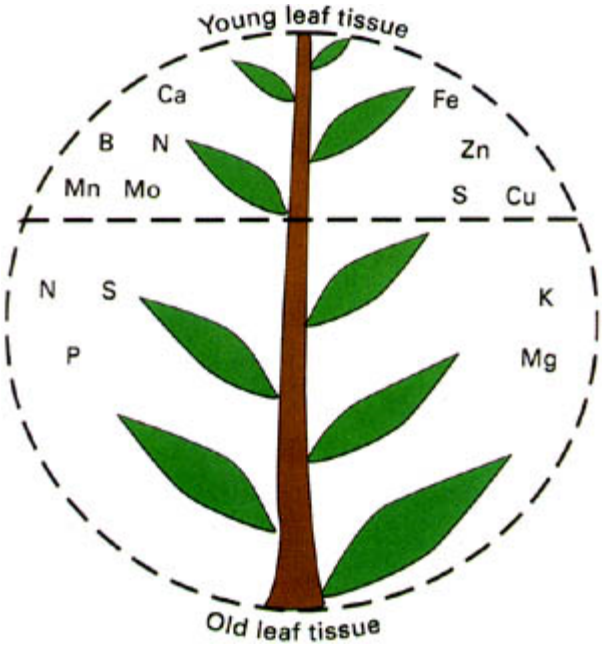
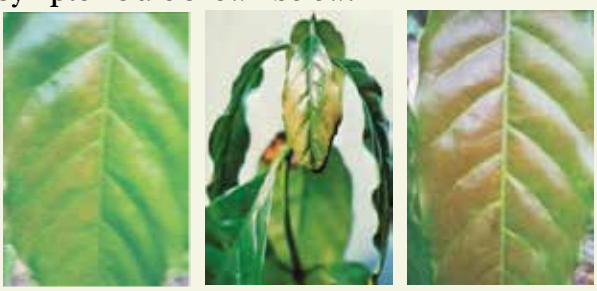


Figure 38. *Diagram showing levels at which nutrient deficiencies manifest in coffee trees*

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 macronutrient and their respective deficiency symptoms is given in Tables 13.

Table 13. 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 center and outwards **Symptoms are shown below:** 
Magnesium (Mg)	• Chlorophyll (green-colour) • 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 center 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 set 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 (green colour) • 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 (green colour) • 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 sprays are used in the nursery for controlling *Cercospora* and leaf rust in coffee fields) **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 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 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 used by smallholder 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 14 contain small amounts of nutrients and the importance of recycling crop residues is to replenish soil organic matter and provide mulch. Cycling crop residues through composting or animals improves the availability of nutrients to the plant.

Table 14. 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 (Table 15). Additionally, they contain a lot of phosphate. Cattle manure is rich in nitrogen when it is fresh but when dry, the nitrogen evaporates. To avoid nitrogen evaporation, cow dung manure should be decomposed under covered conditions.

Table 15. 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 39(a) shows the final heap composting product.

Figure 39(a). *A heap composting method*

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

1. Dig 3 pits measuring 1.5-2m wide and 1m deep next to each other as shown in Figure 31(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, it cannot always 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. The compost then loses its fertility. To reduce this loss, the compost should always be covered. Some useful covers are banana leaves, intertwined palm leaves or a sheet of plastic.

9. Spread the compost to surround the coffee tree atleast 2ft from the plant as shown in Figure 32.

Figure 31(b): *An illustrated procedure for pit composting method.*

Figure 32. *Fertilizer application around each coffee tree*

5.4.4 Commercial Organic Fertilizers

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

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. Advantages and disadvantages of Organic Fertilizers are highlighted in Table 16.

Table 16. Advantages and disadvantages of Organic Fertilizers

Advantages	Disadvantages
• Can be obtained at a low cost and or easily made by farmers through composting processes 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. The food 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. • Stablizes 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.	• In most organic fertilizers 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 and time-consuming. • 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.

Inorganic fertilizer, also referred to as synthetic fertilizer, is manufactured artificially and contains 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. Single element fertilizers contain a single element and include Urea (N), Usually, the formulation is indicated on the package and sometimes reflected in the name. 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. Advantages and disadvantages of chemical fertilizers are presented in Table 17. The common inorganic fertilizers and their formulations is presented in Table 18.

Table 17. Advantages and disadvantages of Inorganic Fertilizers

Advantages	Disadvantages
• **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	• 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. 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 by rain water down the valleys before coffee plants assimilate them

Table 18. 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)	It is water soluble, 18% Nitrogen, 46% P2O5(20% is P)
Calcium Ammonium Nitrate (CAN)	It is granular in form, 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
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 a shown in Figure 33(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 45 kg for 450 trees per acre for Robusta (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 clearly label on the fertilizer pack as shown in Figure 33(b).

5.5.2 Inorganic Fertilizer Blend for Coffee Trees above 3 Years

This fertilizer blend has been developed, by Grain Pulse (U) Ltd, 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: Urea (46%N); DAP (46% P2O5, 18%N) SOP (50% K2O, 45% SO3). The recommended application rates are 90 kgs for 450 trees (an acre) for Robusta 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 Robusta Coffee is presented in Table 19.

Figure 33(a). *Appearance of inorganic fertilizer blend*

Figure 33(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 19. Fertilizer activity program for Robusta Coffee

Period of application	Fertilizer	Application per tree	Role	Amount per acre
About a month to planting	Lime (if soil pH is <5.5	100 g/hole	Neutralizing acidity	45Kgs
	Organic manure	20L basin well decomposed cattle manure (mix with soil)	Improving soil structure	450 basins
At planting	Single super phosphate (18-22% P2O5)	60 g/tree	Enhances early root formation and growth, wood and fruit formation	27Kgs
Young coffee (Newly planted)	Compound fertilizer: NPK (25:5:5)	If pH > 5.4 75 g/tree/rain season	Increase vegetative growth	33.75Kgs
	Urea	N- deficient 76 g/tree/rain season	Increase vegetative growth	34.2Kgs
Young coffee (More than 2 years)	Compound fertilizer: NPK (25:5:5	If pH > 5.4 150 g/tree/rain season	Balance vegetative growth and berry production	67.5Kgs
	Calcium ammonium nitrate (26% N)	If Soil PH < 5.5, 250 g/tree/rain season	1st season (April) for inducing fruit formation & 2nd season for enhancing fruit ripening	112.5Kgs
	Ammonium sulphate nitrate (26% N)	Soil PH < 5.5, Use ASN (26 %) at 250 g/tree/rain season	Increase vegetative growth	112.5Kgs
	Urea	250 g/tree/rain season	Increase vegetative growth	112.5Kgs
	Cattle manure	10 Kg/tree/year	Increase vegetative growth	4.5tons
	Crop residues (maize straw, beans, soya bean)			

Period of application	Fertilizer	Application per tree	Role	Amount per acre
Mature coffee *(5 options)*	Murate of potash (62% K2O	200 g/tree/season	For fruit maturation Increased ability to withstand pests & diseases, drought, frost Improves quality (aroma, colour, taste, shelf-life)	90Kgs
	NPK 15:2:31	250 g/tree/rain season	Balances vegetative growth and flowering	115.2Kgs
	Calcium ammonium nitrate (26% N)	Soil PH < 5.5, 256g/ tree/season	1st season (April) for inducing fruit formation & 2nd season for enhancing fruit ripening	115.2Kgs
	Ammonium sulphate nitrate (26% N) OR	Soil PH < 5.5, 250 g/tree/season ASN	Supplies nitrogen, reduces pH	115.2Kgs
	Double Super phosphate (40-49% P2O5)s	P -deficient 200 g/tree/year	Supplies phosphate Early maturity of berries	90Kgs
	Compound fertilizer (NPK 25:5:5)	250 g/tree/rainy season	Balance vegetative growth and berry production	115.2Kgs

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 source 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 source 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 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 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, soft-drink-bottles and tops can be used to measure the amount of fertilizer applied to each plant. For example, a full, level soda-bottle top contains about 6 g of fertilizer, a small emptied water bottle can be cut to hold a range of grams of granular fertilizer. At planting time when using Single Supper Phosphate (SSP) at a rate of 60g/tree, with a plant population of 450 plants, an application of ten soda-bottle top of SSP/tree is equivalent to 27kg/acre. Fertilizer responses can be classified as follows:

- Poor responses on 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 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 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, 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 N is highly mobile and easily lost from the soil due to leaching, therefore some fertilizers with 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 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. 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.

Disadvantages of broadcasting

i. The weed growth is stimulated all over the field.
ii. Nutrients are fixed in the soil as they come in contact with a large mass of moist soil.

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 in 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 20. Farmers therefore need to use results and recommendations from soil analysis to take appropriate corrective action.

Table 20. 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 34. 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.

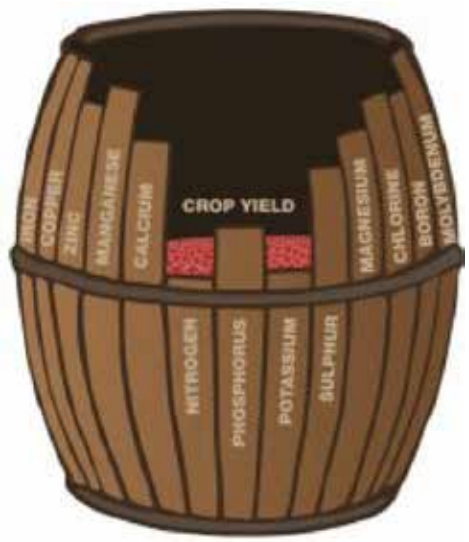


Figure 34. *Barrel analogy*

CHAPTER 6

INSECT PESTS OF ROBUSTA COFFEE AND THEIR MANAGEMENT

6.0 Introduction

Pests and diseases affect the health of the coffee plants, which further leads into quality deterioration, quantity loss and eventually reduced economic return to the farmer. Successful pest and disease management encompasses all 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 be based on Integrated Pest Management (IPM).

IPM is the 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.

6.1 Black Coffee Twig Borer (BCTB)

6.1.1 Description and alternative hosts

The black coffee twig borer, *Xylosandrus compactus* is a very small, highly prolific dark and oval shaped beetle also known as the Ambrosia beetle as seen in Figure 35(a). It probably originated from South Asia and was first reported in Uganda in 1993 in Bundibugyo. The beetle is now present in all Robusta Coffee growing areas of Uganda but has a very wide host range of more than 200 plant species.

The BCTB feeds on Ambrosia fungus and belongs to the ambrosia group of beetles. Once inside the twigs, it does not feed on the host plant material but uses it as a medium for growing the fungus, infesting mainly the primary branches (twigs) but also the soft stems (below 2cm diameter) of coffee. It causes them to wilt and die, thus causing crop loss. Therefore, absence of a suitable host is not a limiting factor.

Any woody material of suitable moisture content and size supports its survival. Some of the alternate hosts in Uganda include Cocoa, Avocado and shade trees such as Musizi (*Maesopsis eminii*) and Musambya (*Markhamia platycalyx*). The life cycle of BCTB is completed in about one month. The pest is distributed worldwide and attacks mainly Robusta Coffee. Highest infestation is found in Busoga region especially in Namayingo district.

Figure 35(a). *Adult Beetle*

Figure 35(b). *Beetle entry hole on coffee stem*

Figure 35(c). *Black coffee Twig borer beetle eggs*

Figure 35(d). *Beetle infestation first signs showing wilting*

6.1.2 Damage and symptoms

The BCTB beetle bores holes on the lower side of the coffee twigs to access the inside of the twigs as seen in Figure 35(b) and lays eggs inside those twigs as seen in Figure 35(c). The hollow sections made inside the twigs block translocation of water and nutrients to the branches resulting in drying of infested twigs as seen in Figure 35(d). The twigs which dry as a result of infestation are the crop bearing branches, thus yield of up to 50% can be lost if attention is not paid to its control. The female beetles initiate infestation but males spend entire life in galleries. The beetle multiplies more under shade conditions and resultant damage is higher during the dry season especially in coffee trees under shade trees or closely planted coffee trees or inadequately pruned or de-suckered coffee. The males spend their entire lives inside the brood gallery. The females, however, leave the brood gallery after mating to infest other hosts/ branches to lay eggs. Adult females can be dispersed atleast 200 meters and it is likely that dispersal over several kilometers is possible, especially if wind-aided. The transportation of infested plant parts is of more importance for long distance dispersal of BCTB and should be discouraged.

BCTB females can reproduce parthenogenetically (without mating), in which case the offspring are all males. As a result, the introduction of only a few females may lead to the establishment of an active population if suitable host plants can be found and environmental conditions are conducive. Based on its prolific reproductive potential and dispersal capacity, BCTB is therefore a high risk quarantine pest in areas not yet infested locally. Management of black coffee twig borer should integrate cultural, biological, physical and chemical measures for greater impact and cost efficiency.

6.1.3 Control

Cultural control; These measures include;

- Use of phytosanitary measures like cutting, chopping and burning affected plant parts (stems/ primaries). Good control results can be achieved by collective community action at village level

towards a landscape approach to acquire skills on managing black coffee twig borer and others.

- Alternate host trees of the black coffee twig borer such as Musizi (Maesopsis eminii) and Musambya (Markhamia platycalyx) should be avoided as intercrops/shade trees.
- Use of pest-free planting materials from only certified coffee nurseries should be promoted.
- Regular inspection of fields to identify any black coffee twig borer infestation and trimming off and burning infested materials if found.
- Avoid bushiness by planting at recommended spacing and doing adequate de-suckering and pruning of coffee and shade trees.
- Enhance plant nutrition through soil fertility and moisture management (highest BCTB infestation occurs where phosphorus is limiting)
- Use the NARO-Uganda Beetle Trap Technology/ Brocca trap as shown in Figure 35(e). The trap is composed of transparent (non-coloured) water bottle, a smaller pharmaceutical bottle and a wire or string. The transparent bottle is used to hold water which drowns and kills the beetle, the pharmaceutical bottle (dispenser vial) is used to hold an attractant for the beetle and the wire/ string is used to hang the trap on the coffee tree. The traps are placed at two-thirds from the bottom of the tree and filled with 75% ethanol lure concentration held in dispenser vials. A trap density of 15-traps/ha is recommended. Traps are best used at beginning of the rainy season and should be replenished (cleaned and refilled) every 2 weeks.
- Plant coffee shade trees recommended by NaCORI

Figure 35(e). *Beetle trap technology used to control Black Coffee Twig Borer Beetle infestation.*

Chemical control; In cases of heavy infestation, chemical sprays by use of a pressure sprayer can be done after cutting and burning already dry twigs to enhance control of the beetle. Apply a mixture of systemic pesticide such as Immidacloprid (Kohinor, Confidor, Imax at 350g/l formulation to kill the pest. The pesticide is diluted at 4ml/L of water. For more effectiveness, another chemical Tebuconazole should be added in the same tank at 6ml/L to kill the hatched larvae.

Biological control agents for the black coffee twig borer include the fungal agents *Beauveria bassiana* (Figure 36(a), *Metarhizium anisopliae* (Figure 36(b), a braconid wasp *Plagiolepsis spp* (Figure 36(c) and Predator ant (Figure 36(d).

Beauveria bassiana is a fungus, which causes a disease known as the white muscadine disease in insects. When spores of the fungus come in contact with the skin of insect, they germinate and grow directly through the cuticle to the inner body of their host where they proliferate throughout the insect's body, producing toxins and draining the insect of nutrients, eventually killing it. Another fungus *Metarhizium anisopliae* infects insects that come in contact with it. Once the fungus spores attach to the outer surface of the insect, they germinate and begin to grow. After penetrating the outside skeleton of the insect, they grow rapidly inside the insect, causing the insect to die. Insects that come in contact with infected insects too become infected. Some ant's spp. has also been known to feed on the eggs of black coffee twig borer.

6.2 Coffee Berry Borer

6.2.1 Description and alternative Hosts.

The coffee berry borer (CBB), *Hypothenemus hampei* (Ferrari), is the most devastating insect pest of coffee throughout the world. The pest is monophagous, feeding exclusively on immature and mature coffee cherries and not damaging the vegetative parts of the plant. The female adult tunnels into green cherries about 8 weeks after flowering. It stays inside the tunnel, until the bean hardens, to lay eggs. They are small beetles that bore 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. The female beetle bores into cherries through the navel region as shown in Figure 37. Most females fly from infested cherries during mid to late afternoon to seek out new cherries to infest. Immature berries can shed off when attacked. The beetles in cherries on the plant or ground can survive for less than 5 months.

Figure 37. *Coffee berry borer beetle on a bean (Left); damage to berries (centre); beetles (extreme right)*

The pest is known to use other plant species for feeding only, including Tephrosia, Crotalaria, Centrosema, Caesalpinia, Leucaena, Hibiscus, Rubus, Vitis, Ligustrum, Oxycanthus and Phaseolus.

Beauveria bassiana *Metarhizium anisopliae* *Plagiolepsis spp.* *Predator ant*

Figure 36. *Biological control agents of the Black coffee twig borer beetle infestation and control*

However, these plants cannot support the life cycle of the insect.

6.2.2 Damage and symptoms

The damage to the bean is caused by adults tunneling into the distal end of cherries to lay eggs and the resultant larvae tunneling around the hardened beans inside the cherries to feed. Coffee cherries are attacked in various stages but tunneling only happens on young green cherries and laying of about 15 eggs occurs only in harden beans. The female adult tunnels into green cherries about 8 weeks after flowering. It stays inside the tunnel, until the bean hardens, to lay eggs. The eggs hatch in about 10 days and the larvae feed on the beans making small tunnels.

Economic damage occurs due to the damage on the beans caused by CBB during its breeding cycle in both young and older cherries. It causes fruit drop of young, green cherries and a small hole at the distal end is evident in the infested cherry. Cherries that do not drop often have defective, damaged beans. Market quality requirements demand the removal of damaged beans from FAQ (green beans) and if the beans are further sorted, they are relegated to the low-grade category that lower prices. It causes significant damage ranging from 50% to 100 % yield loss.

6.2.3 Control

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

Cultural Control; Pruning of coffee and shade trees to reduce shade exposes the pest so that the natural enemies can contain it. Regular picking of ripe cherries (atleast every 2 weeks) can be effective in controlling the pest. Hygiene (Sanitation) through keeping the coffee field clean and removing dropped cherries are a source of new infestation is very important. Fallen berries on the ground can inhabit the CBB during the period when trees have no cherries until the next blossom, therefore, farmers are advised to bury all fallen berries in the ground to suffocate it or burn them. Old berries remaining on the trees too are a source of new infestation and should be stripped and burned. Shaded coffee trees attract a higher number of birds which reduce coffee berry borer levels by feeding on them.

Brocca trap. The trap is composed of transparent (non-coloured) water bottle, a smaller pharmaceutical bottle and a wire or string. The transparent bottle is used to hold water which drowns and kills the adult beetle, the pharmaceutical bottle is used to hold an attractant for the beetle and the wire/string is used to hang the trap on the coffee tree. The traps are placed in an area located at two-thirds from the bottom of the tree and filled with 75% ethanol lure concentration. A trap density of 15-traps/ha is recommended. Traps should be cleaned and refilled every 2 weeks.

Chemical control; Good result is achieved through the use of Fenitrothion 50% EC at a rate of 6ml in 4.5L of water applied at early fruit set (2mm cherry sizes) and later 120-150 days after fruit set if required. Farmers can also use Cypermethrin and Deltamethrin, pyrethroids (0.01%) at 26ml in 15L of water, or Chlorpyrifos ethyl used at 5mls per litre of water. Spraying infested coffee with a combination of an insecticide like Immidacloprid (4mls/litre of water) and a fungicide Tebbuconazole targets both the beetle and the *Ambrosia* fungus (food for the beetle) thus reducing its population through starving as well. While handling chemicals, farmers are advised to strictly follow safe chemical use procedures.

Biological control; Agents include *parasitoids*, predators, nematodes and fungal *entomopathogens* such as the *Cephalonomia stephanoderis, Prorops nasutu, Phymastichus coffea, Beuveria bassianaand parasitoid braconid Heterospilus coffeicola (Schmiedeknecht)*. The first two *parasitoids* enter tunnels made by CBB and lays eggs on its larvae and *pre-pupae*. The emerging *parasitoid* larvae feed on all the borer stages and kill them. The adult *parasitoid* also feeds on all life stages of *CBB. P. coffea parasitoid* lays eggs on

borer beetles when it enters the berry. The White *Muscardine* fungus, B. *bassiana* infects and kills the beetle under favorable environmental conditions of high humidity (relative humidity above 80%) and optimum temperature between 25-30oC.

The Black *thrip Karnyothrips flavipes* (Jones) is another predator of egg and larvae of the coffee berry borer (reported to exist in Kenya). Another beetle *Leptophloeus sp.* near *punctatus* is known to prey on larvae. Spraying the field with molasses and or mulch attracts BCTB predators *Plagiolespis sp* into the coffee thus enhancing its biological control. Spiders have also been observed to prey on the coffee berry borer, although their preference for this insect is low.

6.3 Coffee Mealybug

6.3.1 Description

Mealybugs *(Planococcus spp.)* are small sucking insects (about 3mm long) found mainly in Arabica Coffee but also of economic importance in Robusta. There are several species similar in appearance to the naked eye as seen in Figure 38.

They are generally more of a problem in the dry season when water is lacking and trees are experiencing water stress. They feed by sucking sap from young shoots, leaves, flower buds, berries and roots resulting into yellowing and defoliation of the plants. While sucking, they produce honeydew (excreta), which attracts attendant ants that protect them from natural enemies.

One of these is these natural enemies is the ladybird beetle whose adults are reddish brown with black wings and about 4mm long. Severe damage causes ultimately death of the plant. Serious infestations of mealybugs are often found where there has been use of insecticide sprays, especially highly toxic organo phosphate sprays which kill almost all insects, including natural enemies of mealybugs.

Figure 38. *Large white mealybug*

6.3.2 Damage and symptoms

On the trees, they usually form a mass of many insects identifiable by a white mealy wax cover as seen in Figure 39. White waxy colonies are usually found on the underside of tender leaves and in soft stem areas around cherries as seen in Figures 40 and 41. Also, they are found on young roots near the main root, especially where soil is loose around the trunk as seen in Figures 42. Heavy infestations are manifested by sooty mould as seen in Figure 43.

Figure 39. *Early white waxy mealybug infestation in coffee on leaves*

Figure 40. *Ripe cherry infestation and damage*

Figure 41. *Green cherry infestation and damage*

Figure 42. *Mealybug attack on coffee roots*

Figure 43. *Heavy mealybug infestation causing black sooty mould on leaves*

6.3.3 Control

Complete removal and replacing of badly damaged or dead trees may be the only solution to this pest menace. Remove suckers and branches that touch the ground to prevent ants has in some cases been effective.

Chemical control is fairly effective through tree banding with 20cm wide plastic bands covered with a sticky substance (e.g. warmed up and then cooled oils) mixed with insecticides (e.g. products containing Chlorpyrifos) can prevent ants assessing the bugs and allow natural enemies to control the mealybugs. Spray Chlorpyrifos on the soil around the tree to kill ants as they disrupt the natural enemies of the mealybugs. Fenithrothion and Carbaryl sprays can also be effective. Farmers may also apply oils (such as vegetable oils, neem oil or mineral oils) or soapy solutions (1 to 2%) to kill mealy bugs by suffocation. Use soapy water or oils only during non-hot and non-sunny periods to prevent discolouration of leaves. Apply according to label recommendations and strictly follow safe use procedures.

Biological control is normally sufficient. The most important predator is the mealy bug ladybird *(Cryptolaemus montrouzieri)* which feeds on the mealybugs as shown in Figure 44. Another biological control is a parasitic wasp *Leptmastix dactylopii)* and lacewings such as *Oligochrysa lutea* are also effective predators of mealy bug. If no chemicals are sprayed, the mealy bugs are often naturally controlled by parasitic wasps (*Anagyrus kivuensis*) that eat up the insides of the bug.

Figure 44. *Ladybird adult feeding on mealybug*

6.4 Coffee Leaf Miner

6.4.1 Description

Coffee Leaf miner *Leucoptera caffeina* (Washbour) larvae 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. Can be managed by spraying with a recommended insecticide.

6.4.2 Damage and symptoms

Coffee leaves infested with coffee leaf minor is recognized by the presence of large, irregular, brown spots on the upper surface of the leaf as seen in Figure 45. 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 45. *Symptoms of the coffee leaf miner*

6.4.3 Control

Control is usually achieved by spraying when the caterpillars are still small and are in large numbers, using Fenitrothion 50% E.C. 70ml in 20litres of water or Pyrinex 1ml per litre of water. Spray when population of 30 moths per tree is sited. Strictly follow safe chemical use procedures.

6.5 Coffee Leaf Skeletonizer

6.5.1 Description

Leaf skeletonizer *(Leucoplema dohertyi* warr) is a minor pest in both Robusta and Arabica Coffee. Attacks are minor in the field but serious outbreaks in nurseries may occur. Can be managed by spraying with a recommended insecticide.

6.5.2 Damage and symptoms

Larvae feed on leaf upper surface leaving veins and upper epidermis to create a 'window' as seen in Figure 46. The caterpillars feed on the under surfaces of leaves, usually close to the mid-rib. They eat up all the leaf tissues leaving only the main veins and upper epidermis, resulting in irregular patches on the leaves.

Figure 46. *Symptoms of coffee leaf skeletoniser*

6.5.3 Control

Spraying can be done when the caterpillars are still small and are in large numbers, using Fenitrothion 50% E.C. with 70 ml in 20 litres of water or Pyrinex with 1 ml per litre of water. Strictly follow safe use procedures.

6.6 Tailed caterpillar

6.6.1 Description

Tailed caterpillar *Epicampoptera andersoni (*Figure 47) occurs occasionally in large numbers and can cause defoliation of coffee in the nursery. Larvae feed on leaf lamina, sometimes causing serious defoliation. Recorded on other plant species – *Markhamia lutea* (Musambya), guava and *Albizia coriaria* (Mugavu).

Figure 47. *Tailed caterpillar larvae*

6.6.2 Damage and symptoms

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 as seen in Figure 48. The older caterpillars, however, feed at the leaf margin, sometimes devouring everything except the mid-rib.

Figure 48. *Tailed caterpillar damage symptoms on coffee leaves*

6.6.3 Control

In a small number of plants, the pupae can be collected by hand and destroyed. Spraying with insecticide can be done when the caterpillars are still small and are in large numbers, using Fenitrothion 50% E.C. with 70 ml in 20litres of water or Pyrinex, 1ml per litre of water. Strictly follow safe chemical use procedures.

6.7 Tailed Ant

6.7.1 Description

Tailed ant *Oecophylla longinoda* don't affect coffee directly, but affect labourers working on coffee. Less common than the biting ant but more troublesome in some Robusta areas than the biting ant. They nest mainly in Robusta Coffee but can be found on other trees such as cashew, citrus and mango where they are extremely aggressive. Can prevent picking, pruning or other management activities.

6.7.2 Symptoms

The tailed ant is a yellowish red insect about 10 mm long (adult) (Figure 49(a) which form colonies of multiple nests (Figure 49(b). They also attend some scales. Workers construct nests by weaving together leaves using larval silk as seen in Figure 49(c).

6.7.3 Control

Spot spraying with an insecticide as in the case of biting ants. If the ants are attending scales an insecticide band should be applied to the stem. e.g. 700ml Dursban 48% E.C. in 20 litres of water with 15gm methylene blue added.

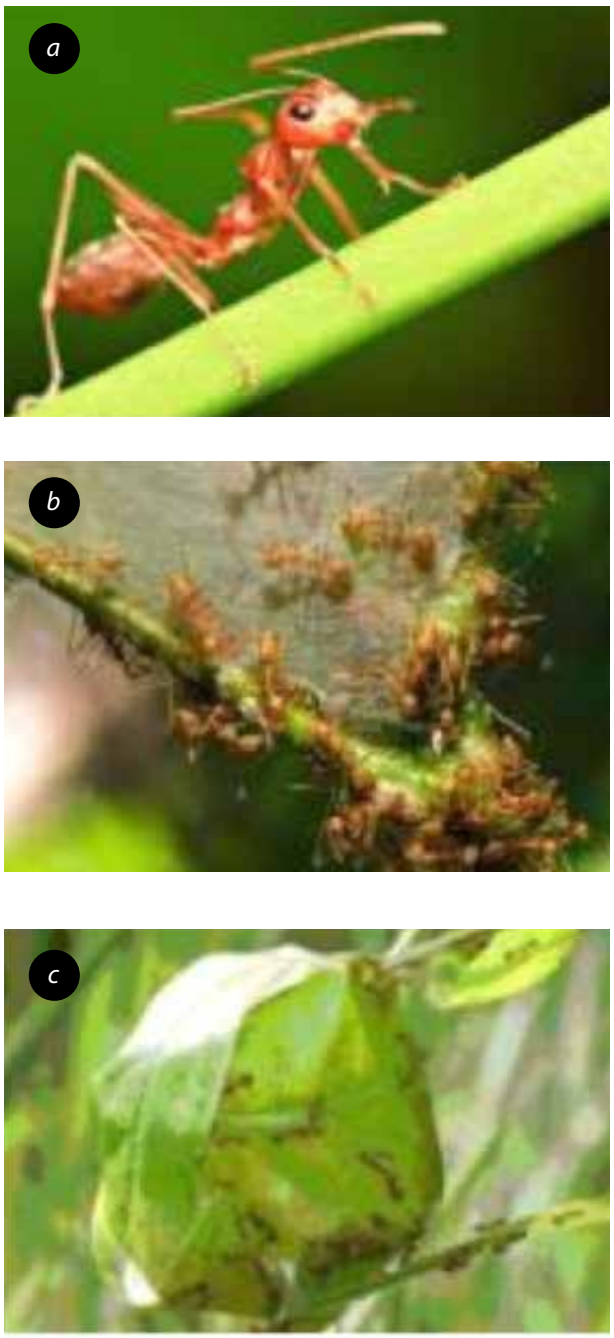


Figure 49(a). *Tailed adult ant,* ***(b)*** *Ant colony and* ***(c)*** *Ant nest*

6.7.2 Symptoms

Tailed ants form colonies (Figure 50(b) with multiple nests in coffee trees, each nest being made of leaves stitched together using the silk produced by the ant larvae. Workers construct nests (Figure 50(c) by weaving together leaves using larval silk.

6.7.3 Control

Spot spraying with an insecticide as in the case of biting ants. If the ants are attending scales an insecticide band should be applied to the stem. e.g. 700ml Dursban 48% E.C. in 20 litres of water with 15 gm methylene blue added.

6.8 Biting Ants

6.8.1 Description

Biting ants *Macromischoides aculeatu* don't affect coffee directly, but affect labourers working on coffee. Commonly found in most Robusta Coffee areas and mainly found in Robusta Coffee. Can prevent picking, pruning or other management activities.

6.8.2 Damage and symptoms

They are small black and extremely aggressive ants, which makes papery nests between leaves.

6.8.3 Control

Biting ants can be managed by spraying with a recommended insecticide. It does not, however, generally encourage infestation by scales and mealy bugs. Spot treatment of the nest with 40ml of Fenitrothion 50 % EC in 20 litres of water can contain the infestation.

CHAPTER 7

DISEASES OF ROBUSTA COFFEE AND THEIR MANAGEMENT

7.0 Introduction

A number of fungal diseases are found on Robusta Coffee, which under favourable conditions may cause damage to the crop. Presence of a disease 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. The common diseases affecting Robusta Coffee in Uganda include Coffee Wilt, Coffee Leaf Rust, the Red Blister Disease and Root Rot Disease.

7.1 Coffee Wilt Disease

7.1.1 Description

The coffee wilt disease (CWD) also known as "Fusarium wilt" or "Tracheomycosis spp" is caused by the fungus *Fusarium xylarioides* or *Gibberella Xylarioides* and is seen as the most important biological threat to coffee production in Uganda. Attacks only Robusta Coffee in Uganda, occurrence can be sporadic leading to epidemics. The fungus attacks the vascular system of the coffee plant, causing blockage of water and nutrient transportation from roots to other parts of the plant.

This causes wilting and eventual death of the affected plant. The disease is soil borne. Its spores enter through the plant tissue/wounds/cracks on the stems (collar region) and the root system. The spores from infected plants are spread within the coffee field by wind, running water and human activities such as movement of infected soil or planting material, movement and/or use of infected coffee husks (as mulch) and carrying dried plants (as firewood) and use of unsterilized garden tools. Has no chemical remedy.

7.1.2 Disease symptoms

The affected coffee tree may start by yellowing and/or curling of leaves, wilting and rapid leaf defoliation as shown in Figure 50. This is followed by progressive die back of whole tree starting from the apex (tips) of the stem and progressively spreading downwards to all branches and eventually the whole plant as shown in Figure 51.

Once the back is chipped, a dark strip running all the way from bottom to top of wilting stem can be noticed. Sometimes black sporulation may be seen on the back. On a multi-stemmed coffee plant, stems die in sequence (one after the other) until the whole plant completely dries up. At advanced stages, cracks (or cankers) usually occur around the collar region of the stems of affected plant.

Coffee berries on the affected tree ripen prematurely, dry up, but remain attached to the primary branches. An infected and dried up coffee plant remains firmly rooted in the ground unlike one that is infected by other fungi like *Armillaria mellea*, which easily topples over when pushed. Infected plants do not recover even after pruning and/or stumping. When pruned or stumped, any suckers that may sprout later wilt and dry up.

Figure 50. *Early symptoms of coffee wilt*

Figure 51. *Wilted coffee due to coffee wilt*

7.1.3 Control

The ultimate control starts with good planting materials purchased from reputable coffee nurseries and planting in a freshly opened field. Planting material should be obtained from official distributors or from areas that are known to be free of the disease. Trees that have been attacked by the disease must be destroyed where they are uprooted and not dragged through healthy trees as this will spread the disease. Following destruction of diseased trees the land should be left fallow or an alternative crop grown. Coffee branches that dry due to coffee wilt disease should not be used for firewood. This is because collection from the field, tools used and transportation would aid in spread of the disease. Any wounding of the tree, especially in the stem near soil level or in the roots, will allow the fungus to gain entry. Treat wounds with disinfectant or a suitable fungicide soon after the wounds are made. Great care should be taken, therefore, to minimize damage when weeding and pruning with a machete, hoe or other implement.

A coffee field that has been infected by coffee wilt disease and trees uprooted should not be replanted with coffee for atleast $1^1/_2$ years. In the meantime, it is recommended that a fresh field, away from the infected one be prepared and planted with clean planting material such as clonal coffee. Even if a coffee bush with *Tracheomycosis* already has berries, farmers should not harvest these berries from infected trees. Such berries should be destroyed with the infected plant, as they are a channel for further disease spread. Coffee husks from infected berries can be a source of coffee wilt disease. Until the disease is completely eradicated from the country, farmers are advised not to use coffee husks for mulching their coffee fields;

Garden tools in infected fields must be sterilized or with disinfectant (e.g. 'JIK') before moving from one tree to another and before use in a fresh field. Do not use cutting tools between infected and healthy plants. If possible, all tools should be sterilized in a fire. Reduce run off using e.g. mulching, banding etc. Unless planted with a resistant cultivar, replanting with coffee should not be carried out for atleast two years to allow inoculum of the fungus in soil to decline.

7.2 Coffee Leaf Rust

7.2.1 Description

Coffee leaf rust is a leaf disease caused by the fungus *Hemileia vastatrix*. The disease occurs in all Robusta districts in Uganda, which are found between 1000–1500m above sea level. Some Robusta cultivars are more susceptible than others. Severe attack of the disease results in premature leaf fall and reduced yield.

7.2.2 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 shown in Figures 52(a) and 52(b). Old parts of the lesions become necrotic and turn brown. 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. Rust causes premature defoliation and loss of photosynthetic surfaces. Consequently, the plant resorts to stored carbohydrates in the roots to sustain developing berries. This leads to loss of fine feeder roots. Repeated attacks of rust lead 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 as shown in Figure 53. 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.

Figure 52(a). *Coffee leaf rust symptoms on coffee leaves*

Figure 52(b). *A lower side of coffee leaf heavily attacked by coffee leaf rust*

Figure 53. *A heavily defoliated coffee tree as a result of coffee leaf rust*

"Insect pest and disease control is a climate smart adaptation and mitigation measure"

7.1.3 Control

Good field management practices starting with proper field preparation, clean planting materials from recommended nurseries, cultural practices such as proper pruning, weeding etc. The use of resistant/ tolerant varieties if available is effective. Chemical control is not economical and is not recommended in the case of Robusta Coffee but rather in Arabica where it can be very destructive.

7.3 Red Blister Disease

7.3.1 Description

Red blister disease, *Cercospora caffeicola* is a serious and widespread berry disease on the old traditional seedling of both Robusta Coffee occurring mostly in the East African region. 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

Small red and slightly raised spots appear on both green and ripening cherries. The spots enlarge and join forming unsightly red blisters as seen in Figure 54. The centres of the lesions dry up and turn black. Infected dry cherries do not pulp properly which lead to loss of quality.

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. It helps to grow coffee under shade, (atleast 50% shade cover) to discourage the disease. Finally, ensure proper drainage. Chemical control is not necessary if good management is employed.

Figure 54. *Green and red Robusta Coffee berries infected with red blister disease*

7.4 Root rot or Collar crack disease

7.4.1 Description

Root rot or Collar crack -*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.

7.4.2 Disease Symptoms

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. In the case of slow decline, the main symptoms are 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.

7.4.3 Control

Control can be achieved through ring barking trees prior to felling which is the removal of the bark of the coffee tree 1- 2 meters around and 2 meters from the tree. 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 correctly by removing the bark, but leaving the tissue of the wood alive. 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 two to three 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 is achieved by drenching with fungicides. The area can be drenched with copper fungicide to reduce infection of future transplants. Copper oxychloride in a mixture of 150gm in 20litres of water may be applied.

CHAPTER 8

ROBUSTA 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. Harvesting is the process of picking the ripened fruit (berries) from the coffee trees. Coffee berries ripen progressively and may be picked at intervals of 10-15 days over a period of several months. Good post harvest practices are critical in maintaining quality.

8.1 Robusta Coffee harvest seasons

Two harvest seasons exist in Uganda. They include the main harvest season and the minor season (fly). The coffee harvest seasons in various regions of Uganda are shown in Table 21.

8.2 Robusta Coffee harvesting best practices

The best quality coffee is obtained from "*selective picking of red ripe cherries*" and this is recommended for all farmers as shown in Figure 55. Selective picking is the best way to ensure that quality in the tree is transferred to the cup. This harvesting method maximises the amount of ripe coffee harvested, as the unripe green beans are left to mature and harvested after 6 to 8 days after. In order to harvest properly farmers must stick to the following harvesting quality controls:

Figure 55. *Selective harvesting of Robusta Coffee by hand*

Table 21. Robusta Coffee harvest seasons

Region	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep
Central	X	Main Crop Season Robusta				x	x	Fly Crop Robusta			x	x
Masaka	X	Fly Crop Season Robusta				x	x	Main Crop Robusta			x	x
Eastern	X	Main crop Robusta			x	x	x	Fly Crop Robusta			x	x
Western & S. Western	X	Fly crop Robusta			x	x	Main crop Robusta				x	x
Mid-North	X	Main crop				x					x	x

- Ripe red cherries should be selectively picked by hand as shown in Figure 56. Well-harvested coffee maintains quality and attracts better prices on the market. Picking green 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 56. *Ripe Robusta cherry ready for harvesting*

- Use clean containers while harvesting in order to avoid development of mould. Have a clean tarpaulin or hessian square under the tree while harvesting. This will help the farmer to separate qualities, coffee found fallen on the ground from that freshly harvested. Secondly, in case of rain, our farmers can gather the harvested coffee quickly.
- Harvesting cherries picked from the ground must be avoided. They are frequently highly contaminated with Ochratoxin A that may be from mould growths.
- Immediately after harvesting, remove leaves, twigs and start drying the coffee.
- Avoid harvesting over- ripe and immature cherries. The best cherries are usually of a bright red colour as seen in Figure 57. The delay to harvest is normally done intentionally to have most of the coffee ripen. However in the process some coffee becomes overripe and this may result in poor cup taste in addition to possibility of mould growth (OTA) risk.

Figure 57. *Well-picked bright red Robusta Coffee cherries*

The Robusta Coffee varieties grown in Uganda do not ripen uniformly, necessitating farmers not to harvest it by strip picking as shown in Figure 58. Farmers must avoid strip picking of coffee at all costs. Despite poor quality due to immature cherry harvested through stripping, the practice also destroys leaves, coffee bearing loci and parts of the primary branches are damaged leading to reduced yields in the subsequent season. Strip picking of coffee must be avoided due to following reasons:

- It introduces cherries, that are green and immature, insect damaged and overripe into a coffee sample. After drying, all cherries turn black as shown in Figure 59 making it impossible to differentiate between qualities of coffee except by cup tasting.

Figure 58. *Appearance of strip picked coffee*

Figure 59. *Coffee colour turns black after drying due to strip picking*

- Over-ripe cherries have a negative impact on the cup quality due to fermentation while unripe and diseased cherries are one of the causes of black beans. Black beans also have a negative impact on cup quality and price.
- Stripping introduces green immature cherries, which would otherwise be left to mature and increase the yields and income to the farmer.
- Stripping interferes with the development of intrinsic factors of the coffee beans, which affects the coffee quality/density/weight and ultimately, the final price.

8.3 Robusta Coffee Processing

Proper coffee processing is important because it sustains bean quality and thus ensures better prices to growers. Two methods for coffee processing exist. These are dry processing and wet processing. The major difference between dry and wet processing is how the fresh cherry is treated.

Dry processing involves direct drying, after picking the coffee cherry. Dry processing is a natural process and is simple. The cherries are dried with the seeds still in the fruit or in their entirety and mostly using the sun to produce dried coffee locally known as *Kiboko*.

8.3.1 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 as shown in Figure 60.

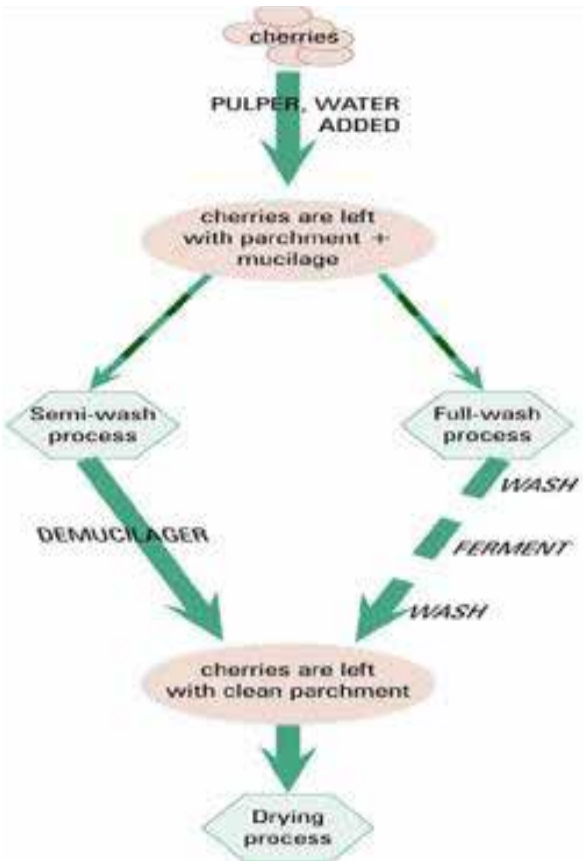


Figure 60. *Diagrammatic presentation of the wet processing methods*

In the **full wash** process the skin of fresh cherry is physically removed using a manual or powered pulping machine with addition of water (pulping). The sugar coating (mucilage) 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 -10 L/kg) water of fresh cherry and requires very good management of the fermentation and washing process to ensure the coffee flavor is not compromised in the process.

In the **semi-wash** process, the skin of the fresh cherry is physically removed by a pulping machine (Figure 61) with addition of water, as with full-wash processing. The mucilage is then removed immediately after pulping using a mucilage remover. Notably, this process does not ferment the mucilage as it is mechanically removed by a mucilage remover. Immediately after removing the mucilage, the clean parchment is ready for drying until the bean inside reaches 12-13% moisture content. Recent technological advancements have shown that pulper/mucilage remover units are a cost efficient and an effective way to consistently produce high quality coffee without the need for fermentation and washing. These units typically use less water (about 0.5L of water per kg of fresh cherry) and reduce 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 mucilage remover units, there is no need for fermentation tanks and washing systems. Pulper/ mucilage remover units are recommended for semi-washed wet coffee processing.

Figure 61. *A manual coffee pulper*

The drying of parchment coffee takes between 10 to 15 days. Parchment coffee must be properly dried to avoid mould growth and contamination in order to achieve/maintain good quality.

It is advisable to dry parchment coffee on raised wire mesh platforms under moderate sun to avoid cracking of the parchment skin. Coffee should not be dried directly on the ground/soil or dirty surface as this may lead to dirty coffee or earthy flavors in the finished coffee. Coffee should not be spread out too thick on the drying surface/areas. The coffee should be continuously dried until the moisture content has reached 12-13% moisture content. Good storage of parchment coffee, in clean sisal/jute bags and on pallets in clean stores is essential.

8.3.2 Dry processing

The process of drying Kiboko coffee takes 14 -30 days depending on weather conditions. Dried Kiboko coffee must have moisture content of 13-14% prior to sale or processing. It should be black in colour and must have no smell and free of extraneous matters such as stones, dust and mould with a minimum out-turn of 50 %. Kiboko must be properly dried to avoid growth of mould including OTA. Proper drying of coffee leads to maintaining good quality of the coffee. Always dry coffee on cemented floor, tarpaulins, raised tables and raised wire mesh as shown in Figures 62, 63, 64 and 65 respectively.

To quicken the drying time, farmers are now shifting to the use of large or small scale solar dryers as shown in Figures 66(a) and 66(b) respectively.

Cherry must be turned with a rake to allow uniform drying and should be covered at night and during rainfall to avoid re-wetting. 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 speed the drying process and avoid mould growth.

Figure 62. *Drying of Kiboko Coffee on cemented concrete slab*

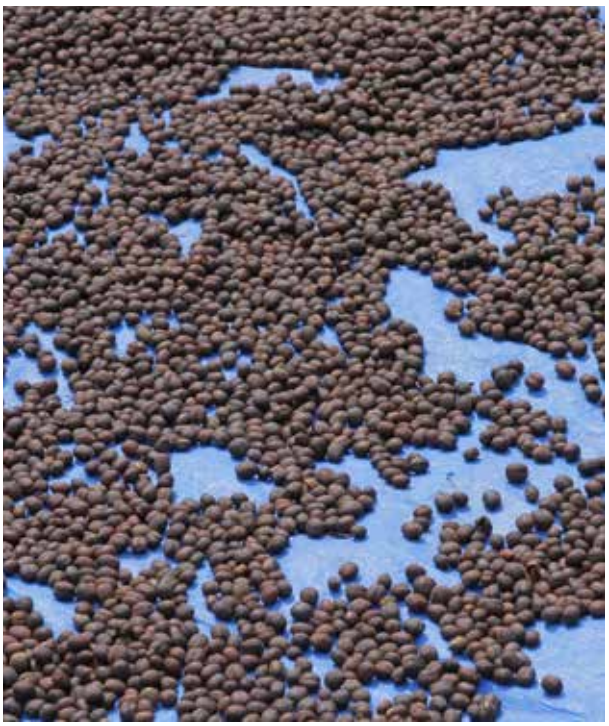


Figure 63. *Drying coffee on tarpaulin or mat*

Figure 64. *Drying of Kiboko Coffee on raised tables*

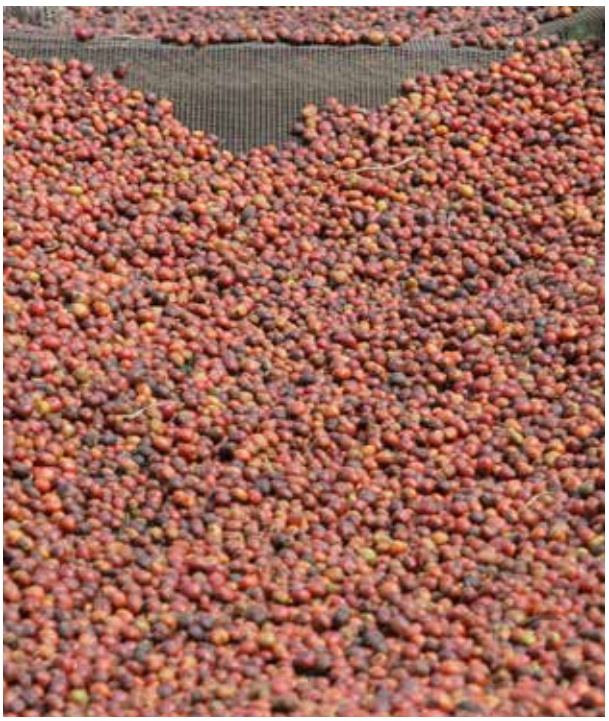


Figure 65. *Coffee drying on raised mesh*

Figure 66(a). *Large scale solar drier*

Figure 66(b). *Small scale solar drier*

8.4 Robusta Coffee storage

Even when parchment or Kiboko is dried well before storage, to avoid mould growth, it can still grow mould during storage if good care is not taken into account. Therefore, a store or warehouse for coffee should be isolated from strong smelling liquids such as petrol or paraffin or diesel, or agricultural fertilizers and chemicals to avoid contamination of the final cup. Parchment or dry cherry (Kiboko) should be stored silos or in either clean sisal bags as shown in Figure 67. Do not store parchment or Kiboko in polybags bags (Figure 68) as the coffee will absorb moisture and grow mould due condensation. The coffee bags should be placed on pallets, as seen in Figure 69, that are raised to atleast 15cm to avoid wetting by ground moisture and stacked bags should be placed atleast 30cm away from the walls and ceiling.

The coffee store should have cemented floor, plastered wall and must be well ventilated. Proper procedure for receiving coffee into storage should be developed. The first in first out (FIFO) system should be followed.

Figure 67. *Sisal gunny bags*

Figure 68. *Woven polybags should not be used for holding green beans*

Figure 69. *Coffee bags placed on pallets in a warehouse*

CHAPTER 9

ROBUSTA COFFEE VALUE ADDITION

9.0 Introduction

Various value addition activities exist within the coffee value chain. Value addition starts with selective picking of the cherry, the wet processing or hulling process and grading of the green bean Fair Average Quality (FAQ) into various screen sizes prior to sale.

9.1 Sorting Dry Parchment and Kiboko

A machine may be used to clean and sort hulled coffee by size, density and aerodynamic shape. However, ultimately, the human hand is needed to carefully "hand-sort" coffee ready for export as seen in Figure 70.

Figure 70. *Hand-sorting coffee before export*

Figure 71. *Appearance of sorted coffee beans*

9.2 Quality Testing of FAQ

Once coffee beans have been sorted (Figure 71), the out-turn test should be used as a method of quality testing of the FAQ. Out–turn % is a percentage or ratio that expresses the amount of desirable product (green coffee beans- FAQ) out of a known raw quantity of Kiboko or parchment coffee. The equipment used to establish out-turn of a sample include a sample weighing scale and a hand huller. Using the sample scale, weigh a certain quantity of the coffee, e.g. 1 kg (of Kiboko or parchment). Then –hull the measured quantity of the coffee. Winnow the discharged coffee beans that are mixed with husk to remain with clean FAQ. Weigh the FAQ in the polythene bag and subtract the weight of the husks. Using this formula below, establish the percentage out-turns.

Weight of $FAQ_{/1000}$ X100=Percentage Out-turn

If for example 540gm of FAQ are hulled from 1 kg of Kiboko, the out-turn will be as follows:

540/1,000 x 100 = 54%

A higher out-turn is more preferred since it leads a farmer to obtaining more incomes. In order to obtain the highest outturn possible, all good agricultural practices recommended in this handbook should be carried out.

9.3 Grading of green coffee beans

Coffee beans, like any other agricultural product, have variance in the size, colour and shape. Assessing the quality of green beans and finding out its attributes is important in coffee export business. This process involves (a) Grading and (b) Cupping. The first part in the assessment of green beans is grading the beans.

"Grading" is a way of analyzing the physical quality of green beans or coffee clean popularly known as FAQ. Before grading a sample is first obtained, to check for:

- The size of the bean
- Moisture content
- The quantity of defects
- Foreign matter

The size of the bean/coffee is measured using screen (SCR) size as shown in Figure 72. These are replaceable metal sheets that have round holes that retain beans over a certain size and allow smaller beans to pass through. Screen sizes are expressed in numbers (10 to 20). Table 22 below shows standard coffee round screens descriptions and table 23 shows Ugandan export grades for Robusta Coffee.

"Cupping" is the term for tasting in the coffee industry. It is the way of assessing the flavors and taints of a coffee cup.

Table 22. Screen sizes

Screen Number	ISO dimensions (in mm)
10	4.00
12	4.75
13	5.00
14	5.60
15	6.00
16	6.30
17	6.70
18	7.10
19	7.50
20	8.00

Figure 72. *Screen size trays for grading green coffee beans*

In order to obtain a better SCR size i.e. 16 or 1600 and above, farmers need to carry out proper field management practices and proper plant nutrition. The moisture level of green coffee is very important. All the above coffee grades should comply with moisture content up to 13-14%. This is done with a moisture measuring instrument as shown in Figure 73. But, since the moisture level is constantly changing, the amount and speed of change depends on the conditions of your coffee store.

Figure 73. *Coffee moisture meter*

Table 23. Ugandan export grades for Robusta Coffee

Grade	Screen retention	Total defects
Screen 18	18- 92% 15- 7% 12- 1%	7%
Screen 17	18- 7% 17- 90% 15- 3%	7%
Screen 15	17- 7% 15- 90% 12- 3%	12%
Screen 14	15- 10% 14- 85% 12 - 5%	10%
Screen 13	15- 13% 13- 85% 12- 2%	12%
Screen 12	14-13% 12-85% >12-2%	15%
bhp 1899	18-minimum 80%	Sound bean tolerance = 15% Extraneous matter = 2% Stones & metals = 0% Dust free
BHP 1599	>18-10% 15 = minimum 70%	Sound bean tolerance = 15%. Extraneous matter = 2% Stones & metals =0% Dust free
BHP 1299	>15-10% Retained above screen 12 = min 80%	Sound bean tolerance = 15%. Extraneous matter = 2% Stones & metals =0% Dust free
BHP1199	Below screen 12	Sound bean tolerance = 10%. Extraneous matter = 2% Stones & metals =0% Dust free
BHP10.13	Light & broken beans rejected at primary processing level	Sound bean tolerance = 10%. Extraneous matter = 2% Stones & metals =0% Dust free
Black beans	Black and discoloured beans sorted from export grades by hand or colour sorter.	Sound bean tolerance = 3%. Extraneous matter = 2% Stones & metals =0%

Grade	Screen retention	Total defects
Certified coffees (organic, UTZ, Rainforest Alliance, Fair-trade, 4C verified)	Process certified coffees. Certified by other bodies Cleaned and screened above screen 1400 (>14-90%)	Maximum defects 12%
Washed Robusta ungraded	Screened above screen 1400.	Maximum defects 10%

9.4 Transporting of green Robusta Coffee beans

Storage and transportation pose similar risks to coffee quality. Re-wetting of beans due to leaky tarpaulins, or high humidity inside hot containers standing for long periods in tropical ports, can result in the coffee developing mould or musty flavors. Special techniques for handling bulk or bagged green beans for container shipping are now well known. Coffee should be packed well and transported intact to avoid of any re-wetting or damage. The mode of transport must be reliable and in good mechanical condition. The transportation trucks must have sound tarpaulins to avoid re-wetting of coffee. Transport coffee alone, covered with tarpaulin and avoid carrying other substances which may contaminate the coffee e.g. fuels, agrochemicals. Ensure that transit time is as short as possible.


BE CAREFUL
THIS MACHINE
HAS NO BRAIN
USE YOUR OWN

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 marketing system. In order to obtain full benefits from coffee, growers must carry out coffee farming as a business in order to maximise profit. It should be driven by standard production and manufacturing practices aimed at sustaining economic output and product quality in order to maximise profit. The practices should be timely, accurate and efficient in resource utilization. Routine maintenance of financial and operational records is therefore crucial in monitoring of the performance of the business. Factors that affect profitability of coffee farming include:

- Productivity –in terms of Kg per tree/acre/hectare
- Market price – influenced by quality, supply and demand
- Exchange rate- fluctuates depending on market forces
- Milling loss depends on quality of Kiboko or parchment. For example, parchment type P1 has a milling loss of 20%. Parchment 2 has milling loss of 32%. Parchment 3 has a milling loss of 38% and Buni has a milling loss of 50%.

10.1 Objectives of Coffee Farming as Business

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

- Maximizing profits by reducing costs and increasing revenue.
- Maximizing sales.
- Making savings and investments for growth.
- Enhancing quality of coffee.
- Maximizing coffee output.

10.2 Coffee Farming Best Practices

The following principles must be followed in doing coffee as business

- Proper registration of the business
- Good management practices
- Proper record keeping to track all expenditures and incomes
- Proper financial management
- Regular monitoring of the coffee fields to assess performance and detect any problems
- Seeking expert advice
- Using weather forecast data for proper planning
- Using market information
- Proper planning
- Diversification of enterprises to increase returns
- Understanding the needs of the consumer or your client
- Testing and choosing best options that maximise return per unit area, including bargaining for the minimum costs for inputs and maximum prices for sales depending on quality of your coffee

10.3 Types of coffee farming businesses

10.3.1 Sole Proprietor

A sole Business/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 parameters 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. Prospective employees 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 a corporation (for-profit) 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 and/or bonuses.

10.3.4 Cooperatives

Cooperative is a type of business entity owned, controlled and operated by a group of users for their own benefit and common good. 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 and Cooperatives, or the local district cooperative officer for more information. The following principles are important for successful producer organizations:

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 democratic manner.

3. **Member Economic Participation -** Members contribute equitably to the capital of their co-operative. Atleast 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 and training for their members, elected representatives, managers and employees so 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)

10.4 Coffee Farm Records and Accounts

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

10.4.1 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
- Profit and loss account
- Yield or production record
- Labour 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 24, 25, 26, 27, 28, 29 and 30.

Table 24. Sample income and expenditure (Receipts and payment/cash record)

Receipts	Amount	Payment	Amount
Total		Total	

Table 25. Sample farm inventory (Tools and Properties) record

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

Table 26. 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 27. Sample yield (Production record)

Date	Kg/Debes of Cherry	Cumulative Total	Comments

Table 28. Sample labour record

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

Table 29. Sample stores record

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

Table 30. Sample sales record

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

10.4.2 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 as shown in Tables 31 and 32.

Table 31. Differences between farm records and farm accounts

	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 32. 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.
Labour use records	• Family labour. • Hired labour, man hours; • Piecework schedule rates.	• Measurement of labour, work etc. • Rates of work/wages and salaries.
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, i.e. the farm's ability to produce maximum output (i.e. 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 of a farm activity is the difference between the gross income earned and the variable costs incurred. In a year, the total gross margin should not be less than the total overheads, for a farm to break-even. 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 ha. 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.

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

Coffee can either be sold as dried Kiboko, FAQ, graded coffee, roasted beans or as a beverage/coffee cup. Coffee marketing options for the farmer include:

- Trading in Kiboko at farm gate
- Trading in FAQ at the local processing unit
- Trading in FAQ at national markets, to exporters
- Trading in graded coffee for export markets, as an exporter

10.6.1 Trading Kiboko at Farm Gate

Growing coffee as a business implies aiming at producing good quality Robusta cherries. Farmers should avoid all the practices that lead to poor quality. Traders or the market punishes poor quality and farmers will have their coffee discounted. Traders normally discount the coffee for being not properly dried. About 4% loss is incurred by farmers if the coffee is not properly dried. Overall farmer can lose between 10 to 15% if they deal in poor quality coffee. Therefore, good business practices would be to improve the quality of coffee in order to get as high a price as possible. Farmers should bargain for a good price if possible the highest premium possible if they deal in good quality coffee. To be able to get a premium for quality, farmers should know and own their coffee through the entire coffee value chain. Table 33 helps the farmer to look out for issues that traders/market penalizes. However, farmers should also look out for unethical practices by middlemen and should insist on using well-calibrated scales and moisture meters.

Table 33. Scenario 1 - Selling Kiboko at farm gate

Item/issue	Kg	UGX	%
Volume	1,000		
Use of scale that are not calibrated	50		
Discount (high moisture)	40		
Deduct gunny bag weight	10		
Existence of foreign matter	30		
Total kg discounted	130		
Current price per kg		2,300	
Total income Kiboko case 1		2,300,000	
Total income Kiboko case 2		2,001,000	
Total income lost		299,000	
Total income lost %			13

10.6.2 Selling FAQ at the local markets

Farmers can increase their margins by converting their Kiboko coffee to FAQ (Value addition). Farmers can increase their margins from 30 to about 50% by simply processing FAQ and selling it after processing at the hulling facility as shown in Table 34.

Table 34. Scenario 2 - Value Addition for FAQ at local market

FAQ costs	Rate/kg	%	Kg	UGX
Volume			1,000	
Loading to hulling factory	10			10,000
Transport to hulling factory per kg	20			20,000
Off-loading	10			10,000
Out-turn		58%		
Total kg FAQ			580	
Hulling cost per kg	150			87,000
Commission per kg	50			29,000
Total cost				146,000
Price per kg (FAQ) local market				5,500
Total income for FAQ				3,190,000
Margin				3,044,000
Additional income case 1				744,000
Additional income case 2				1,043,000
Additional income case 1 %		32		
Additional income case 2%		52		

10.6.3 Selling FAQ at national markets

Farmers have an opportunity to further increase their incomes further by processing FAQ, transporting and selling it to exporters in Kampala, Mbarara, Mbale, Kasese. Farmers can increase their margins from about 40 to 60% as shown in Table 35.

Table 35. Scenario 3 - Value addition for FAQ at national export markets (Kampala, Kasese, Mbarara and Mbale)

FAQ costs	Rate/kg	%	Kg	UGX
Volume			1,000	
Loading to hulling factory	10			10,000
Transport to hulling factory per kg	20			20,000
Off-loading	10			10,000
Out-turn		58%		
Total kg FAQ			580	
Hulling cost per kg	150			87,000
Transport to Kampala (FAQ)	50			29,000
Commission per kg (group level)	50			29,000
Commission per kg (Association level)	50			29,000
Total cost				204,000
Price per kg (FAQ) local market				5,750
Total income for FAQ				3,335,000
Margin				3,131,000

FAQ costs	Rate/kg	%	Kg	UGX
Additional income case 1				831,000
Additional income case 2				1,130,000
Additional income case 1 %		36		
Additional income case 2%		56		
Additional income case 3				87,000
Additional income case 3 %		2.9		

10.6.4 Selling Graded Coffee for Export Markets

As farmers move up the value chain by adding value, their incomes also increase. Farmers can increase their incomes by about 50 to 70% if they traded in graded coffee compared to selling Kiboko at the local processing unit (Table 36). However, the incremental income depends on farmers obtaining a higher screen size i.e. 16, 17, 18 and above. For good business, therefore, farmers should aim at getting higher screen size by carrying out all the best practices recommended in this handbook.

Table 36. Scenario 4 - Value addition to graded FAQ for Export Markets

FAQ Costs	Rate/Kg	%	Kg	UGX
Volume			1,000	
Loading To Hulling Factory	10			10,000
Transport To Hulling Factory Per Kg	20			20,000
Off-Loading	10			10,000
Out-Turn		58%		
Total Kg FAQ			580	
Hulling Cost Per Kg	150			87,000
Transport To Kampala (FAQ)	50			29,000
Graded Coffee Percent		0.925		
Graded Coffee Volume			536.5	
Cost Of Grading	150			80,475
Commission Per Kg (Group Level)	50			29,000
Commission Per Kg (Association Level)	50			29,000
Total Cost				284,475
Price Per Kg (Graded FAQ)				6,400
Total Income For FAQ				3,712,000
Margin				3,427,525
Additional Income Case 1				1,127,525
Additional Income Case 2				1,426,525
Additional Income Case 1 %		49		
Additional Income Case 2 %		71		
Additional Income Case 3				296,525
Additional Income Case 3 %		9.5		

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. Farmers need to be able to borrow money on affordable terms (low interest rates and long gestation and loan recovery periods linked to the agricultural season.

Farmers can overcome these challenges by forming Village Savings and Loan Associations (VSLAs) or joining Savings and Credit Associations (SACCOs). These can serve as savings and loan schemes or can link farmers

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 should keep cattle, goats, poultry or apiary enterprise (Figure 74), vanilla (Figure75) as well grow other food and cash crops to protect them from food insecurity. Animals can also provide manure for the coffee farm. Farmers can intercrop coffee with vanilla, bananas, beans, groundnuts, passion fruit and avocado to provide food an additional income. However, it is important to check with an extension officer before intercropping coffee with other crops.

Heavy feeder crops such as maize, cassava and sweet potato should be grown as intercrops of coffee but rather on a separate piece of land for food and cash. Farmers may also be engaged in non-farm alternatives enterprises such owning retail or wholesale shops, making crafts and/or having formal employment.

Figure 74. *An apiary enterprise in a coffee shamba*

Figure 75. *Vanilla enterprise in a coffee shamba*

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 business. At all these stages, key decisions should be equitable, encourage participation of all family members (Women, girls, boys) and ensure that the farm benefits everyone involved. If the man in the household takes all decisions on the use of coffee earnings, the woman may need to sell coffee secretly to cater for family needs.

Coffee earnings may be used for school fees health care, investment in the farm, home care (including soap and clothes) 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 ROBUSTA COFFEE PRODUCTION

11.0 Introduction

Climate change is caused by the warming of the earth due to the emission of greenhouse gases. As 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, landslides, thunderstorms etc. Such changes and instability in the ecosystem can disrupt agricultural productivity.

The contradiction that East Africa recently experienced a series of devastating droughts, whereas 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 question. The coffee production areas in 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. 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 was projected to be higher in the Southwest,

Figure 76. *Effect of prolonged drought on coffee*

than in the East 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.

Robusta Coffee production can seriously be affected by climate change causing massive economic losses to the farmer. 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 76.

11.1 Climate change models and projections for coffee production

Due to climate change, areas suitable for Robusta Coffee production are projected to reduce as presented in Figure 77.

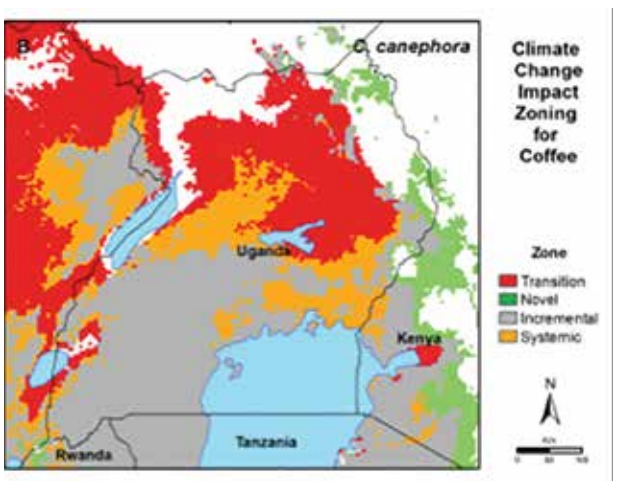


Figure 77. *Map showing future climate change impact zoning for Robusta Coffee by 2050*

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

1. **Transition zone:** These are the areas shown in red in 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 in 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 Robusta Coffee production will be moving to new areas including the protected reserves.
3. **Incremental zone:** These are the areas shown in Grey in 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 in the map. Here adaptation will need to be put in place (shade systems, improved varieties etc.)

11.2 Implications of climate change for Robusta Coffee production

Increasing temperatures can demand replanting with drought/disease resistant varieties, or varieties that are particularly suited to yield in certain climatic conditions. The future climate change impact zoning for Robusta Coffee in 2050 is presented in Figure 78.

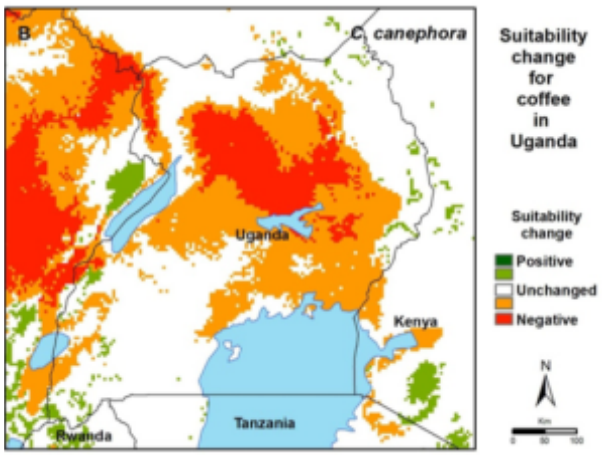


Figure 78. *Map showing suitability areas for Robusta Coffee and how these change with climate change impact by 2050*

According to Figure 78, it is predicted that by the year 2050:

- **Negative (Red areas):** Areas currently suitable for Robusta will no longer be so in 2050. They will be negative, implying it will not be possible to grow Robusta or it will only be grown with heavy

investment in climate smart agricultural practices.

- Positive (green areas: These areas will still be suitable for Robusta Coffee production in the future scenario (2050).
- Unchanged: This indicates areas that are currently not growing coffee.

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 but aimed at lowering the risks posed by a 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 farmers to implement good agricultural practices is an important step in climate adaption and mitigation. Table 37 gives a summary of climate hazards on production and adaptation/mitigation measures to prevent impacts. Table 38 is a summary of climate hazards on post harvest and measures to prevent impacts.

Table 37. Climate hazards on production and adaptation/mitigation measures to prevent negative impacts

Climate hazard	Direct-impact on coffee production	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
Prolonged rain	• Delaying flowering, • Extended vegetative phase • Delayed ripening of fruits • Lowers photosynthesis • Favours fungal diseases	• Enhanced disease control • Shade regulation

Climate hazard	Direct-impact on coffee production	Adaptation/mitigation measures
Prolonged drought/ insufficient rain	• Weaker trees, wilting, increased mortality of young 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 38. Climate hazards on post harvest and adaptation/mitigation measures to prevent negative impacts

Climate hazard	Direct-impact on harvest post harvest handling	Adaptation/mitigation options
Prolonged or unseasonal rain, Winds, Hailstorms	• Poor/difficulty in drying	• Use of artificial solar driers
Winds, Hailstorms	• Increased foreign matter in dried cherry/Kiboko	• Use solar drying
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 Pathway 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 in each 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 on developing (1) a general national and (2) a region specific CSIP. 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 government, farmer representatives and input dealers), resulting in a site-specific regional CSIP.

CHAPTER 12

ROBUSTA COFFEE SUSTAINABILITY FARMING PRACTICES

12.0 Introduction

Sustainability has 3 main pillars. These three pillars are informally 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

To be sustainable, a coffee business must be profitable. However, profit cannot justify the over dominance by the other two pillars. 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

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. This can be achieved through addressing 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. Productivity and quality can easily be improved in the coffee value chain by providing more support and opportunities to women than currently are.
- Youths form the majority of the population in Uganda. Integrating and attracting them in coffee value chains will ensure continued productivity and business sustainability.

The following strategies as outlined in Table 39 help businesses and the entire coffee sector players to address gender and youth economic participation in the coffee value chains. They link to the broader goals of the coffee industry that include maximizing productivity, growing the supply base, strengthening resilience to climate change and improving the livelihood of farmer households. Youths form the majority of the population in Uganda. Integrating and attracting them in coffee value chains will ensure continued productivity and business sustainability.

Table 39. 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 • 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 women and 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 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 those 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. • Create awareness on importance of family farming • Develop models on production and business for rural youth. • Develop groups on youth extension, clubs on young creativeness, etc. • 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, application developers etc. • Develop financial products tailored to the needs of youth. • Equip young coffee farmers with business skills and life skills. • 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.

For example, all children should go to school. Outside school hours, they may do light work on the farm under adult supervision. This helps the children to learn about the farm and they can help with record keeping. Children should not spray chemicals or carry heavy loads.

On the employee side, the coffee businesses should refocus 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 a greed. All payments should be recorded. Workers should have access to clean drinking water, 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, safe storage of agro chemicals etc.

Prevention of water pollution serves many purposes. If a farmer washes coffee in the river, water for all the neighbors down stream will be contaminated. Therefore, 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 puncture to prevent reuse. All plastic and metal waste should be kept safely until the time for their safe disposal.

Agrochemicals may be dangerous if not properly stored and used. In case of disposal, the Uganda National Bureau of Standards agents 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, goggles, gloves and boots when handling or spraying chemicals (Figure 79).
- Do not spray near other people, livestock or water sources.
- Do not spray when it is windy. Never 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 etc. 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. Where possible, keep them in a separate store.

Figure 79. *An illustration showing recommended protective gear while spraying chemicals*

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

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

Good hygiene and health on the farm is of paramount importance. Always keep the farm clean with a functional pit latrine or VIP toilet. All family members and workers should sleep under mosquito nets.

12.4 Certification Programs and Processes for Coffee Farmers

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. The voluntary 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 standards.

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. Certification can sometimes be an expensive and lengthy process, as producers must sometimes pay fees for the assessments as well as bearing the costs associated with compliance. 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 will bring the most benefit is therefore of vital importance.

Considering that there is a multitude of different standards offered worldwide, it may be prudent for producers to choose a certification that is specific to their target market. For example, if all of the coffee grown from a farm is sold into the US then being certified under USA Organic Regulation (otherwise known as the USDA National Organic Program) 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 IFOAM mark. Farmers in Uganda can choose to adhere and practice any of the following Coffee Certification Programs (1) Organic Certification (2) Fair Trade Certification (3) Rainforest Alliance Certification (4) Smithsonian Bird Friendly Certification (5) 4C Common Trade 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 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 system are detailed in Table 40. Farmers growing organic certified coffee must conform to prescribed ware housing facility standards. (Figure 80).

Figure 80. *An organic certified coffee warehouse label*

Table 40. Opportunities and challenges of organic certification

Opportunities	Challenges
• 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 • 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.	• 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 farmers or farmers located where the governance structures/skills are not present for farmers to form cooperatives.

Opportunities	Challenges
• The certification auditor checks the system rather than the individual farmers.	• 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 developing world 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 system are detailed in Table 41.

Farmers growing Fair Trade certified coffee must conform to prescribed production, processing and ware housing standards. (Figure 81).

Figure 81. *A Fair Trade certified coffee warehouse label*

Table 41. Opportunities and challenges of Fair-trade certification

Opportunities	Challenges
• Benefits of marketing/awareness campaigns carried out by Fairtrade International. • If assessors decide 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. May groups also receive assistance in paying certification fees from commercial partners or from NGOs/other partners.	• 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 Focus on small-scale farms even though large-scale coffee estates are influential in promoting ethical supply chains. • The application process will cost €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. They capture human workers' rights, community relations, protection of biodiversity/wildlife, conservation of natural resources, integration of crop/waste management and prohibition of hazardous chemicals. Full information on the standards can be sourced through the website. 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. 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 organic system are detailed in Table 42.

Table 42. Opportunities and challenges of Rainforest certification

Opportunities	Challenges
• During 2012, 375,000 metric tons of coffee, representing 4.5% of global production, was grown on Rainforest Alliance Certified farms, a 45% increase over 2011. • 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.	• 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 our 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 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. The opportunities and challenges for the organic system are detailed in Table 43.

Table 43. Opportunities and challenges for the Smithsonian Bird Friendly certification

Opportunities	Challenges
• 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. • 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 it will save money for producers. The organic inspector who visits the site in the intermediary years will need to visually assess the shade practices. • Provides a completely traceable product to the consumer – could be valuable instrument for market purposes.	• 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 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.

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 organic system are detailed in Table 44.

Table 44. Opportunities and challenges for the 4C certification

Opportunities	Challenges
• 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.	• 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 System" (SCS). Points are awarded in four categories to producers that supply Starbucks coffee. These are:

1. Product quality
2. Economic accountability,
3. Social responsibility and
4. 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 system, 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, traceability), which must be complied in order to be part of the program. For the other criteria, however, the program establishes a quantitative scoring system. So even if you start with a low score, you can be part of the program and then gradually improve your performance in the course of the following years. Essential criteria of the standard includes:

1. Financial transparency- including traceability of the coffee 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
   - No child labour, discrimination, forced labour
   - Decent housing conditions for workers living onsite
   - Access to education, medical care
   - Safe pesticide handling

3. Environmental Leadership (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 (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
6. 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)
7. Report submitted to supplier for approval or comments
8. Final payment to verifier
9. Report submitted to Starbucks Coffee Company (Farmer Support Center)
10. Final approval as "verified", "preferred" or "strategic supplier" by Starbucks

Annex 1: Healthy 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 may help do 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: Robusta Coffee Gross Margin Per Hectare (UGX)

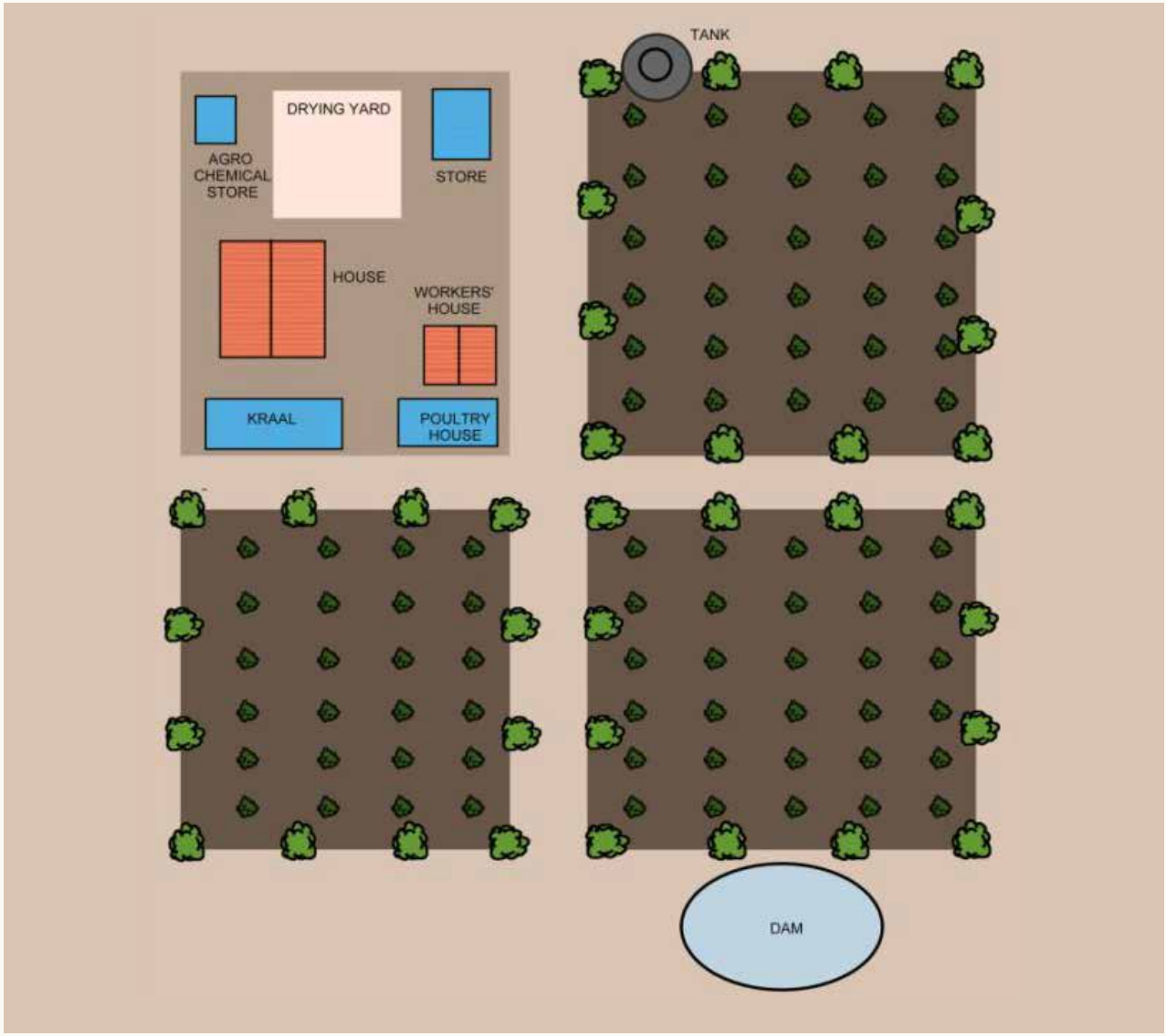
Activity	Physical Measure And Costing (Shs)		Rate	Year 1	Year 2	Year 3	Year 4	Year 5
Bush Clearing	375,000 @Ha	1	375,000	375,000				
Land Opening 1st & 2nd	500,000 @Ha	1	500,000	500,000				
Field Establishment Labour-I Ha								
Well fermented Cow dung Manure	Truck @150,000		300,000	300,000				300,000
Field marking	1,110 holes marking	1,110	50	55,500				
Digging planting holes	1,110 holes digging	1,110	500	555,000				
Refilling the holes with soil and manure	1,110 holes refilling	1,110	200	222,000				
Shade trees planting				200,000				
Recommended Robusta seedlings	1,110 plantlets (clones)	1,110	1200	1,332,000				
Planting seedlings into holes	1,110 seedling planting	1,110	100	111,000				
Field Acclimatization (first month)				250,000				
Provision for gap filling					50,000			
Coffee/Banana intercrop 4:1	275 banan plants holes digging	275	1500	412,500				
Banana coffee planting materials cost	275 banana suckers	275	2000	550,000				
Beans intercrop seed cost	40 kgs per year	40	6000	240,000	240,000			
Beans intercrop planting cost				50,000	50,000			
Mulching	Bundles of straw			400,000	400,000		400,000	
Pruning					40,000	86,800	86,800	86,800
Erosion controls e.g. Fertigation trenches	40 Man days	40	8000	320,000	250,000	60,000	60,000	60,000
Sub-Total				**5,873,000**	**1,030,000**	**146,800**	**546,800**	**146,800**
Inputs								

Activity	Physical Measure And Costing (Shs)		Rate	Year 1	Year 2	Year 3	Year 4	Year 5
Fertilizer: CAN, NPK 25-5-5, 500 g per tree per year	shs 140000@ bag		140000		1,554,000	1,554,000	1,554,000	1,554,000
Fertilizer and chemical applications labour costs	12.5 man days	12.5	8000		100,000	100,000	100,000	100,000
Farm tools and equipment	Hoes, Pangas, Secateurs etc…			60,000	60,000	60,000	100,000	100,000
Pests and disease controls	5litres @SHS 40,000				200,000	200,000	200,000	200,000
Herbicides and application	A litre@ shs 30,000					150,000	150,000	150,000
Tarpaulins	@60,000				60,000	360,000	360,000	360,000
Gum Boots	2 pairs			40,000				
Farm Overall	2 overalls			50,000				
Water can, jerry can, spade, garden fork slasher				50,000				
Wheelbarrow	one wheel barrow			120,000				
Gunny bags	bag @3,000				21,000	177,600	244,440	244,440
Sub-Total				**320,000**	**1,995,000**	**2,601,600**	**2,708,440**	**2,708,440**
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
Banana pruning/Thinning	200,000 per year				200,000	200,000	200,000	200,000
Sub-Total				**900,000**	**1,000,000**	**600,000**	**600,000**	**970,000**
Harvesting of Coffee and Beans								
Harvesting of Coffee	150 SHS/kg of cherry				171,428	1,522,285	2,095,200	2,095,200
Harvesting of Beans and after harvests costs				150,000	150,000			
Drying processes	Costed in lots (a lot of 400 to 600 Kgs Dry				35,000	210,000	210,000	210,000
Transport expenses; Home & Market	Truck hire @50,000/ trip				50000	400,000	500,000	500,000
Sub-Total				**150,000**	**406,428**	**2,132,285**	**2,805,200**	**2,805,200**
Provision for 5% Contingency costs	Contingency 5%			100,000	100,000	100,000	100,000	100,000
Amortized cost (shs/ha)1				0	0	0	0	0

Activity	Physical Measure And Costing (Shs)		Rate	Year 1	Year 2	Year 3	Year 4	Year 5
Depreciation of equipment (shs/ha)				0	0	0	0	0
Total Variable Costs (TVC)				**7,343,000**	**4,531,428**	**5,580,685**	**6,760,440**	**6,730,440**
Expected Income								
Annual Yield (kg/ha) of dry Kiboko	(1kg of cherries=0.43kg of dry Kiboko)				500	4,440	6,111	6,111
Unit cost of production (shs/kg)	Unit cost=TVC/ Total output					1256.911	1106.273932	1101.3648
Farm gate prices (shs/kg of dry Kiboko					2650	2,650	2,700	2,700
Gross income from Beans	1200 kg@shs 1800			2,160,000	2,160,000			
Gross income from banana Yield (shs/ha)	156 bunches @shs 10,000			1,560,000	1,560,000	1,560,000	1,560,000	1,560,000
Gross income-coffee					1,325,000	11,766,000	16,499,700	16,499,700
Overall gross income				3,720,000	5,045,000	13,326,000	18,059,700	18,059,700
Gross margin	Gross income- Total variable cost			(3,623,000)	513,572	7,745,315	11,299,260	11,329,260
	Cumulated net income/Hectare			(3,623,000)	(3,109,428)	4,635,887	15,935,147	27,264,407
	Cumulated net income/Acre			(1,466,802)	(1,258,878)	1,876,877	6,451,477	11,038,221
Assumptions of Recommended Coffee practices farmer								
1. He/She adopts most 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								
I bag of dry cherry weighs 75 Kg								
A drying lot of 400 to 600 kg dry is dried at 35,000								

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. 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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