COFFEE HANDBOOK

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Manual for Arabica cultivation

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PPP PROJECT “IMPROVEMENT OF COFFEE QUALITY AND SUSTAINABILITY OF COFFEE PRODUCTION IN VIETNAM”

Manual for Arabica cultivation

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Foreword

This manual aims to introduce Good Agricultural Practices to farmers. The purpose is to improve coffee quality and sustainability in Arabica production. It is a compilation of the joint experiences of the PPP project "Improvement of Coffee Quality and Sustainability of Coffee Production in Vietnam", the Tan Lam Agricultural Product Joint Stock Company and the farmers from Huong Hoa district, Quang Tri province that participated in this project.

The project team would like to thank the Douwe Egebrts Foundations which provided funding for the project. We would also like to thank all the farmers from Huong Hoa who worked with us and provided us with an insight in their management procedures and gave excellent feedback on the technical contents of the manual.

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Khe Sanh, 31-12-2004

Table of Contents

History of Arabica coffee

This chapter describes the history, origins and subsequent spread of Arabica coffee over the world.

Discovery

According to legend the rise of coffee began in the year 600 with the discovery of Arabica. The story goes that a goat herder by the name of Kaldi was herding his goats in the mountain forests of what is now called Ethiopia. Kaldi was having a nap and his goats wandered of. When Kaldi awoke hours later his goats had disappeared. Kaldi panicked and went looking for his animals. When he finally found them, the strangest thing caught his eye. His goats were very active, dancing on their hind-legs. Further investigation showed that they had been eating from a strange tree with red cherries (Figure 1). Kaldi worried even more now and was afraid his goats might get sick after eating the funny cherries.

Figure 1: Kaldi and his goats (Source: www.ineedcoffee.com)

It took Kaldi quite some time, but finally he managed to gather his animals and take them home. Kaldi didn't tell anything to his parents, but the next day when he took his goats out, they immediately went back to the same bush and started eating again! Kaldi, seeing that the cherries didn't seem to harm his goats, took some cherries as well. He noticed the effect immediately and felt energetic and very awake!

To cut a long story short, Kaldi took the cherries home and showed them to his parents, which gave them to some monks in a nearby monastery. These were very happy with the strange cherries, because chewing them kept them awake during long praying sessions. The monks started drying the cherries so that they could be transported to distant monasteries. There the monks added water to the dried cherries, ate the fruit and drank the liquid (1).

Movement of Arabica

After Kaldi discovered the cherries, word about the refreshing cherries spread through the middle-east (Figure 2). Coffee cherries moved from Ethiopia to the Arabian peninsula and were cultivated in what is now called Yemen. In Yemen the people used the skin of the cherry to make a sort of tea. It was not until it reached Turkey where people started to roast the coffee beans that coffee as we know it now was discovered.

During that time the Arabs tried to guard the secret of coffee. Nobody was allowed to travel with live coffee cherries or beans. Only in roasted form was coffee allowed to be transported. Although coffee was already available in roasted form in England and other European countries around 1640, live seeds and plants had yet to be seen by non-Arabs.

It was not until early 1700 that the Dutch managed to smuggle a coffee plant from Yemen and the world truly became familiar with coffee. The Dutch introduced it first in Java, Indonesia and from there it spread quickly.

Coffee houses quickly spread across Europe, becoming centers for intellectual exchange (Figure 3). In the 1700's, coffee found its way to the Americas by means of a French infantry captain who nurtured one small plant on its long journey across the Atlantic. This single plant, transplanted to the Caribbean Island of Martinique, became the predecessor of over 19 million trees on the island

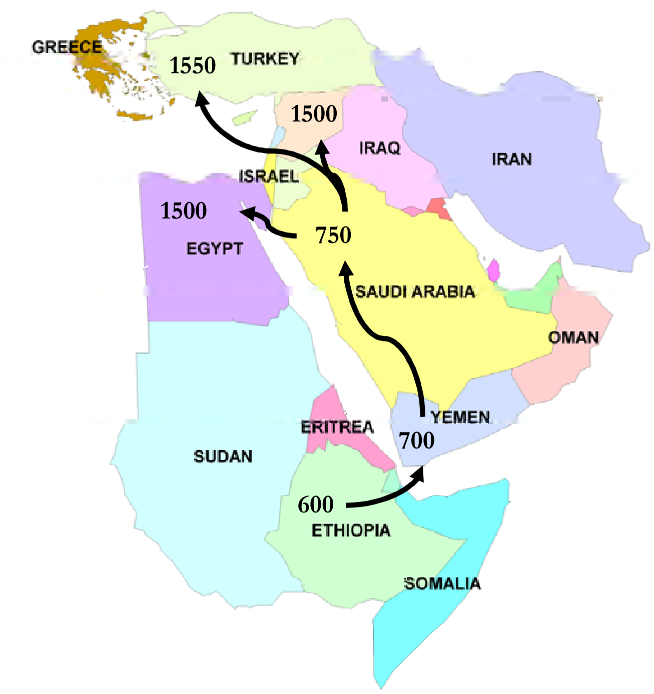


Figure 2: Origin and early spread of Arabica. The bold numbers represent the estimated year of arrival of coffee in that country.

within 50 years. It was from this humble beginning that the coffee plant found its way to the rest of the tropical regions of South and Central America.

Figure 3: European coffee house early 1700s

Coffee was declared the national drink of the then colonized United States by the Continental Congress, in protest of the excessive tax on tea levied by the British crown.

Today, coffee is a global industry employing more than 20 million people. It ranks second to petroleum in terms of worldwide trade.

With over 400 billion cups consumed every year, coffee is the world's most popular beverage. Presently, coffee is grown in over 80 countries (Figure 4).

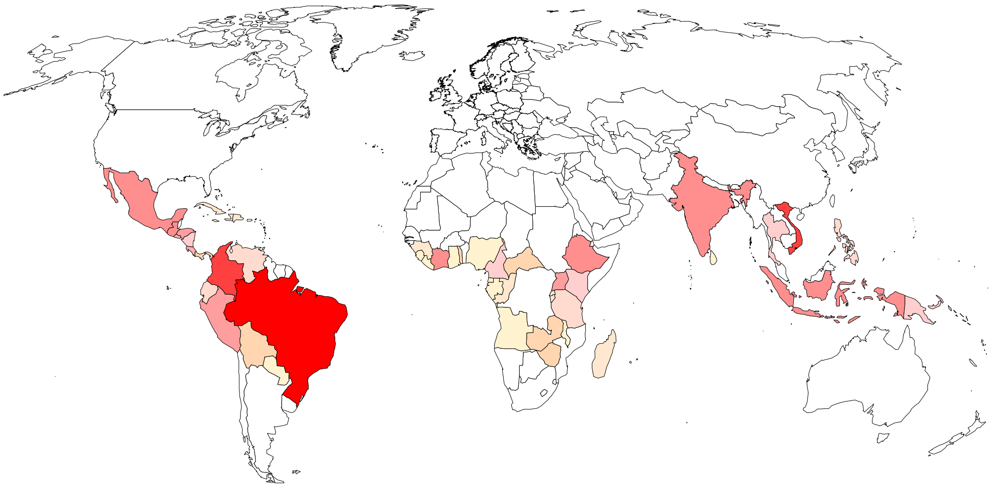


Figure 4: Coffee producing countries in 2003, the world's largest producers (in terms of volume) are colored red, lighter colors represent smaller producers (Source of data: ICO)

Commercially grown types of coffee are of the Robusta (*Coffea canephora*) and Arabica (*Coffea Arabica*) varieties (Figure 5 to Figure 8). In some countries Liberica coffee (*Coffea exelsa*) is grown as well, but market demand for this variety is limited (Figure 9 and Figure 10).

The Arabica tree in Figure 5 is of the Catimor variety. This is a so-called dwarf variety. Catimor is a cross between the varieties Hybrido de Timor and Caturra. This variety was created in the 1980s and is Coffee Leaf Rust resistant. Catimor can reach a height of up to 2.5m. The beans of Catimor produce a lower quality coffee brew than other Arabica coffees because of lower acidity and body (2 important taste and quality characteristics).

Figure 5: Arabica tree

Figure 6: Arabica leaves and cherries

Figure 7 shows a Robusta tree. The leaves of Robusta are bigger than Arabica and the tree can remain productive for a longer time. Cherries and beans of Robusta are easily distinguished from Arabica because their shape is more rounded. Robusta can reach a height of 7-10m. The beans of Robusta produce a bitter coffee brew, in some markets this is appreciated, but less so in others. It is often used in blends with Arabica.

Figure 7: Robusta tree

Figure 8: Robusta leaves and cherries

Figure 9 shows a Liberica tree. The leaves of Liberica are bigger and more rounded than Arabica and Robusta. Liberica trees can reach heights of over 10m. Their yields are typically low. The coffee brew of Liberica beans is very bitter and sour. The inconvenience of harvesting tall trees and the low quantity and quality of the crop has reduced the amount of Liberica.

Figure 9: Liberica tree

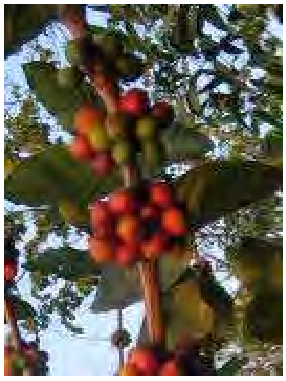


Figure 10: Liberica leaves and cherries

Development of coffee in Vietnam

Coffee was first introduced in Vietnam by the French around 1850. By early 1900 several plantations were established in northern provinces like Tuyen Quang, Lang Son and Ninh Binh. Also in the south Arabica appeared, for example in Nghe An and Ha Tinh province. Although Vietnam started with Arabica, many of the plantations used Liberica coffee. It wasn't until much later that the French started plantations in what is now the Central Highlands (Tay Nguyen).

Originally, plantations in the Central highlands grew Arabica, but these were plagued by severe leaf rust out breaks. Eventually, most of these plantations were converted to Robusta and Liberica.

In Quang Tri, coffee was also first cultivated by the French. This coffee was mostly of the Liberica type.

From the early 90s onwards the production of coffee in Vietnam developed very rapidly (Figure 11).

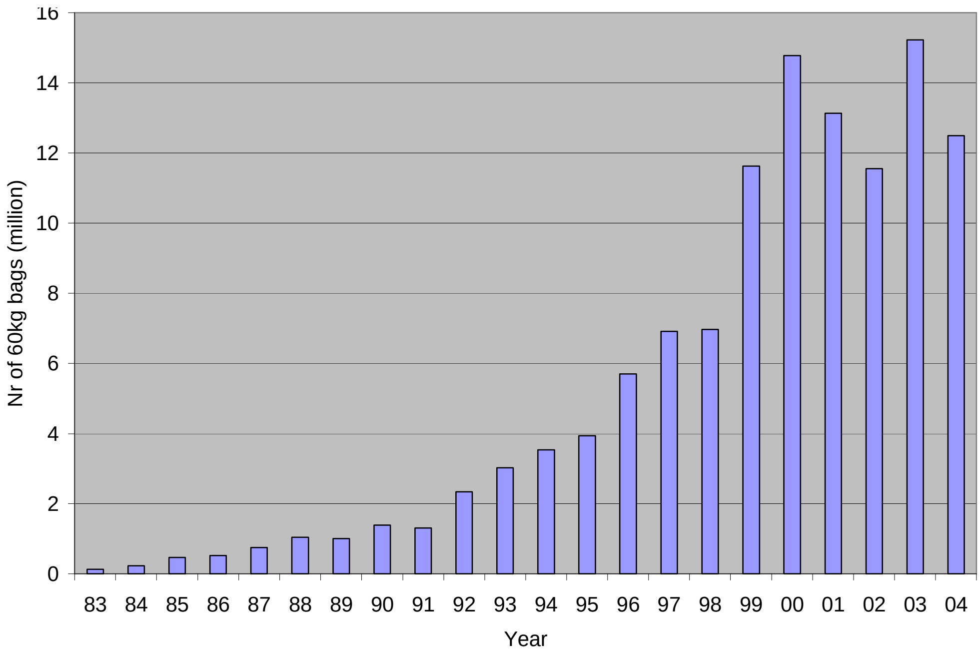


Figure 11: Vietnamese production in million 60kg bags green bean from 1983 to 2004 (Source of data: ICO)

Figure 5 shows the years from 1983 to 2004 on the horizontal axis and the production in million bags green bean of 60kg each on the vertical axis. The major increase of the late 90-ties can be attributed to:

1. implementation of land allocation to farmers;

2. High coffee prices in 1994 and 1996-1998; and

3. Resettlement schemes moving people from the lowlands to the highlands.

The largest expansion took place in the Central Highlands. Most of the newly planted coffee during this period was Robusta coffee. The central province of Dak Lak saw the largest expansion and is now responsible for around 50% of Vietnams production.

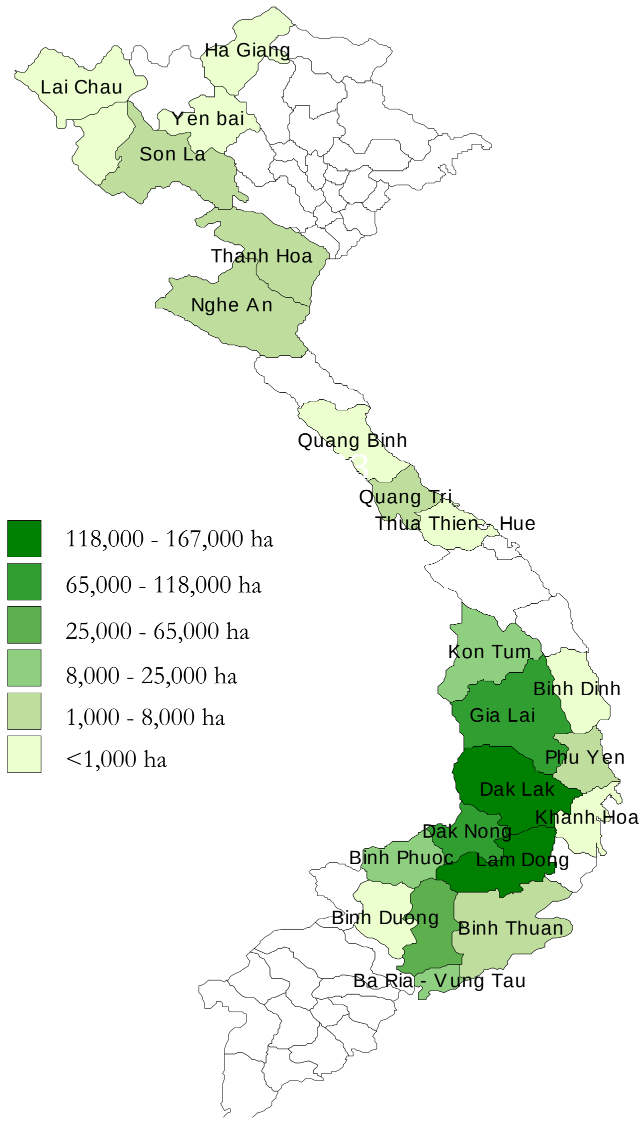
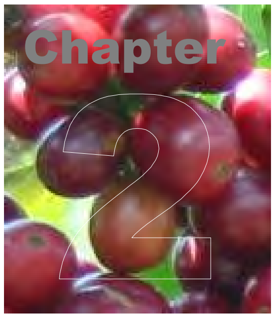


Figure 12: Vietnam production areas 2003 in ha (Source of data: GSO)

Presently, Vietnam ranks as second exporter in terms of volume after Brazil and has an estimated market share of 13%.



Introduction to Arabica

This chapter gives a general description of Arabica coffee in terms of physiology and ecological requirements.

Growing conditions

Arabica coffee originated from the mountain forests of Ethiopia. There it was growing under shadow of the forest canopy. The original Arabica tree is a shadow loving type. However, years of breeding have resulted in varieties that give good yields in full light conditions such as *Catimor*. Arabica is grown in tropical regions with an altitude of over 500m, but preferably from 1000-1500m. Higher altitudes generally produce a better quality crop. Some 1200-2000mm of annual rainfall should be well-distributed. Arabica can not stand frost and the minimum temperature should be above 4-5°C. Optimum temperature for Arabica cultivation range from 18-25°C. Flowering is initiated after the first rains and maturation of cherries requires a dry period that can be up to 5 months.

Arabica has a deep root system and requires well-drained deep soils rich in organic matter. The organic matter is important as it buffers the crop against fluctuations in available moisture and nutrients. The optimum pH range is from 5.4 to 6.0.

Classification

Arabica coffee is part of the *Rubiaceae* family. This family contains over 70 species. Only 2 are commercially grown in large numbers: Arabica and Robusta. Others like Liberica and Excelsa are also commercially grown but in such low quantities that their importance is limited. Each of the species has numerous varieties.

In Huong Hoa, Arabica of the Catimor variety is grown, however, there are still some scattered plots with Liberica and leftover Robusta trees.

Besides Catimor, several Brasilian Caturra and Catuai varieties are presently being tested in Huong Phung (Figure 13, 14, 15 and 16) in the Tan Lam coffee variety trial. Although previous experiences with these varieties in Quang Tri did not turn out well

(2004, personal communication with farmers) due to Coffee Leaf Rust infections the present test looks promising. Tested varieties show more vigor than the local Catimor in the same trial and have more stable yields.

Figure 13: Arabica catimor (red)

Figure 14: Arabica catimor (yellow)

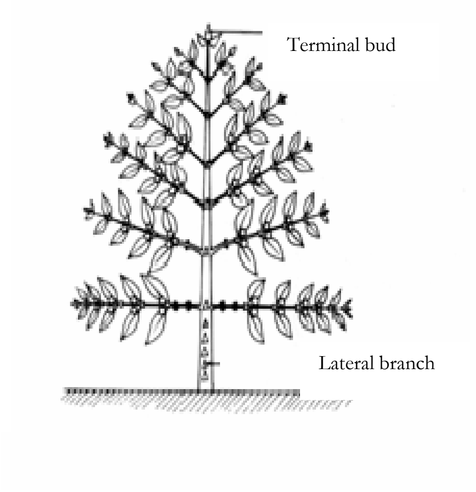
Figure 15: Arabica catuai

Figure 16: Arabica cattura

Structure

The structure of a coffee tree refers to the growth shape of the tree. The stem goes straight up and is called **orthotropic** (which means vertical) (Figure 17). Multiple stems within a tree, grown from suckers, can also be found. Lateral branches (Figure 17) spring on opposite sides of the stem and are called **plagiotropic** (which means horizontal).

Auxiliary buds (buds arranged around an axle, i.e. a stem or a branch) on the stem consist of a primary bud that can grow into a lateral branch, and several buds that develop into suckers and **inflorescences** (that is where the flowers grow from). The primary branches can be further divided in secondary and tertiary branches (Figure 18).



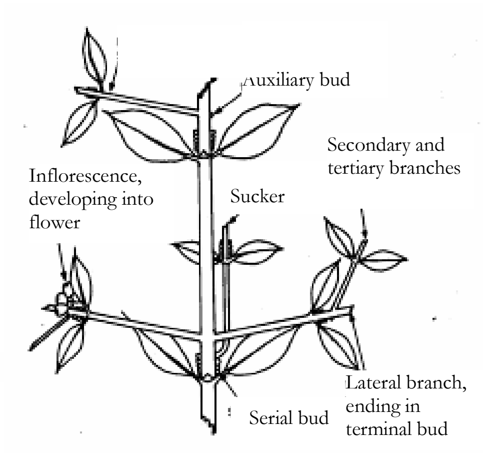


Figure 18: Detailed structure of Arabica tree

Figure 17: Structure of Arabica tree

Flowering

Flowering takes place on lateral and secondary branches. Full development from the flower buds to the inflorescences takes around 2.5 months. The inflorescences (Figure 19) that develop into flowers are found on 1-year old wood. The flower buds are dormant until the first rains initiate blossoming (Figure 20). However, if rains come directly after the harvest the buds can develop into branches. Initiation of flowering typically takes a week to 10 days after the first rains. There may be several flowering periods, each triggered by sudden rains. For the flower to develop into a fruit it has to be **pollinated** (pollination is the process where pollen from one flower is transferred to the stigmata of another by wind, insects and gravity). Arabica is largely **self-pollinating** (this means that flowers from a particular tree can pollinate each other, i.e. there is no differentiation between male and female flowers).

Each flower has 2 so-called **loculi.** When fertile pollen comes in touch with the loculus the plant is feritlised (Figure 21) and two beans will develop as a result. However, only a relatively small proportion of fertilized flowers (16-20%) result in ripe cherries because some flowers are attacked by pests (e.g. aphids) and drop down.

Figure 19: Flower buds about to blossom

Figure 20: Flowering coffee

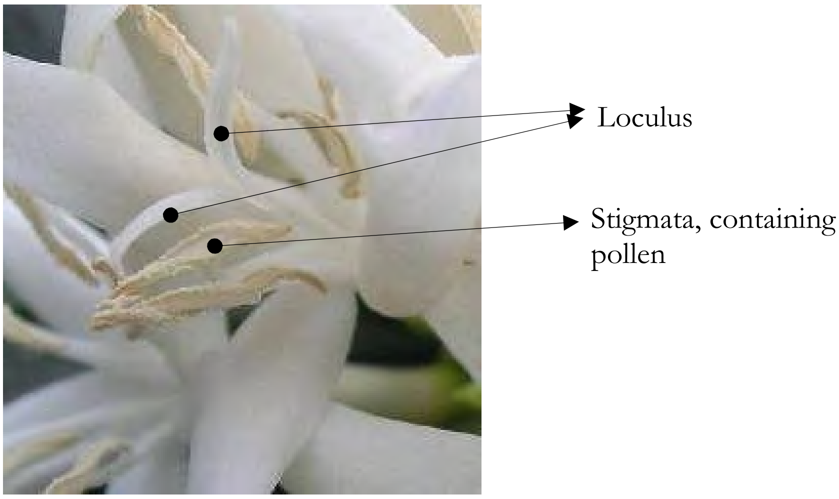


Figure 21: Detail of stigmata and loculus

Deformed flowers sometimes occur, called **starflowers**. Such flowers are **sterile,** this means pollination can not take place. Therefore, no cherries will grow from them. Common reasons for the occurrence of starflowers are: too high temperatures and insufficient difference between seasons.

Cherries

After flowering the development of cherries enters the pinhead stage (Figure 22, Figure 23). This period takes approximately 6-8 weeks and is marked by very slow growth of the cherries. In the next period cherries grow strongly for 8-10 weeks (Figure 24). In Huong Hoa this generally takes up to 12 weeks, although exact duration of these periods may vary with climatic conditions. It is during this time that cherry drop can occur. Cherry drop is instigated by moisture stress, poor nutrient status of the crop and linked to overall tree health. At the end of this period of rapid growth the potential of the year's crop has been determined. After the rapid growth period ripening of the cherries starts (Figure 25). When the cherries are red, or yellow for some varieties, they are ready to be harvested.

Figure 22: Flowering

Figure 23: Pinhead (size of pinheads is around 2-4mm)

Figure 24: Filling

Figure 25: Ripening

?

During which stage of cherry development do you think is the nutrition requirement of the tree greatest?

The majority of cherries contain two beans. The beans have a thin layer called the silver skin and this is surrounded by a hard layer called the parchment. Around the parchment is the pulp. The pulp is covered by the skin (Figure 26). Although a cherry normally contains two beans deformations happen. The most important deformations in Huong Hoa are pea berries and floaters. A pea berry forms when only one loculus is fertilized.

Some people say that pea berries have better taste characteristics than normal beans but others disagree. Whatever the case is, the major roasting companies do not want to have pea berries. Because of their different shape pea berries have a shorter roasting time than normal beans of the same size. This leads to unevenly roasted coffee. On the other hand several specialty coffee stores sell pea berry coffees to connoisseurs.

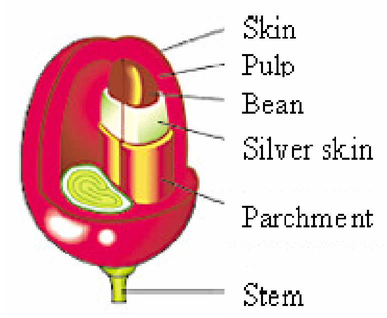


Figure 26: Cross-section coffee cherry

Floaters are cherries in which one or both of the beans is an empty shell. This is caused by genetic as well as physiological factors such as poor nutrient status of the tree and extended drought.

Leaves

The leaves of a coffee tree are shiny and waxy and dark green or brownish in color. The colour and thickness of the leaves varies with age, variety and nutrient status. Leaves form opposite pairs. True Catimor has brown leaves at the tip of the branch whereas degenerated Catimor does not have this characteristic (Figure 27, Figure 28).

?

Given the fact that Robusta can grow at lower altitudes than Arabica, what would be the difference in stomata density between the two?

Figure 27: True catimor

Figure 28: Degenerated catimor

Coffee is an evergreen tree. Leaf drop occurs continuously, but is stronger in dry periods and after heavy crops (over-bearing and die-back) as a result of excessive nutrient and sugar movement from the leaves and roots to fill the cherries. The underside of the leaf has microscopically small openings, called **stomata**, for gas exchange with the atmosphere. Through these openings the plant can take up CO_2 and release O_2 and water vapour. The upper side of the leaf also has stomata, but relatively few compared to the underside. This partly explains why Coffee Leaf Rust is found at the underside of leaves. The Coffee leaf rust fungus needs the stomata to "feed" on the leaf.

Root system

The function of the root system is to ensure the plant is firmly anchored to the ground and receives its supply of water and minerals. Arabica has a deep root system (Figure 29: Seedling Figure 30: Seedling root & Figure 31: Mature root system) that consists of:

- A central taproot that extends 40-60cm, depending on the porosity of the soil the taproot can reach up to 2m depth.
- Vertically growing coaxial roots, usually 4-8 of them
- Downward growing lateral roots, with numerous root hairs that absorb water and nutrients. These are particularly found in the top 30cm of the soil where the organic matter is concentrated and form up to 80% of the total root volume.

Figure 29: Seedling

Figure 30: Seedling root

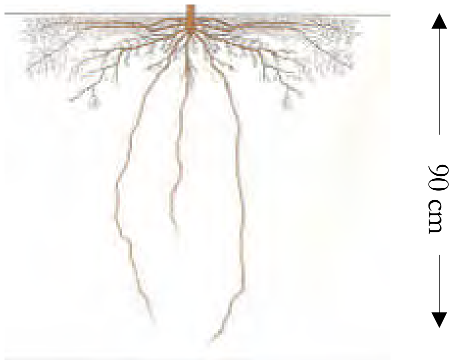


Figure 31: Mature root system

When you are planting, how can you prevent the development of crooked taproots in mature trees?

Proper development of the root system is vital. Trees with underdeveloped root systems can perform well during the first 3-5 years but will have problems later on, especially during years of heavy crops and/or little rain. Proper root development starts already in the nursery through selection of strong seedlings with straight taproots (see also section Preparation of soil and planting bags

). Sufficiently deep planting holes are important. This is to ensure that the taproot can actually penetrate the deeper soil layers.

Coffee plants require several factors for growing and producing cherries (Figure 32). Coffee, like all green plants, needs light as a source for energy that allows it to convert carbon-dioxide or CO_2 from the air into sugar. CO_2 is abundant in the air, and is breathed out by human beings and animals. When converting CO_2 into sugar, the plants need water and release oxygen or O_2. The oxygen is breathed in by human beings and animals.

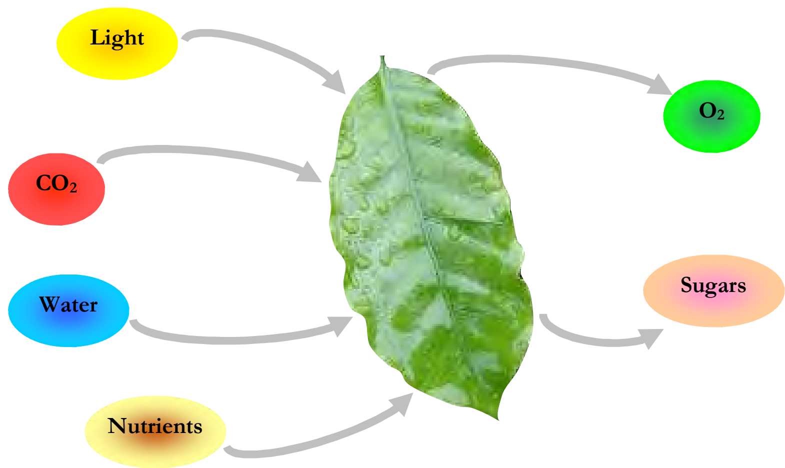


Figure 32: Requirements for growth

Nutrients are needed to allow conversion of sugar into other substances, such as the tissues that leaves are made of and the wood of the stems. That is why the coffee requires Nitrogen, Phosphorus, Potassium and many other nutrients for growth. Apart from leaves and stems, the coffee plants also produce **hormones**. These are substances that in certain combinations and concentrations induce the crop to do something specific, such as formation of flowering buds. Internal characteristics, such as the age and size of the crop, but also external conditions, such as rainfall, often stimulate or hamper the production of hormones. This is why young plants do not flower, and why flowering in older plants is stimulated by rainfall.

The conversion of light and CO_2 into sugar takes mainly place in the leaves, although also somewhat in the green cherries. Transforming sugar into other substances is done both in the leaves and in the roots. Both processes are affected by the temperature of the air and of the soil. Generally there is a range of temperatures (between 15-25°C) where these processes are done fastest. When plants grow in temperatures outside this range, either in cooler or warmer temperatures, the speed of the processes will be lower, even when enough light and CO_2 are available. This will result in slower growth. At very low (below 4°C) and very high temperatures (above 40°C), these processes are not possible anymore and the plant will not grow. Apart from having effects on the speed of the processes, very low and very high temperatures may cause dying of tissues, especially leaves and roots. To a certain extend, the plant can control its temperature through transpiration of water. This can be increased to lower the temperature of the plant when there is strong sunshine or high air temperatures, or be decreased when there is not so much light and the temperature is low. You can check the fact that plants transpire water by putting a plastic bag around some leaves. When you do this while the plant is in broad daylight, you will soon see water being formed at the inside of the plastic bag. At night, hardly any water will be formed in this way.

?

During which commonly found disease does blocking of stomata occur?

The plant absorbs light on its leaf surface, and plants with a small leaf surface will grow slowly, while those with a large leaf surface may grow fast (when other conditions are optimal). The plant breathes CO_2 in and oxygen and water out through small mouth-like openings in the leaves. These openings are called stomata. Blocking these stomata, e.g. when some fungus grow into them, will hamper the breathing of the leaves and the plant will reduce and eventually stop growing. The required nutrients and water are mainly taken up by the roots, although some nutrients and some water may be taken up by the leaves, which is why foliar application of fertilizers may work. From the roots, the water and nutrients, as well as some substances produced in the roots, are transported to the leaves in tiny tubes called **xylem** within the plant. These lay in the woody part of the stem and shoots. Sugar and other substances are transported within some water to the roots, among others to provide energy and building material for the substances produced in the roots. This flow takes place in tiny tubes called **phloem** in the bark of the stem and shoots. Since these tubes are in soft tissue and close to the surface of the plant organs, some insects like aphids can suck the sugary liquid out of these tubes, which results in the roots to get less substances than required and hence to a lower growth and production of the crop. Often, aphids suck too much of the sugar and release the excess (Figure 33). This is why places with a lot of aphids are often quite sticky. Fungi may grow on the excreted sugar, which causes the spots with excreted sugar to become black.

Figure 33: Aphids feeding on plant sugar

The fact that phloem lies close to the surface of the stem is also used by humans when they want to kill a tree by removing the bark. Then the flow of substances to the roots is completely shut of and the tree dies in a short time.

?

Why would the tree give preference to filling cherries rather than maintaining leaves when water or nutrients are in short supply?

The produced sugar and other substances are distributed from leaves and roots to other parts of the plant, such as stem, shoot, flower, cherry, but also to themselves. This is needed to allow the leaves and roots to maintain their structure and tissue. This can be compared to the maintenance required by motorbikes: when they are used a lot, parts of the engine are weakened and break down and new parts are needed. When the cherries are growing, they get preference of these flows. When there are not enough leaves to feed the cherries, the leaves will suffer, because they do not get enough sugar and substances to maintain themselves and eventually they will die, as well as the shoot on which they grow. This is called dieback. Since these dead shoots can not produce new flowers or new shoots, the production in next year will be lower.

Propagation

This chapter describes two commonly used forms of propagation; by seed and by vegetative parts. Nursery management is also discussed.

Introduction

The use of a suitable variety in relation to the agro-ecological conditions is of great importance for sustainable production. Suitable varieties in Vietnam are commonly distributed by research institutes and extension centers. However not every coffee growing province is reached by these institutes. Therefore this chapter is included so you can learn how to propagate on the farm.

Propagation can be done in numerous ways. The two most common ones, propagation by seed and vegetative propagation, are discussed here.

Propagation by seed uses ripe cherries. Cherries are formed after flowers have been pollinated, which means that genetic information from a male part of a flower (called **pollen**) is mixed with that of a female part of the flower (called 'egg' or **ovule**). With Arabic coffee, this mixing can be from parts of one specific flower, of different flowers from one plant, or from flowers from different plants. In any case, the resultant embryo has genetic information that is a mix of that in the male and the female part. Even when male and female parts come from one plant, but more likely when they come from different plants, the resulting embryo may have another combination of genetic information than that of the original plants. Each specific combination of genetic information is called a **genotype** which is a specific combination of a large set of genes. Sometimes, a specific combination of genes can be seen as the plant grows.

?

How could you avoid the deviation from the genetic base of the mother plant when propagating?

For example all trees with a true Catimor genotype have brown top leaves, while ripe cherries of Cattura Arabica have a yellow color while most other varieties have red cherries. Using seeds for propagation can result in new genotypes that have different characteristics than the mother trees. This may be beneficial, when the new combination results in a plant with, for example, better resistance to Coffee Leaf Rust. When using seeds from a good variety however, it generally results in a part of the plants that are not as good as the parents. This we see happening in Huong Hoa, where several "Catimor" plants are not resistant to Coffee Leaf Rust ,do not have brown top leaves or have different ways of growing than the real Catimor.

In vegetative propagation a leaf or shoot of the mother tree is used to create a new tree. As there is no pollination involved the genotype of the new tree will be exactly the same as the genotype of the mother tree. The new tree will have all the traits of the mother tree.

Propagation by seed

Propagation by seed starts with careful selection of seed trees. In Huong Hoa a first criteria for selection is the year of planting of the mother tree. Trees that were planted between 1993 and 1995 are cloned and of known origin and these trees have a true Catimor genotype. Trees that were planted later come from various sources and the exact variety is in most cases not clear. Therefore, when starting propagation ensure you take seed from trees planted between 1993 and 1995.

Seed tree selection

During seed tree selection it is important to observe your potential seed trees over a long period of time. Therefore, the first step in selection is at least 1 year before you intend to start actual propagation.

After the harvest in December select trees that look healthy and vigorous. The trees can be marked by loosely tying a piece of string around the stem. Simultaneously, write down the position of the tree in the field (row number and number of the tree in the row) for reference.

?

Do the leaves at the tip of the shoots also give you an indication of the trueness of the Catimor variety?

After 8 months, just before the new harvest, a second evaluation takes place. Locate the trees that were marked the first time and check if they are performing well. Select a final number of trees that you intend to use and remove the markers of the others that were discarded.

Harvesting and processing

Cherries that are ripe during the peak of the harvest are usually the best for propagation purposes. When harvesting the cherries for propagation only pick the big, healthy red cherries, thereby increasing the chance of successful germination and propagation. Cherries from the middle part of the tree are preferable over those from the bottom and top part of the tree as these developed in a lightly shaded environment leading to better quality.

As soon as possible after harvesting the cherries should be processed.

First put all the cherries you harvested in water and skim the floaters from the surface. If the cherries contain some green ones you should remove them now.

Figure 34: Packing parchment for fermentation

Processing can be done hand. Squeeze the ripe cherries by hand until the beans pop out. Then sort out the beans. Pulping does not remove all the pulp. Final cleaning of the parchment is done by fermentation. After pulping pack the beans in plastic bags (Figure 34), close them, and leave them overnight (approximately 10 hours). After fermentation the beans should be washed 2 -3 times with clean water to remove all remaining pulp.

The next step is drying. The beans (or parchment coffee as it is called after fermentation and washing) can be dried in the sun. From 9am to 3pm the sun is too strong and the parchment should be moved to the shadow to ensure even drying. Spread the parchment in a layer of 2cm deep on a clean surface and turn the beans every second hour on the first day. At night and during rain the parchment should be moved into the house to avoid rewetting.

Figure 35: Parchment, 25% moisture content

On the second day the parchment should be turned every third hour. The following days the parchment should be turned every 4 hours. At around 25% moisture content the drying is finished (Figure 35). The parchment now looks white and is tight around the beans. The color of the beans is bluish.

The final step of processing is the removal of pea berries, broken and insect invested parchment as well as parchment with more than 2 beans (Figure 36, Figure 37). Parchment is ideally sowed now, but preservation to a later date is also possible.

Figure 36: Pea berries

Figure 37: Broken parchment

For preservation the parchment can be packed, but the thickness of the layer should not exceed 10cm and it should be stored in a light airy place at room temperature to avoid fungus development. The parchment should be turned every day. To avoid fungus also fungicides like Benomyl or Vibenci can be mixed in (instructions for application can be found on the package and should be followed!).

Seedling development

Seedling development can be done on two ways. The first is to sow the parchment in a nursery bed, taking care to have the flat side of each bean facing downwards. Just before or shortly after the first leaf pair appears the seedlings can transplanted to soil-filled plastic bags. This method allows for a selection process, where seedlings with abnormal root development can be discarded. The second method is to sow directly in plastic bags, again with the flat side of the bean facing downwards. Although this method saves time it is not recommended because the lack of selection results in poorly developed root systems of about 20% of all trees planted. In the past farmers in Huong Hoa used the second method and this can still be seen in the field (Figure 42, Figure 43).

Nursery preparation

A nursery plot consists of a raised piece of land. Ideally it should be 1.2m wide and 20cm deep. The bed consists of fertile topsoil (50%) mixed with sand (50%). The soil should be clean, so remove any old roots, sticks and stones. Before sowing, the parchment should be submerged in water of 50-60°C (at this temperature the water is just bearable to touch) with 2% of lime (add 20g of lime to 1l water), stir it well and leave it for 24h. Lime will increase the pH level of the water, stimulating germination. The parchment should be sown at a depth of 1cm. Distance between the parchment should be 2-3 cm, and the distance between the rows is 3cm. The first 20 days the

Figure 38: Shaded nursery

nursery can be kept dark. After this initial stage the nursery should be shaded to control light intensity, temperature and humidity. In Huong Hoa one should aim for 70% sun light penetration of the nursery canopy (Figure 38, Figure 45). The seedlings should also be protected from strong winds.

After sowing it takes 1-2 weeks before the root penetrates the parchment. In colder weather this can take longer, up to 3 weeks. Another 2 weeks will see the young plant emerge from the soil with the parchment still covering the top. This is called **epigeal** germination. When the parchment is shed the first two leafs will appear. There are oval-shaped and called the **bracteoles**. Together with the bracteoles the terminal bud appears.

Preparation of soil and planting bags

Just before or shortly after the emergence of the bracteoles it is time to transplant the seedlings to plastic bags. To ensure good root development the bags should be sufficiently large with a diameter of minimum 17cm and a depth of 25cm or more. Shorter bags can inhibit proper root development, and more narrow bags will result in a too close spacing of the seedlings, which then will become long and thin. These are more susceptible to wind damage after transplanting the seedlings to the field. Each bag should have some holes in the bottom to allow for drainage.

Why is it recommended to use topsoil and not soil from deeper down?

The plastic bags are filled with fertile top soil (80%) and 20% organic manure. Per m^3 of soil-manure mixture 10kg of Phosphate fertilizer (16.5% P_2O_5) should be added to stimulate root development. $1m^3$ of soil-manure mixture fills around 180 bags. When filling the bags the soil-manure mixture should be moist but not wet. If you take a hand of mixture and squeeze it, water should not run out between your fingers. Care should also be taken to compact the soil in the bags. Too loose soil dries out the roots and too much compaction results in stunted roots. The right amount of compaction is reached when you can still penetrate the soil with your finger.

Transplanting

The seedlings are gently removed from the nursery. Before planting a root inspection will determine whether the seedling is to be maintained or discarded. Seedlings with double taproots can be maintained, but one root should be removed. Other than that only seedlings with a straight taproot should be used. Any others can result in lagging development later on (Figure 39 to Figure 43).

Figure 39: Twisted taproot

Figure 40: Taproot deformation

Figure 41: 8 years old tree with 25 cm taproot

Figure 42: Close up of figure 41

Figure 43: Tree of Figure 41 and 42

A stick can be used to push a planting hole in the soil of the bag. The planting holes should be around 10cm deep. The seedling should be gently lowered into the bag, making sure that the taproot goes down straight. The **collar** (the collar is a slight thickening where the root becomes stem, marked by the red circle in Figure 44) of the seedling should be positioned at soil level and the soil should gently be compacted in three steps of 5 cm each. This is to make sure that there are no open spaces surrounding the roots. Such open spaces can dry out the roots leading to premature dying off.

Figure 44: Root collar position

The first 2 days after transplanting the nursery should be watered to facilitate good establishment of the seedlings in their new environment.

In 10-12 weeks after sowing, the terminal bud will develop into a pair of primary leaves. Every new pair of primary leaves takes 3-4 weeks to emerge (Figure 45). When transplanting seedlings to the field it should have 5-7 of pairs of leaves and an overall height of 20-30cm.

Seedling development stage

Time	2-3 weeks	10-12 weeks	4 months	4.5 months	5 months
Shadow requirements	90%	70%	50%	30%	0%

Root development stage

Figure 45: Seedling development and light requirements

Figure 46 shows a time-line of seedling development in relation to rainfall. Unfortunately, only rainfall data from Khe Sanh is available, as Huong Phung does not have a weather station. Experience has taught that typically rains start and stop one month earlier in Huong Phung. Timing of seedling development should be such that the seedlings are ready for transplanting to the field at the start of the rainy season. Two options are available to farmers: either you can start in February and plant in June, or you can start in December and plant in April. The first option is preferable because the rainy period following planting lasts longer.

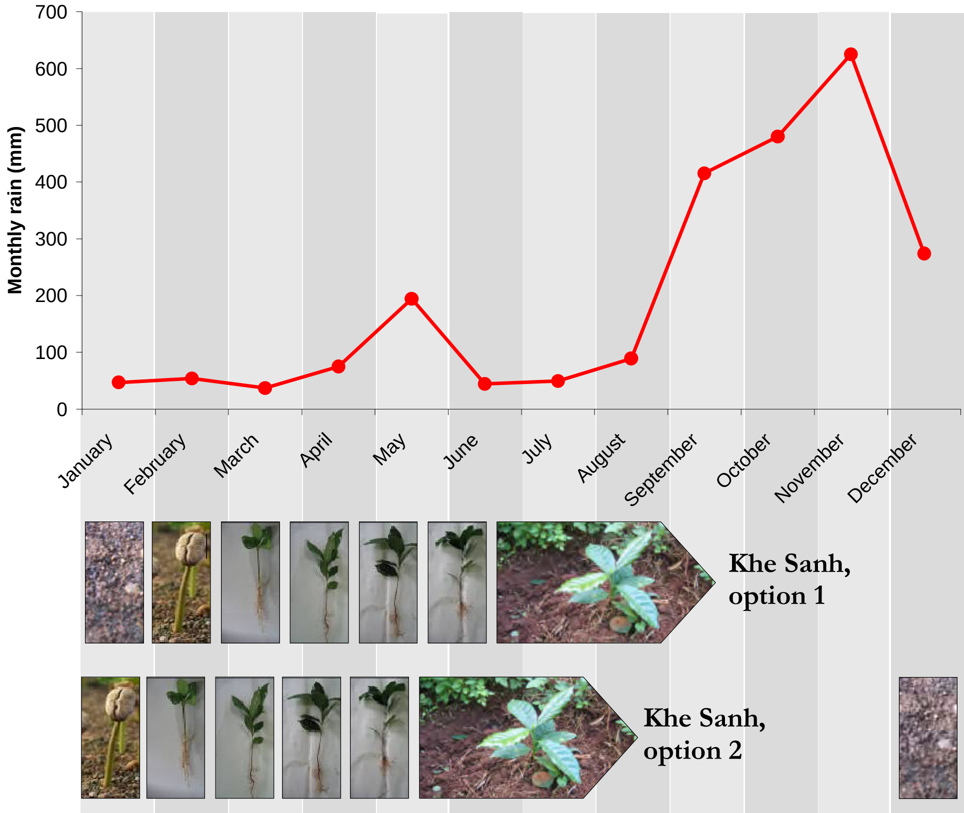


Figure 46: Time-line seedling development in relation to rainfall (average data for years 1995 to 1999)

Nursing the seedlings

During development of the seedlings, shadow requirements decrease (Figure 45). Leaf spots are an indication of too much light penetration. In propagation timing is essential. The whole process can take up to 6 months and planting in the field should not take place during the dry season.

The growth speed of the seedling in the nursery thus influences the timing. Therefore regulation is very important. This can be done by using fertilizers:

- To speed up growth in anticipation of coming rain spray water with 1% Urea (10g of urea per 1 l of water). This can only be done in the late afternoon, heavy sunshine can scorch the leaves when they have been sprayed with this mixture. As an additional precaution against scorching Urea application should be followed immediately by a spraying of plain water;
- To slow down growth water with 5% Phosphate (50g of phosphate, 16.5% P_2O_5, on 1 l water) can be used.

How can you identify seedlings that have received too much nitrogen?

Water application with Urea or Phosphate for growth regulation can be done 2-3 times, up to a month before planting. The timing for application is dictated by seedling health, and application is done if and when deficiency symptoms are spotted. If you notice that the soil becomes hard after spraying, it can be turned lightly around the seedling with a small stick. This facilitates air and water flow in the soil.

The seedlings will not all develop at the same speed (Figure 47), and seedlings which are lagging in their development can be removed. Make sure the other seedlings are not moved at all at the risk of unwittingly damaging the roots. Initially, the underdeveloped seedlings can be kept in a separate part of the nursery where more intense treatment can be administered. If this does not yield results, these seedlings should be discarded.

If pests occur a manual (removal of the insects by hand) or chemical control can be done. Fungus development can occur where the stem collar makes contact with the soil. If an infected tree is spotted it should be removed as soon as possible to contain fungus spread. Additionally fungus development can be prevented by spraying copper-based products once a month (also refer to the chapter on Pest and disease identification and prevention).

Which nutrient related disease is often observed in nurseries?

Figure 47: Irregular seedling stock

Another important activity is weed removal, which is best done as soon as weeds appear in the bags. Normal watering should be aimed at keeping the soil in the bags moist.

When the seedlings have 5-7 pairs of leaves they can planted out in the field. (also refer to the chapter on Land preparation and planting).

Vegetative propagation

Vegetative propagation can be done in two ways: via grafting and cutting. Both will be discussed here. The purpose of grafting is to combine several traits of different trees into one. For example, some trees have very good root systems, but have low yields. Other trees have good quality characteristics whereas their root system is mediocre. Combining a good root system with a decent quality yielding tree can result in a better overall performance in the field. A potential advantage of vegetative propagation is that the new trees will have the same genetic characteristics as the mother tree.

Top grafting

Previously, grafting of coffee trees in Vietnam was performed with the receiving tree at an age of 8-12 months. However, the survival rates of these grafts were rather disappointing. Subsequent research at the Tay Nguyen research institute proved that the optimal age for grafting is when the receiving tree is from 4-6 months old. By far the easiest method of grafting is called top grafting. This is what will be discussed in this chapter.

Timing of grafting is very important and depends largely on the weather. The best time to start grafting is at the beginning of the minor rainy season (May and June). During this time the weather is cool and relative humidity high. Such weather conditions improve the survival rate of the grafts.

?

Based on the conditions in Huong Hoa, which combination of species and varieties would be suitable for grafting?

The first step in grafting is to carefully assess which varieties and species could be used in the local conditions. Considerations to be taken into account are climate, soil, water supply and soil borne diseases, such as nematodes (Table 1).

Table 1: Available coffee species and varieties in Huong Hoa

Species	Plus	Minus
Arabica *Catimor*	• High productivity • Reasonable to good quality • Leaf rust resistant	• Sensitive to drought • Less extensive root system • Sensitive to nematodes
Arabica *Caturra*	• High productivity • Good quality	• Uncertain performance in Huong Hoa • Sensitive to leafrust
Robusta	• High productivity • Extensive root system	• Sensitive to nematodes • Not adapted to Huong Hoa conditions
Liberica	• Extensive root system • Resistant to nematodes	• Low yields • Unappreciated quality

In conclusion, a suitable combination in Huong Hoa seems to be a Catimor top grafted on a Liberica root system. The Catimor variety is leaf rust resistant, while the more extensive root system of Liberica increases drought tolerance of the tree. However, this has only been tried out a limited scale, therefore be advised to experiment first before engaging in wide-spread planting!

Grafting procedure

Besides suitable trees and shoots one needs a pruning scissor, razor blades, plastic bags and some thin string.

Selecting trees from which to take cuttings for grafting is the same as selecting seed trees in propagation by seed (Propagation by seed). Suckers are used to take cuttings from that can be grafted on the receiving tree. To increase the number of suckers on a suitable mother tree it can be bended over and fixed in that position. The area of the stem that is exposed to sun light will grow new suckers. To further increase the exposed area the stem can be pruned clear of branches on the top side.

If one wants to introduce new root systems to the garden, grafting can be done in the nursery. For this purpose specially grown seedlings with desirable root characteristics have to be grown (see Propagation by seed). The receiving seedlings should be 4 to 6 months old, and have 3 to 5 pairs of leaves. The top pair of leaves is cut away in such a way that the stem sticks out 3 to 4 cm above the first primary leaves. The part of the stem that sticks out should be cleft for 2 to 3 cm (Figure 48). After making the cleft the graft should be inserted and tied off as soon as possible. If the exposed inner tissue of the cleft or the graft dries out changes of a successful graft are reduced.

What is the advantage of grafting over propagation by seed from a disease resistancy point of view?

Figure 48: Receiving seedling with top cleft

The part that is going to be grafted in the seedling is the tip of a sucker or top of another seedling or tree. Care should be taken that the diameter of the stems of the receiving seedling and the new cutting are as equal as possible. Cutting of grafts is best done before 9 am when the sun is not too strong. The cutting is 4 to 5 cm in length with the top leave pair not yet opened. The leaf area of the opened leaves has to be reduced by at least 50%. This is to decrease evaporation and facilitates higher survival rates. The bottom end is sharpened in such a way that it forms a V-shape. This can then be inserted in the cleft of the receiving seedling and secured by means of some soft plastic line (Figure 49 to Figure 51). Grafts should be used immediately after cutting them. Waiting too long will dry out the cut and decrease the chance of survival of the new graft, the same holds true for the cleft.

Figure 49: Top graft

Figure 50: Insertion of graft

Figure 51: Securing the graft

After fixing the graft as in Figure 51, the top of the tree is covered by a plastic bag. This will increase the humidity around the graft and improves the survival rate of the grafts. After 7 to 10 days the plastic bag can be removed.

Alternatively, grafting can be done in the field on newly grown suckers of stumped trees. The procedure is similar to grafting in the nursery, only now shadow has to be created by placing some palm or banana leaves around the new graft.

Cutting

Propagation by cuttings is another technique. For this method of propagation similar cuttings as in top grafting can be used. After cutting, they should be put in water immediately and transferred as soon as possible to a nursery bed. The best time to do this is in January and February when the weather is cool.

The nursery bed is similar to that for propagating by seed (see Nursery preparation). However less light should be allowed to penetrate the nursery canopy (80% as opposed to 70% for propagation by seed) to avoid excessive **evapotranspiration** (similar to sweating in humans, evapotranspiration refers to plants loosing moisture while exposed to heat and light). 400 to 500 cuttings can be placed on $1m^2$, these should be covered with a clear plastic sheet. The cuttings should be aired by carefully removing the plastic sheet twice per day for a period of 1 hour per time. During aeration water can applied, 2 to 3l per m^2 twice per day, except when it is raining during aeration. After 2 weeks, watering once per day will suffice. After 6 weeks watering once per 3 days is enough. The entire process takes 2.5 to 3 months and by then the cuttings can be transferred to plastic bags, similar to seedlings (Propagation by seed). Another 6 to 7 months will result in 5 to 7 pairs of leaves and the cuttings can be transplanted to the field.

Generally, root systems developed from cuttings are less vigorous or well-developed as trees propagated by seed. Therefore, this technique should not be used in areas where drought is likely to occur.

Soil identification and improvement

Soil is one of the most important issues in coffee cultivation. This chapter will help you to asses the suitability of your soil for coffee cultivation and suggest ways on how to improve it.

Soil requirements for coffee

Arabica has specific soil requirements, although it can perform well on different types of soil. Numerous examples show that it grows well on soils of volcanic origin, such as in Khe Sanh, but also on granite-based soils as found in Huong Phung. Although the type of soil is of less importance, the texture and structure are decisive for the performance of a tree. The pH should be from 4.5 to 6, but excellent plantations can also be found on neutral (pH 7) soils [2]. Soil organic matter should be from 2 to 4%. On most soils in Huong Hoa coffee can be grown successfully. However, it is important to realize that different soils require different management.

Soil identification

Before we can decide whether a soil is suitable for coffee we have to identify the soil type and understand more about soil properties and how these interact with the performance of a crop.

To understand soil productivity, soil-tree relations must be taken into account. Several external factors that influence the performance of a tree are: air, heat (air and soil temperature), mechanical support, light, nutrients and water. For most, the coffee plants depend on the soil to provide these. Most of the factors are linked. For example sufficient moisture in the soil will facilitate uptake of nutrients by the tree.

Soil fertility is a very dynamic process. Nutrients are constantly being removed from the soil in the form of coffee cherries. Others can be lost by leaching or erosion. Again others can be tied into the soil by clay particles and remain present but hardly available

?

Apart from fertilizer and compost application what other mechanisms contribute nutrients to the soil?

to the tree. If coffee production was a closed system, the balance of nutrients might be relatively stable. However, this is not the case as cherries (and the nutrients they contain) are removed and sold during every harvest. Therefore, understanding the principles of soil fertility and how removed nutrients that have to be replaced by fertilizers and compost behave is vital to efficient crop production.

Plant nutrients

Essential for plant growth are nutrients. In total, seventeen nutrients (or chemical elements) are known in relation to tree growth. These are divided in two groups: non- mineral and mineral.

Non-mineral nutrients are: CO_2 (part of the air) and H_2O (water). Under normal conditions these are freely available and are absorbed by the tree through leaves and roots. Although water availability might be insufficient during dry spells.

Fourteen mineral nutrients can be divided in three groups (Table 2).

Table 2: Mineral nutrients

Primary nutrients	Secondary nutrients	Micronutrients	
Nitrogen (N)	Calcium (Ca)	Boron (B)	Manganese (Mn)
Phosphorus (P)	Magnesium (Mg)	Chloride (Cl)	Molybdenum (Mo)
Potassium (K)	Sulfur (S)	Copper (Cu)	Nickel (Ni)
		Iron (Fe)	Zinc (Zn)

?

Primary nutrients are used in large quanities, what does this imply for foliar fertilizer application?

Primary nutrients are called such because they are present in the tree in larger quantities. The secondary and micronutrients are present in much lower concentrations. Usually, the tree will show deficiencies of primary nutrients, although after the harvest Calcium and Magnesium deficiencies can be observed in coffee trees. In general the tree uses large amounts of primary nutrients and only smaller amounts of secondary- and micronutrients. Still the second and third groups are just as important to the tree.

Texture and structure of soil

Soil texture describes the porosity of a soil. This is determined by the relative share of each of the primary soil particles and the organic matter content. Primary soil particles are sand, silt and clay. Primary soil particles differ in size (Table 3). Secondary soil particles are mainly organic matter.

For texture, the general rule is that a clay soil has smaller particles. Conversely, a soil sandy soil has larger particles.

Table 3: Soil particles

Type	Size
Sand	0.06 – 2mm
Silt	0.002 - 0.06mm
Clay	<0.002mm

- A soil high in sand content is defined in texture as "sand"
- When small amounts of silt or clay are present the soil becomes either a loamy sand or sandy loam.
- Soils composed mostly of clays are "clay"
- When sand, silt and clay are present in equal proportions the soil is called "loam".

Soil texture and structure influence the amount of air and water available to the plant. Particle size is important because:

- Smaller clay particles can be fitted more tightly together. This results in smaller pores for water and air.
- An equal volume of soil with small particles has greater surface area than a soil with large particles. As surface area increases the amount of nutrients that can be absorbed also increases.

?

Give the importance of pore size for tree development, which would be better: mechanical or manual land preparation?

Water in the soil is mainly located in the pores between the soil particles. When the pores are big, a lot of water can be stored in these pores, and it is easy for the water to enter and leave these pores. This explains why sandy soils, which have large pores, can hold a lot of water, but are prone to drought since the water is also easily lost through drainage into deeper soil layers. Since the drained water also takes nutrients with it that are dissolved in it, sandy soils are also prone to lose nutrients rather fast.

Clay absorbs per volume generally less water than sand, but holds on to it in the small pores and can withstand the gravity so not so much water is lost through drainage.

Given the different properties of different soils, it is important for farmers to be able to identify what kind of soil they have. The examples given in the previous section shows that on a loamy or clay soil the farmer can benefit from some rainfall after fertilizing. A farmer on sandy soil however, will quickly lose any nutrients because his soil will drain the rain water, in which nutrients (especially Nitrogen) dissolve, quickly.

Two simple tests are available to the farmer to identify his soil (Figure 52, Table 4).

- A ball is formed of about 2.5 cm diameter from 1 spoon of fine soil;

- Water is slowly dripped onto the soil until the soil becomes sticky. I.e. it just sticks to the hand;
- The extent to the moist soil can be shaped is indicative of its texture (Figure 52, Table 4).

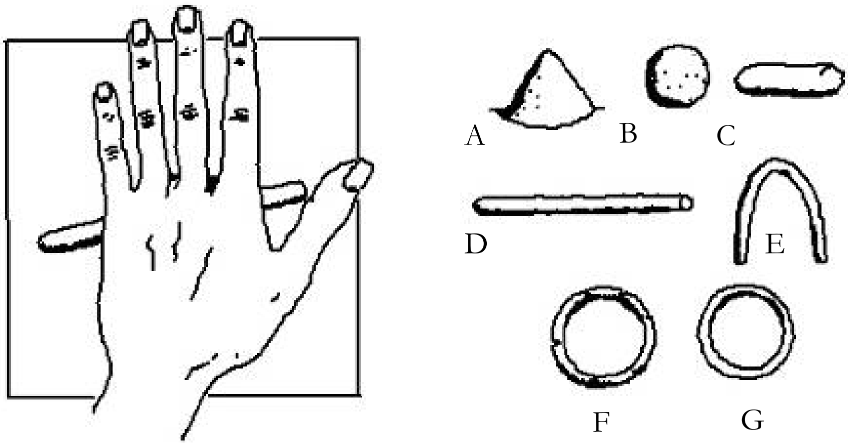


Figure 52: Soil test (Source: Agricultural Compendium)

Table 4: Soil test key (Source: Agricultural Compendium)		
A	Sand	the soil remains loose and single-grained and can only be heaped into a pyramid
B	Loamy sand	The soil contains sufficient silt and clay to become somewhat cohesive and can be shaped into a ball that easily falls apart
C	Silt loam	As for loamy sand, but the soil can be shaped into a short thick cylinder
D	Loam	Because of about equal sand, silt and clay content the soil can be rolled into a cylinder of about 15cm long that breaks when bent
E	Clay loam	As for loam, although the soil can be bent into a "U", but no further without being broken
F	Light clay	The soil can be bent into a circle that shows cracks

G	Heavy clay	The soil can be bent into a circle without showing cracks

Secondly, soil can be mixed with water to separate the primary and secondary soil particles.

First, a small amount of soil (around 0.2kg) taken from the top 10cm of the soil surface. Mix it thoroughly with a 0.5l of water in a transparent canister (e.g. a La Vie bottle). After around 60 minutes the soil particles have separated. On the surface of the water you will find organic matter, the next layer consist of clay and loam and the bottom layer is sand. This can be repeated for deeper layers, taking 10cm soil depth at a time.

Table 5: Soil analysis Huong Phung, take care that this sample is not representative for the whole commune

Depth (cm)	Field situation	Sample (0-10cm on the left, 10-20cm on the right)	
0 cm 10 cm 20 cm 			
	Figure 53: Field	Figure 54: Soil sample Huong Phung, depth 0-10cm	Figure 55: Idem Figure 54, depth 10-20cm

Observation

The bottom layer in the bottle contains heavy soil particles, the sand fraction. The second layer contains lighter particles, the silt fraction. The third layer contains the clay fraction. Organic matter floats on the surface of the water. Suspended materials are organic matter and unsettled clay particles. Using Figure 59 we can classify this soil as a silt loam.

Note that at a depth of 10-20cm there is hardly any organic matter! Also the top layer contains much more clay.

Soils from Khe Sanh are quite different (Table 6).

Table 6: Soil analysis Khe Sanh, again take note that this sample is not representative for the whole commune

Depth (cm)	Field situation	Sample (0-10cm on the left, 10-20cm on the right)	
0 cm 10 cm 20 cm			

Figure 56: Field

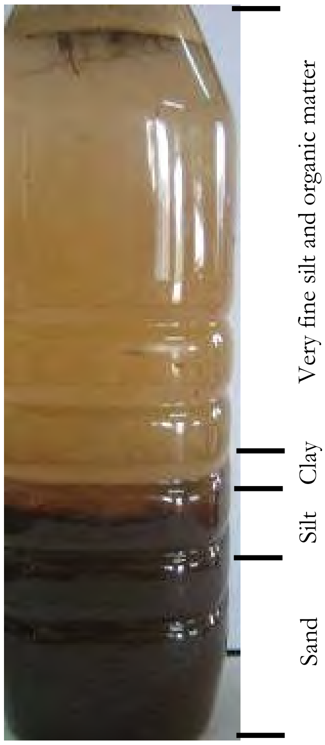


Figure 57: Soil sample Khe Sanh, depth 0-10cm

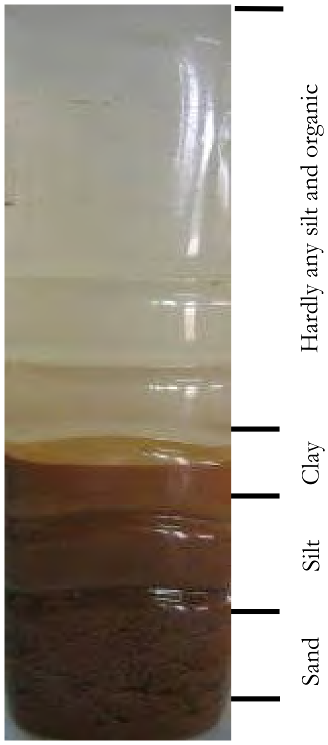


Figure 58: Idem Figure 57, depth 10-20cm

Observation

The bottom layer in the bottle contains heavy soil particles, the sand fraction. The second layer contains lighter particles, the silt fraction. The third layer contains the clay fraction. Organic matter floats on the surface of the water. Suspended materials are organic matter and clay. Using Figure 59 we can classify this soil as a clay loam.

Note that the sample from Khe Sanh has more organic matter which is also more evenly distributed between the two layers.

Using Figure 59 allows you to name your soil.

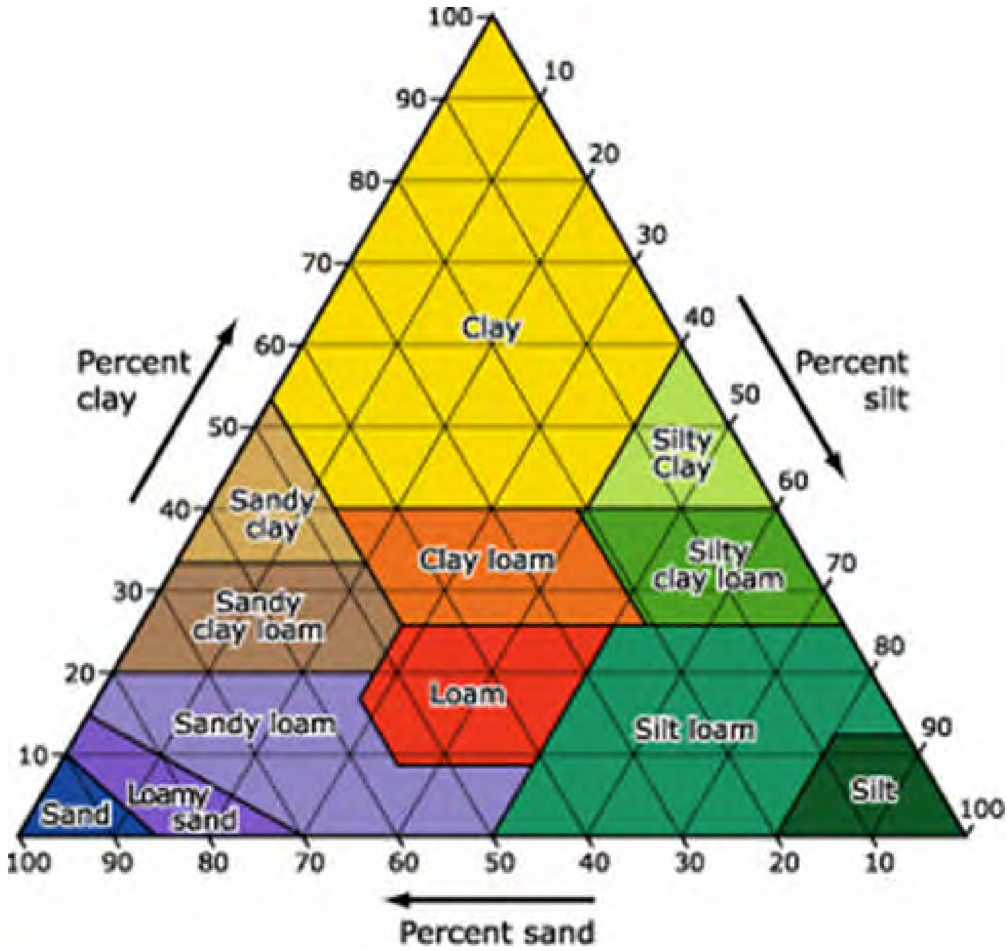


Figure 59: Soil texture classes (Source: Soil Fertility Manual)

Furthermore, it may be noted that when dry, loam or silt will give off fine powdery dust if scratched or blown upon, but a clayey soil will not. Silt is extremely powdery because of its very low clay content.

A loam when wet feels soapy and more or less plastic, when rubbed between the fingers it leaves dust on the skin, clay does not.

When digging a hole, clay that has a slightly moist condition displays shiny faces, a loam does not.

Positive and negative charged elements

Soils originate from so-called parent material. Parent material consists of the types of rock that during a process of weathering (decomposition of rock under the influence of water and wind erosion) formed the main component of the soil. In Khe Sanh the parent material is of basaltic origin, whereas in Huong Phung the parent material is granite. Different types of rocks have different characteristics, also after weathering. This explains differences in soil types between areas.

Looking at the surrounding landscape what seems a likely origin of the basaltic parent material in Khe Sanh?

During the weathering process rock and soil minerals are broken down to extremely small particles. Clay minerals are the smallest particles. The amount of clay minerals in a soil depends on the parent material (for example parent material of volcanic origin will give more clay minerals than granite parent material). Clay minerals have a so-called negative electric charge, this implies that they can retain positively charged particles. The same holds true for organic matter, this is also negatively charged.

Elements, as found in fertilisers and compost, also have an electrical charge, some positive (called **cations**), others negative (called **anions**). Similar to magnets, soil particles and nutrition elements function of opposite charge attract each other. Similarly charged particles and elements repel. (Figure 60)

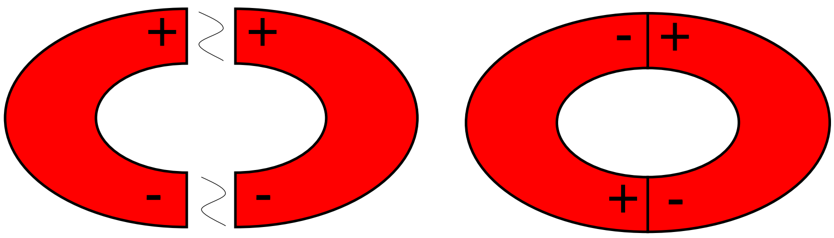


Figure 60: Magnets illustrating attraction and repulsion

As we saw that the clay minerals and organic matter are per definition negatively charged it follows that positively charged elements will be retained by the clay particles and organic matter in the soil (Table 7) whereas negatively charged elements can be lost easily through leaching and drainage of water.

Table 7: Cations, their ionic forms and the fertilisers in which they are present

Cation	Ionic form	Found in…
Potassium	K^+	Kali, NPK
Ammonium	NH_4^+	Urea
Sodium	Na^+	NPK, foliar fertilizers
Hydrogen	H^+	Ammonium sulphate
Magnesium	Mg^+	NPK, foliar fertilizers

Calcium	Ca^{2+}	NPK, foliar fertilizers

Negatively charged elements are called anions (Table 8).

Table 8: Anions, their ionic forms and the fertilizers in which they are present

Anion	Ionic form	Found in…
Chloride	Cl^{-}	Kali
Nitrate	NO_3^{-}	Ammonium nitrate
Sulfate	SO_4^{2-}	Ammonium sulphate (SA)
Phosphate	HPO_4^{2-} ; $H_2PO_4^{2-}$	Phosphate, NPK

The negative and positive charges of elements explain why some can be better held by the soil (and utilised by the plant) than others

Figure 61).

Which particle will bond more strongly with the clay particle Mg^{2+} or K^{+}?

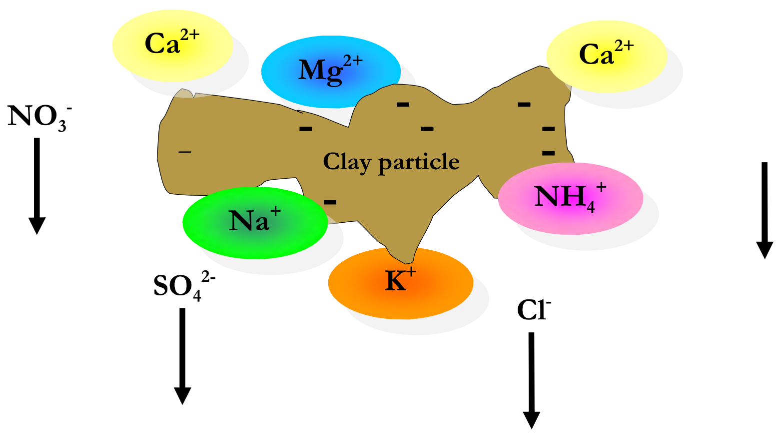


Figure 61: Cation attraction by clay particles and organic matter, repulsion of anions that will be solved in the groundwater and lost easily

When fertilising nitrogen in the form of Urea, the nitrogen becomes available to the tree as NH^{4+} while applications of SA result in NO_3^{-} becoming available to the tree. The latter is more easily leached from the soil then NH_4^{+} from Urea. However, trees prefer to absorb NO_3^{-}. Over time, NH_4^{+} is slowly converted into NO_3^{-}.

Phosphate is easily bonded by Aluminum and Iron particles. Soils in Khe Sanh and Huong Phung are rich in both and available Phosphate is low. Both Aluminum and Iron particles are positively charged and form bonds with phosphate. The resulting substances can not be dissolved in water and can therefore not be taken up by the tree. In acid soils, such as in Huong Phung and Khe Sanh, this process is intensified. However, around roots of plants often some small fungi grow, that facilitate the uptake of phosphate by the plants. This may be the reason that generally speaking, there is not so much deficiency to P in coffee plants in Huong Hoa district.

Cation Exchange Capacity

An important indicator for soil fertility is the so-called Cation Exchange Capacity (CEC). The higher the CEC of a soil the more cations it can hold and the more fertile the soil may be (Figure 62). Exchange of cations takes place with all soil particles but the CEC of sand and silt is very small and for practical purposes can be ignored. Clay can be an important source of exchangeable cations, but this depends very much on the type of clay present in the soil.

Can you think of more reasons than the one mentioned why it's better to give several small fertilizer applications rather than one or two large ones?

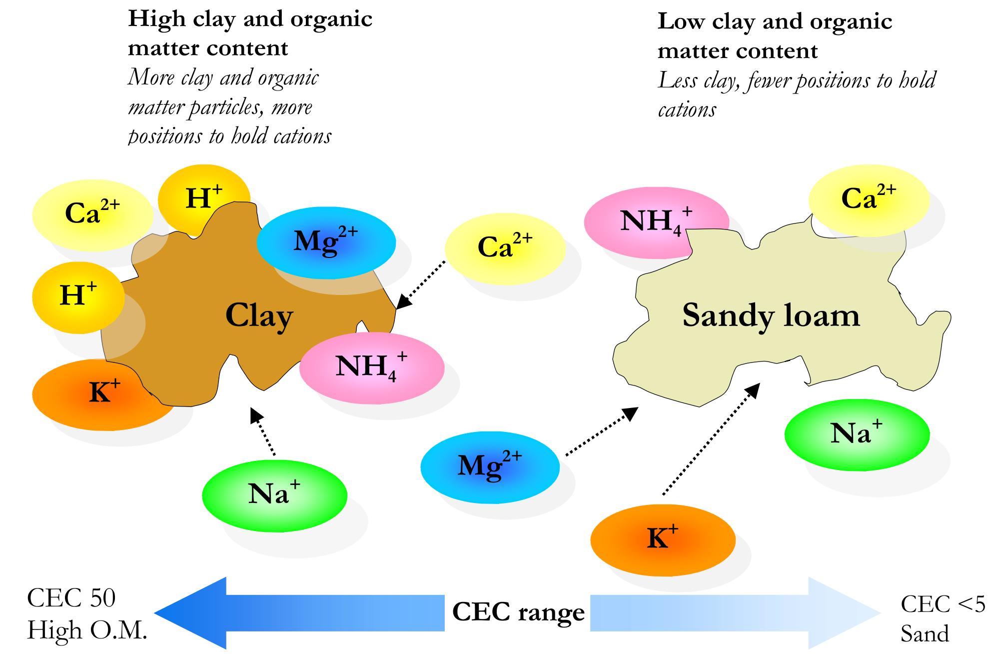


Figure 62: Comparing CEC and soil fertility for a clay and sandy loam

As can be seen in Figure 62 soils with a high organic matter and clay content retain cations much more than sandy soils with lower clay and/or organic matter contents. This has implications for fertilizer applications. Generally speaking, soils in Khe Sanh contain more clay and organic matter than those in Huong Phung. On sandy soils nutrients, especially Nitrogen and K can be easily lost if substantial rain falls after fertilizing. This is also part of the reason why it is better to apply fertilizers in a several small applications rather than one or two large ones.

Soil organic matter

Soil organic matter consists of plant, animal and microbial residues at various stages of decay. In Khe Sanh and Huong Phung soils organic matter is average to low, ranging from 2 to 3%.Soil organic matter has several benefits for the soil:

- Increases aeration and infiltration
- Reduces soil erosion
- Increases water holding capacity
- Increases soil CEC
- Supplies nutrients to the plants, including N, P and S.
- Buffers the soil against rapid changes in pH

Generally speaking organic matter can contain maximally 5% of N on a dry weight basis and generally less, so it serves as a buffer for the plant. However this N is not freely available to the plant but tied up in organic matter. As organic matter decomposes (compare fresh coffee pulp, with pulp that has been lying for a year) this N becomes slowly available. Organic matter also contains mineral elements such as Mg, P, Ca and S, these are mineralized (released from their original compounds and turned into cations) and become available to the plant over time.

?

How much composted coffee pulp in dry matter would be needed to apply 150 kg of N (assuming a 5% N content)?

So, although a soil may have a high organic matter content, additional fertilizer may be needed to ensure a supply of readily available N for the plant. This is especially the case in intensive cropping systems with high yields such as in Khe Sanh and Huong Phung.

Decomposing takes place by micro-organisms in the soil. To break down organic matter micro-organisms need N to feed themselves (they use N to make proteins). If a type of organic matter contains a high rate of carbon (its main component) in relation to the amount of N the micro-organisms will consume much of the available N to decompose the material. Because the N is initially tied up in the bodies of micro-organisms it will only become available to the plant after such micro-organisms die. Examples of materials with a high C/N ratio are un-composted coffee husk, rice straw and dried grass.

Soil pH and liming

PH is an indicator for the relative acidity or alkalinity of a substance. For example lemon juice is very acid and soap alkaline. The pH scale runs from 0 to 14. A pH value of 7 is neutral. Values above this are alkaline, values below are acid. Most soils in Khe Sanh range from 4.2 to 5 and are acid. Values for Huong Phung are lower and therefore even more acid.

An acid is a substance that releases hydrogen ions (H^+). When saturated with H^+, a soil behaves as a weak acid. The more H^+ held on by the clay and organic matter particles, the greater a soil's acidity. Aluminum (Al) also acts as an acidic element and activates H^+. As we could see in Figure 62, the number of positions in a soil particle where nutrients can be attached is finite. That means that soils with a low pH and more H^+ has less positions to which nutrients can be attached and is therefore generally less fertile.

Soil pH indicates the activity in the soil of H^+. Practically this means that each point down on the pH scale means a ten-fold increase of pH activity. So a soil with pH 6 has ten times more active H^+ then it would have if it was pH 7, and a soil of pH 5 has a hundred times more active H^+ (10*10=100).

Influencing soil pH
Soil pH is affected by numerous factors:

- **Decompostion of organic matter**. Soil organic matter is continuously being decomposed by micro-organisms. CO_2 (Carbondioxide, a gas that forms during combustion of organic material) Some of the products from the decomposition process combine with Mg and Ca that become soluble as a result. The moment these are soluble they can leach away in the ground water. As all cations, Mg and Ca were originally bounded to the clay particles. The places they left open are occupied by H^+, this increases soil acidity.

- **Parent material**. Soils developed from acid rocks generally have lower pH than those developed from basic rocks.

- **Rainfall**. As water from rainfall passes through the soil elements like Mg and Ca can be leached. The positions they leave open on the clay and organic matter particles can be occupied by H^+, resulting in increased acidity.

- **Crops grown**. Soils often become more acid when annual crops are grown. For example legumes contain higher levels of alkaline compounds than grasses and result in more acidification of the soil. Perennial crops like coffee have limited influence on soil pH, but management of coffee has, especially as a result of Nitrogen fertilization.

- **Nitrogen fertilisation**. Nitrogen, whether from fertilizers, organic manure or legume fixation increase acidity (see section on Plant nutrition and fertilisation for more details).

- **Soil depth**. Generally, soil pH increases with soil depth. Therefore, the loss of top soil by erosion can lead to decreased acidity in the top layer of the soil where the roots grow.

?

Why does pH generally increase with soil depth?

Soil pH as such does not necessarily decrease crop yield. Many crops are well-adapted to low pH levels. However, with lower pH nutrient availability can decrease and Al toxicity can occur. Al toxicity implies that levels of Al are of such a level that it impairs root growth and development of the plant.

Al toxicity decreases with higher pH. At low pH levels Al toxicity can limit root growth of the coffee tree. Al toxicity can be revealed by soil testing, but this might not be feasible for most farmers. As a rule of thumb ferrallitic soils, such as the red soils in Khe Sanh area, with a pH lower than 5.5 are likely to have Al toxicity.

Usually, Al toxicity is more pronounced in the sub soil. As it limits root growth, plants can not scavenge for water in the subsoil during dry-spells. In the field this can appear as wilting after even a short dry period.

Liming

Liming is commonly used to increase pH and thereby reduce Al toxicity. Alternatively, organic material can be used. 1 ton of organic material has roughly the same pH increasing effect as 100 kg of lime. Because the neutralising effect of organic material wears of as it decomposes fresh material has to be added every 1-2 years to maintain a lasting effect.

The effect of liming to reduce Al toxicity lasts longer, up to 5 years if applied in large quantities of around 3 Mt/ha. Roughly, each Mt of Calcium carbonate leads to an increase of 0.2-03 pH points. Different liming materials can be used, some more effective than others (Table 9).

Table 9: Liming materials and their relative neutralising value as compared to Calcium carbonate

Liming material	Relative neutralising value
Calcium carbonate ($CaCo_3$)	100
Dolomitic lime	95-108
Calcitic lime	85-100
Burned lime	150-175
Wood ashes	40-80

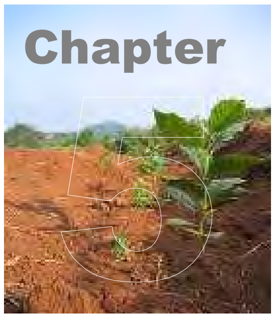
Another important parameter when deciding which material to use is the granule size of the liming material. The finer it is, the greater the neutralising effect.

Figure 63: Liming in combination with coffee pulp application, soil still has to be covered

Applying lime

The effectiveness of lime is heavily influenced by the placement of the liming material in the soil. Liming material should be worked into the soil, there where rooting is expected to take place. The neutralising effect of lime can only take place in the presence of water. Therefore, the soil should be moist at the time of application.

In Khe Sanh animal traction can be used for lime application (Figure 63). In this case a plough has been used to make a furrow in which the pulp and lime is deposited.



Land preparation and planting

Field design and planting techniques are of major influence of the potential of a coffee garden. This chapter will detail proper techniques for these activities.

Considerations

Assuming the designated soil is suitable for coffee as outlined in chapter Soil identification and improvement some additional considerations should be made. These are:

- Deep soils are preferable over shallow ones
- The soil should be well-draining, such that no water logging occurs (Figure 64)
- Organic matter content should be 2.5% or higher
- If the slope of the land exceeds 5% contour planting should be practiced

Figure 64: Water-logged planting hole

?

How to determine the slope of a field?

Planting density

In Huong Hoa planting densities vary from 3,000 to 5,000 trees per ha (Table 10). Planting density is dictated by the soil type, the variety grown and the desired stumping cycle.

Higher planting densities will have shorter stumping cycles. In Huong Hoa, a planting density of 5,000 trees/ha results in stumping after 10-12 years. On the poorer soils of Huong Phung, where rainfall is also less it can be beneficial to work with lower densities per ha and use more shadow. A suitable density for Catimor and Caturra would be anything from 3,000 to 4,000 trees per ha. In Khe Sanh where the soils are more fertile densities of up to 5,000 trees are the standard.

Table 10: Plant spacing

Distance tree to tree (m)	Distance row to row (m)	Nr of trees per ha
1.6	2.0	3,000
1.4	1.8	3,968
1.2	2.0	4,160
1.3	1.8	4,270
1.0	2.0	5,000

Soil preparation

The most suitable time for soil preparation in Huong Hoa is from January to April, in between the two rainy periods. This will see the soil ready just before the onset of the coming rainy period during which planting can be done. This will ensure a good success rate of the new trees. Land preparation can be done mechanically but manual preparation is preferable because this will cause less damage to the structure of the soil (Figure 65). Heavy machinery can compact the soil, which will make it more difficult for the roots of the young trees to penetrate to deeper soil layers.

Figure 65: Manual land preparation

The first step is to remove a number of trees, if any. If the trees present in the new field are useful as shadow trees a number of them can be newly planted (Figure 66) or maintained (Figure 67). The next step is to clean weed the entire area. Then, two methods of planting can be followed depending on the slope of the land.

Figure 66: Newly established field with Leucena shadow trees

Flat to 5% slope

On this type of land no special preparations have to be taken. The rows can set out on the field using a string according to the desired row spacing. A useful tool is then to have a stick, the length of which represents the tree to tree distance. Follow the line by over-turning the stick and plant a marker in the soil at every turn. These will be the planting holes.

Figure 67: Plantation where trees have not been removed during establishment

Each planting hole should be 0.5*0.5*0.5m. The top 20cm of the soil should be kept separate during the digging (Figure 68). This can later be mixed with fertilizers and manure or compost before it is returned to the hole.

Figure 68: Preparing planting holes, the topsoil is kept separate in front of the lady

After digging the planting holes 1.5 to 3 Mt of lime per ha should be evenly divided over the holes. Each planting hole should also receive 5kg of manure or compost. A phosphate fertilizer should be distributed as well, approximately 0.3 kg per hole.

All these ingredients should now be mixed up with the topsoil that was kept separate and returned to the hole. The remaining soil from the hole is spread out around the hole, but not inside it. Old weeds can be laid on top of the holes to protect it from rain impact (Figure 69).

?

Why is it important to use top soil in the planting mix?

The holes should now be left for around 2 weeks and after 1 or 2 rain showers planting can start.

Sloping land

On sloping land with steepness exceeding 5% contour planting should be practiced (Figure 72 & Figure 73). This is to prevent excessive loss of fertility and nutrients by erosion. Rain water that runs straight down steep land will wash out fertile topsoil (hence the large amount of silt on low-lying fields like the sample in Figure 54), organic matter and nutrients. These end up at the bottom of

Figure 69: Old weeds being collected for later use as soil cover around the young tree

the valley in the stream and are lost for the farmers. **Amounts of fertile topsoil lost on sloping fields that are not contour-planted can amount to 30 Mt/ha/year or more** (Figure 70 and Figure 71).

?

Assuming a bulk density of 900 kg/m^3 for the soil in Figure 70 to what depth is the soil eroded if the total amount lost is 30Mt/ha?

To further reduce erosion the contours can be planted with Vetiver grass (see section: Intercropping for soil coverage) in combination with shadow trees (see section: Permanent shade).

Figure 70: Severe soil erosion in Dak Lak, note that entire coffee trees have been washed away! (Courtesy: Dave D'Haeze)

Figure 71: Idem Figure 70, but in close-up

Figure 72: Contour planting

Figure 73: Mechanical land preparation, non-contour planted

In contour planting the trick is to keep the rows level over the field. This means that the rows will follow the contours of the land rather than going straight.

Most farmers in Huong Hoa lay out new rows of coffee on sloping land visually. Although this can work, the use of an A-frame will increase accuracy and thereby reduce erosion potential.

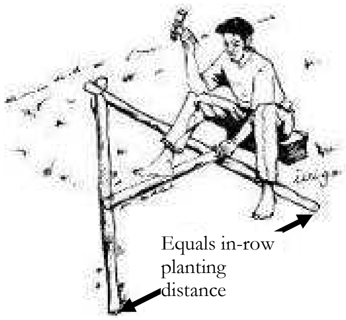


Figure 74: A-frame construction

The A-frame consists of 3 poles lashed together. The two standing legs of the "A" should equal the in-row planting distance (Figure 74).

A piece of string is tied to the top of the "A". The string should extend past the horizontal bar. Tie a stone to the end of the string.

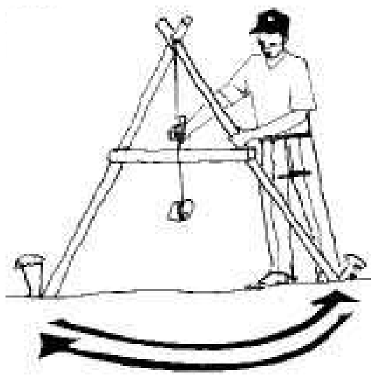


Figure 75: Calibrating the A-frame

The A-frame should now be calibrated. Keep it upright on a level surface and mark the position of the two legs on the surface. Now mark the position where the string bisects the horizontal bar (Figure 75).

Turn the frame around so that each leg stands exactly where the other has stood. Mark the position again where the string bisects the horizontal bar. You now have two marks on the horizontal bar. Halfway between these marks is where the frame stands level, mark this position as well.

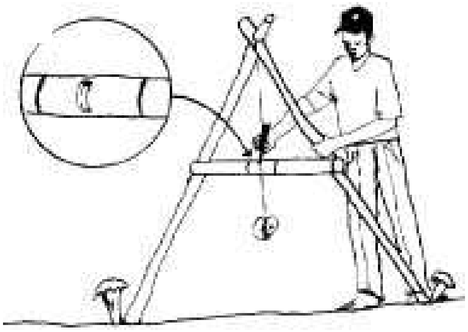


Figure 76: Using an A-frame

In the field select the place on the slope where you want the first row to start (Figure 76).

Level the A-frame by moving one leg up or down the slope until the string lines up with the central mark on the horizontal bar.

The positions of the legs indicate the places where the first two coffee trees will be planted.

Now pivot the frame whilst maintaining the second leg firmly on the surface (Figure 77).

Move the frame again until the string lines up with the mark on the horizontal bar.

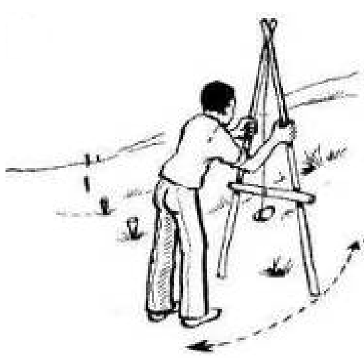


Figure 77: Using the A-frame, continued

Continue pivoting the frame and marking the positions of the legs until you reach the end of the field. The row follows the contours, move up the desired row spacing and repeat the procedure.

Planting

The best time to plant coffee in Huong Hoa is from May to July for Huong Phung and from June to August for Khe Sanh. At the time of planting the weather should ideally be dry and cloudy with some rain during the previous days. Strong sun during planting decreases the success rate, which will lead to more work replacing ailing young trees.

Young trees from the nursery should have 5 to 6 pairs of primary leaves and be free of pests and diseases.

?

Why is it important to loosen the soil in the planting hole sufficiently deep?

Use a hoe to dig down into the planting hole and loosen up the soil to 50cm depth. The soil level in the hole should be around 10cm lower than the surrounding area. Now take the bag and carefully compact the soil by squeezing the bag. Put the bag in your left hand with the young tree parallel to your arm and use a knife to cut the bottom 3cm of the bag perpendicular to its length (Figure 78).

A second cut is made over the length of the bag, the plastic is carefully removed and the young tree can be lowered into the planting hole. Fill the planting hole with the top soil that was prepared earlier, and gently put your feet on each side of the seedling to compact the soil (Figure 79).

Figure 78: Cutting the bag

Figure 79: Compressing the soil around a newly planted tree

Nursing the first year after planting

The planting holes of the young trees have been covered with old weeds or other material such as coffee pulp, husk or straw (Figure 80). This will lessen the impact of rain on the soil, and maintain better soil moisture content.

?

How does covering the soil prevent excessive moisture loss?

Figure 80: Mulching

In between the rows a cover crop can be planted. This is strongly recommended as it will provide soil cover and can be used as green manure (Windbreaks, shadow trees and covercrops).

Generally, the garden should be visited often, at least for three months after planting. Recurring tasks are checking for insect infestations and removing them manually if they occur and do damage. The soil around the trees should be checked for compactness, soil that is too loose directly around the stem will allow the stem to wriggle in the wind and can damage the bark. After heavy rains the soil in the planting hole may need to be loosened with a small stick (Figure 81). Do take care not to damage the roots in the process.

Figure 81: Loosening the soil after heavy rain

After about three weeks a small amount of fertilizer is needed. In total approximately 16g of Nitrogen per tree should be given. When using Urea 46% this translates into:

16/46% = 35g per tree.

For SA 21% this would be:

16/21% = 76g per tree.

Two months after planting a second application is given, this time including phosphate to stimulate root development. When using NPK 10:10:5 apply 100g per tree. That means: 10g N, 10g P and 5g K.

For single fertilizers use:

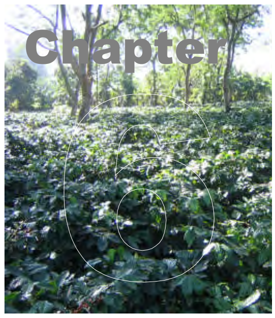
21g of Urea 46% or 48g of SA 21%;

60g P_2O_5 16.5%; and

9g of K_2O 58%

Weeding is important during the first year to avoid nutrient competition. However, with a decent cover crop, this work will be limited to cleaning the planting holes bi-monthly.

Pest and disease prevention can be necessary during the first year, but is normally limited to Brown eye spot and nutrient deficiencies. The latter occurs during dry spells shortly after planting when the young roots have not sufficiently developed yet. Also refer to chapter "Pest and disease identification and prevention".



Windbreaks, shadow trees and cover crops

A major part of field design is thee layout and species selection for windbreaks, shadow trees and intercrops, or cover crops. This chapter will deal with these issues.

Windbreaks

Windbreaks are an essential part of the garden. They provide shadow, but most importantly limit the damage from strong winds to the coffee trees. Additionally, the use of windbreaks can conserve soil moisture, limit erosion (especially in cultivation systems where clean weeding is practiced). This is why on sloping land the spacing between windbreaks should be closer. Additionally, windbreaks can increase biodiversity.

Windbreaks are positioned perpendicular to the prevailing wind direction. So if the prevailing wind direction is west, then the windbreak should run north-south. If the area suffers from very strong or dry winds additional windbreaks in the field itself might be required. As a rule of thumb a windbreak is needed every 30-50m (Figure 82 & Figure 83). Optimally the windbreaks are planted at least one year before coffee planting starts.

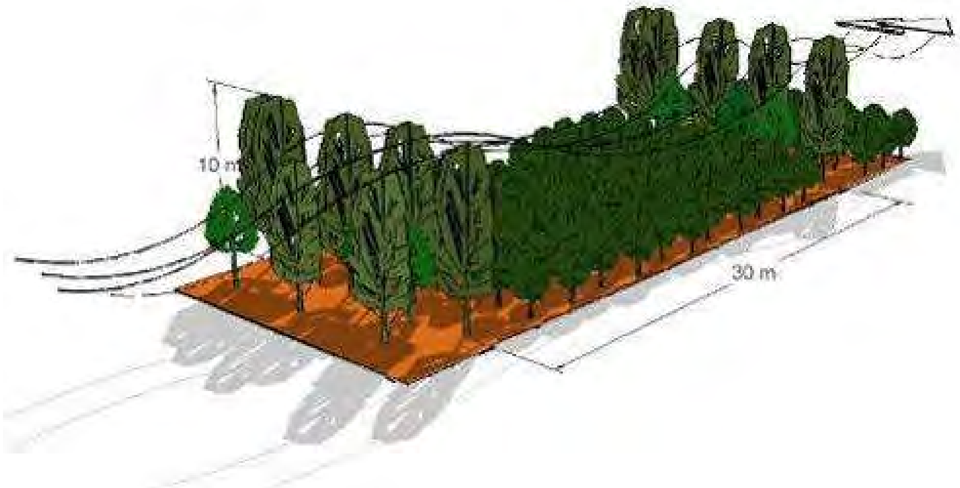


Figure 82: Windbreak function on sloping land, spacing between the 2 windbreaks is 30m, the fluid line represents air movement

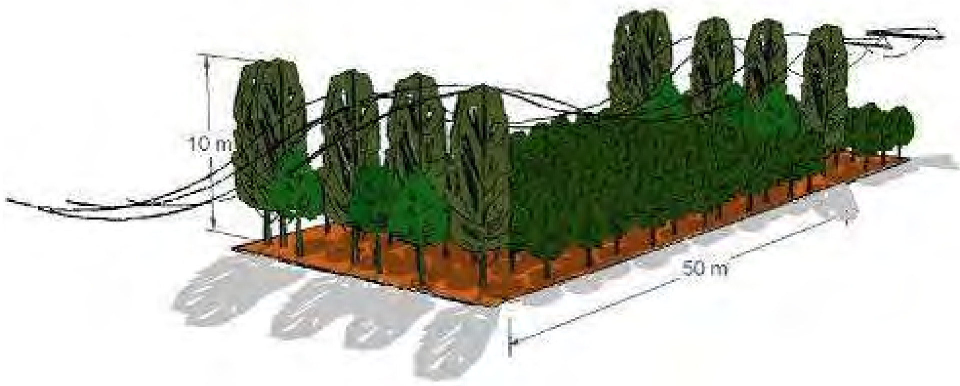


Figure 83: Idem, but on flat land, note that windbreak spacing is increased to 50m

Windbreak species selection

Suitable species depend on the location, in Huong Hoa the commonly used Acacia (*Acacia auliculiformis*) performs quite well. When establishing a windbreak there are some considerations with regard to species selection, The resulting trees should:

1. not exceed 15m in height when mature for ease of later firewood collection and felling;

2. root deep rather then shallow to avoid water stress and competition with the coffee;

3. be moderate at most in water use (avoid Eucalyptus);

4. preferably return relatively high levels of nitrogen to the soil from leaf drop with leaves that relatively easy break down (avoid Eucalyptus); and

5. provide marketable timber and or fruit

Why would one prefer deep rooting windbreak trees?

Ideally a windbreak should have a minimum of two species. One grows tall until around 10 to 12m, the other stays smaller (Table 11). Together they form a shield protecting the coffee. Additionally, using more species increases bio-diversity, because different tree species attract different insects, birds and other organisims. Typically, a windbreak is around 4 -5m wide, incorporating two rows of trees. Depending on the preference of the farmer, the two species can either be planted in separate rows or mixed. Initially the trees can be spaced 1m apart with 2m between the rows. After 4-6 years, depending on the development of the windbreak every second tree should be felled to create enough space for the remaining trees to develop.

Table 11: Suitable windbreak species

Top storey			**Lower storey**		
Species	**Advantage**	**Disadvantage**	**Species**	**Advantage**	**Disadvantage**
Acacia confusa Dai loan tuong tu	Grows fast Returns nitrogen Deep rooting	Sensitive to wind damage Pruning wounds rot easily	*Wrightia annamensis* Muc trung bo	Medium sized Grows well on wide range of soils	Seedlings are not shade tolerant
Acacia auriculiformis Keo bong vang	Grows fast Returns nitrogen to soil Very deep root system	Broad crown diameter	*Leucena leucocephala* Keo dau	Easily planted Also on poorer soils Edible seed	

Shadow trees

As discussed in the section History of Arabica coffee, the Arabica tree originates from the mountain forests in Ethiopia. Coffee being a small tree, it was growing in the lower canopy layer of the forest and received a lot shade. This fact, amongst others, has prompted many people to state that shade is beneficial for coffee, because shading reflects the natural habitat of the coffee tree.

Again other sources state that intensive breeding and selection over the last 1500 years have resulted in varieties that perform very well under full-sun or only very light shade conditions. So far there has been, to the best of our knowledge, no conclusive research where actual light reception levels by the coffee tree were compared in different shading systems with parameters like flowering, yield and farm income. However, based on field observation it can be stated that shade is beneficial for coffee under certain conditions.

Effects of shade

Some research has been done on the influence of shade on the quality of coffee and trials in Costa Rica found that the body and acidity of Catimor improved under shade, whereas aroma was slightly reduced. Bean size also increased as did overall appearance of the green bean. A similar experiment was done for Caturra, but there the effects were much lower [3]. These results can be considered important for Huong Hoa because the environmental conditions on the test site closely match as does the variety.

?

Apart from reducing evapotranspiration, what orher effects can shade have on moisture?

In more intensive cropping systems shade is used to regulate yields. That means when coffee prices are low, the farmers leave the shadow trees to grow because more shade will reduce the amount of nutrients needed as yields will be lower. When the coffee price increases or is expected to increase the farmers prune the shadow trees heavily resulting in more light for photosynthesis and therefore higher yields, which require then higher applications of fertilizers.

In relatively dry, or low lying areas with high temperatures (such as Huong Hoa) shade can be beneficial because it reduces evapotranspiration. This enables shaded trees to withstand longer periods of drought without adverse effects as compared to fully sun-grown trees. Shadow trees also play a role in efficiency of nutrient applications by taking up leached nutrients that are outside the reach of the coffee tree and returning these nutrients to the topsoil through litter fall (Figure 84).

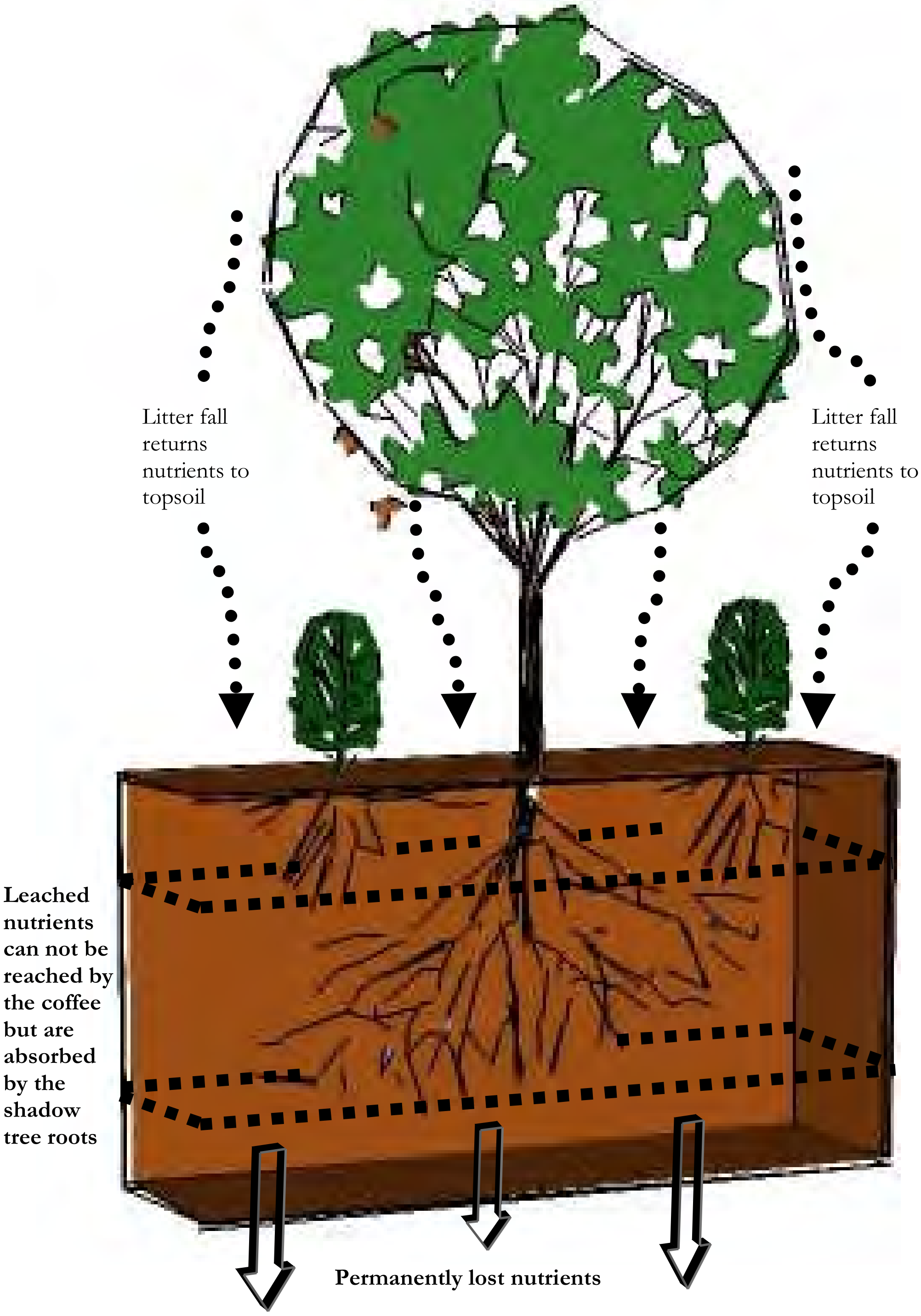


Figure 84: Nutrient cycling by shadow trees

Furthermore, the occurrence and vigour of weeds is reduced by shade. Finally, it reduces the intensity of wind speeds and soil erosion.

Figure 85: Tree after heavy crop and dry year in sunny part of the garden

Figure 86: Tree in the same garden as Figure 85 but with shade

Figure 87: Shaded garden

On the other hand, higher relative humidity resulting from shadow in the garden is favourable for disease development such as Coffee Leaf Rust. Shadow trees may compete for moisture and nutrients with coffee. Managing shadow trees can lead to increased labour requirements for pruning, although this effect might be off-set by reduced labour needs for harvesting.

How can you in the design of your coffee field limit the potential amount of competition for water and nutrients between shade and coffee trees?

Figure 88: Garden with shadow, note that the coffee in the centre the figure does not receive much shadow, foliage is a shade lighter green.

For Huong Hoa, and especially for Huong Phung shade can be considered beneficial. The climate in the district is suitable for coffee but not very. A well-managed shade cover can to some extend reduce temperatures associated with the sub-optimal altitude at which coffee is grown in Huong Hoa. In 2003 this became very clear when a heavy crop and below average rainfall resulted in massive dieback. In most gardens, only those trees under shadow retained their leaves and yielded reasonably well in 2004 (Figure 88).

Temporary shade

Most new fields will not have ready to use shade covers in an appropriate planting density. Therefore an integral part of designing new fields is the incorporation of shadow trees. However, it may take several years before the shadow trees provide sufficient shadow. To overcome this temporary shade can be used in new plantations (Figure 89).

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What is still needed in Figure 89 to optimize conditions for the newly planted coffee trees?

The crop used in Figure 89 is a nitrogen fixing species. It does not have any marketable products, but does greatly contribute to improved soil properties (see section Intercropping). After around 10-12 months the crop can be cut down, leaving the residues in the field. After the third or fourth year the shadow trees that were planted before or during field establishment will be sufficiently developed and cover cropping is not necessary anymore.

Figure 89: Temporary shade with *Mu Vang*

Permanent shade

Several species can be used for shadow. The main consideration is that the species used are Legumonisae and that the root system penetrates either very deep or is not very extensive to avoid excessive competition for water and nutrients with the coffee. An income generating strategy that can be followed is plant double the number of shadow trees needed. When the crowns of the trees touch after some years alternating rows or trees can be felled and the lumber sold (Figure 92).

Spacing depends very much on the canopy shape of the shadow trees. Some species form broad canopies, whereas others spread out less. The first type needs a wider spacing than the latter. In Khe Sanh, using Leucena (*keo)* a spacing of 10 to 12m between rows and 8 to 12m in the row is suitable (Figure 90).

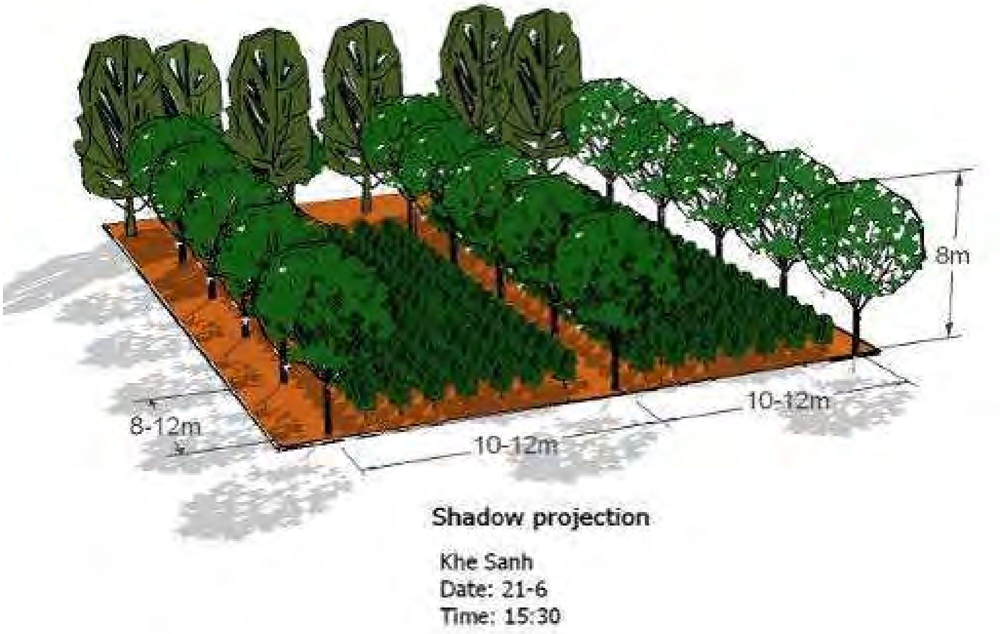


Figure 90: Shadow projection and shadow tree planting density in Khe Sanh

Temperatures in Huong Phung are higher and rainfall distribution is less optimal. Therefore planting density of shadow trees in Huong Phung should be denser at 8 to 10m between rows and 6 to 8m in the row (Figure 91).

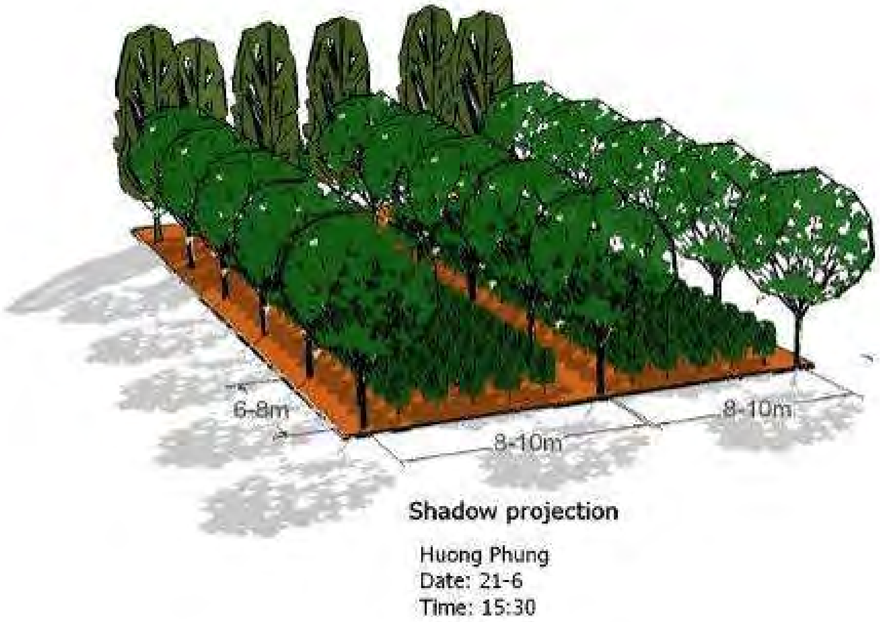


Figure 91: Shadow projection and shadow tree planting density in Huong Phuong, note that shadow tree spacing is more dense than in Khe Sanh

Managing permanent shade

Managing shade in the garden is very important to ensure that the coffee does not flower excessively but also that yields are not too low. This balance is difficult to find and the amount of shade needed will vary with climatic conditions, soil type and nutrient application level. Unfortunately, there are no clear cut recommendations, only a few rules of thumb:

Figure 92: Closely spaced shadow trees in newly established garden

1. lower branches of the shadow tree should be at least 3m above the top of the coffee trees to allow sufficient air circulation; and

2. Light penetration can be controlled by pruning the canopy (during times when coffee prices are expected to increase it might be interesting to prune shadow trees more intensively, leading to more light penetration and higher yields).

On fertile soils with adequate moisture content shadow can be quite light. In comparison with un-shaded areas the shade level should be from 10-20%. However, no clear guidelines are available and the farmer should experiment on his field with pruning techniques and canopy densities to identify options that suit their management style.

Intercropping

In this section the growing of other crops in the coffee field is discussed. Distinction is made between intercropping with the purpose of covering soil and intercropping to grow additional food and/or marketable products. However, one should realize that these functions can overlap.

Figure 93: Beans used as cover crop in newly planted coffee field, Huong Phung (Xa Ri)

?

If cover cropping is not an option in a newly established field, how could weed control be practiced without resorting to clean weeding?

Intercropping for soil coverage

A tour of Huong Hoa coffee area often shows newly established fields that are clean weeded. In older fields with closed, or nearly closed canopies this practice is quite common. Especially during fertilizer applications, as clean weeding avoids nutrient competition for the coffee from weeds. However, in recently planted fields clean weeding is not recommended because it:

1. increases erosion from wind and water;
2. promotes leaching of nutrients;
3. increases surface temperature; and
4. results in lower available soil moisture.

To avoid weed pressure, without the negative effects of clean weeding, cover crops can be used.

Properties of cover crops

Cover crops have influence on many soil characteristics and processes (Table 12).

Table 12: Influence of cover crops on soil properties

Soil characteristic or process	Influence of cover crop
Erosion	Cover crops increase vegetative and residue cover during periods when erosion potential is high, especially when main crops do not furnish adequate soil cover. Additionally, root systems of a covercrop increase porosity of the soil which increases infiltration rate of rain water thus reducing erosion.
Compaction	Increased biomass, when decomposed, increases organic matter promoting increased microbial activity and aggregation of soil particles. This increases soil porosity
Soil aggregation in the top layer	Aggregate stability will increase with the addition of and the decomposition of organic material by micro organisms
Infiltration	Surface cover reduces erosion and run –off. Cover crop root channels and animal activities such as earthworm, form macro-pores that increase aggregate stability and improve infiltration
Nutrient loss	Decomposition of increased biomass provides a slow release of nutrients to the root zone. Legume cover crops fix atmospheric nitrogen and provide nitrogen for the crop
Biological activity	Cover and green manure crop increase the available food supply for micro organisms resulting in increased biological activity.
Weeds	Increased soil cover reduces weeds

Cover crop species

Several crop species can be used as cover crop (Table 13). All of them are nitrogen fixing plants and facilitate improvements as listed in Table 12. Planting is best done at the start of the rainy season in the end of April or the end of August.

Table 13: Cover crop species (all pictures in this table from www.ecocrop.fao.org, unless stated otherwise)

Dau Ma

Lablab purpureus

Figure 94: *Lablab pupurea*, close-up

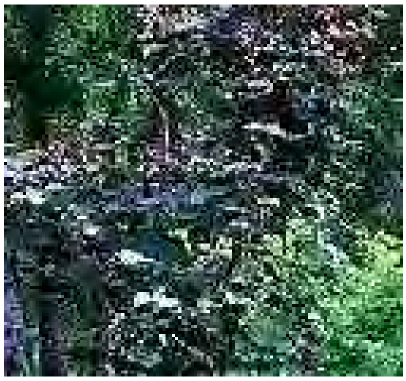


Figure 95: *Lablab purpurea*, whole plant

Use

It is not particular to soil type as long as they are well drained. Reported soil pH range for growth is 4.5-8 with the optimum between 5-7.5. It can grow in infertile soils but will not withstand salinity.

With a dense growth, the lower leaves are shed. These form an excellent mulch and provide nitrogen upon decomposition.

Co Stylo

Stylosanthes gracillis

Figure 96: *Stylosanthes spec*, close-up (Source: www.biology.smsu.edu)

Figure 97: *Stylosanthes spec,* whole plant

Use

Stylosanthes is slow-growing up to six weeks and then rapid, the increased growth coinciding with the increase in nodule size. The older nodules are more effective than the young ones. Its growth during the wet season is good. If uncut, it collapses and new shoots arise from the collapsed stems. In this way it has a valuable suppressive effect on weeds. It can tolerate highly acid soils, and nodulates at pH 4.0. Soil pH range is reported to be 4.0-7.7 with the optimum between 4.5-6.0.

Dau Dua

Centrosema pubescens

Figure 98: *Centrosema pubescens*, close-up

Figure 99: *Centrosema pubescens*, whole plant

Use

Centrosema is a creeping perennial that doesn't form any wooden growth It is fairly drought resistant and can be cut back for mulching. Its creeping nature makes it well suited for weed suppression.

Dau Son Tay

Flemingia spec.

Figure 100: *Flemingia spec*, close-up of leaf (Source: www.hktree.com)

Figure 101: *Flemingia spec*, whole plant

Use

Flemingia can easily be integrated in the existing crop system, especially along borders. It can thrive in acid soil and is drought resistant. It is particularly used in hedges to provide and for soil amelioration and soil erosion control in hilly areas.

Leafs of Flemingia make ideal mulch. Rich in nitrogen they decompose slowly, effectively suppressing weeds.

Dau Sang

Cajanus cajan

Figure 102: *Cajanus cajan*, close up of flower and leafs (Source: www.kitada.com)

Figure 103: *Cajanus cajan*, whole plant (Source: www.cornell.edu)

Use

Cajanus has a strongly developed taproot and can survive for up to 4 years. It has the advantage of improving the soil as it is legume crop and thereby providing mulch through production of leaves with the through nitrogen fixation with the help of rhizobia

Young leaves, shoots and pods can be eaten. Ripe seeds are also edible.

Vetiver

Figure 104: Vetiver grass (Source: www.vetiver.com)

Figure 105: Field planted with Vetiver hedgerows (Source: idem previous)

Use:

Vetiver is a grass that is used around the world for soil reclamation, erosion control and foraging. Especially the potential of Vetiver in erosion control is useful in Huong Hoa. Vetiver's extensive root-system effectively holds the soil in place. On sloping land Vetiver should be planted along contour lines. After some years natural terracing will occur.

Intercropping with food crops

Many coffee farmers worldwide intercrop their coffee with food crops. An advantage is that it reduces the negative effects in household income from fluctuating coffee prices. On most farms in Huong Hoa intercropping opportunities are very limited. Most fields have high planting densities of up to 5,000 trees per ha. This limits the window of opportunity for intercropping to the first 2 years after field establishment and during a year of stumping. However, the intensity of field management and consequent high yields might render a sole focus during the available period on cover-cropping (for soil coverage) more sensible.

High planting densities also limit species choice to annuals. Some observed practices have shown stumped and newly planted coffee intercropped with maize, vegetables and ginger.

A small number of farmers intercrop coffee with pepper. This can be successful, but care has to be taken to space coffee and pepper sufficiently apart in the field. Coffee trees within a range of 2m of pepper typically lead to problems with the pepper after 4-5 years (yellow leafs as a result of competition for nutrients and water).

Plant nutrition and fertilisation

Together with hired labour, fertilizer is the largest investment on most coffee farms. Fieldbook data indicates that many farmers can make improvements in the efficiency of fertilizer applications and thus save money. This chapter explains the mechanisms underlying efficient fertilizer application

Importance of fertilising

All plants need nutrients for growth. In a closed system where no nutrients are removed, shortages of nutrients will hardly occur. A fine example of this is a primary forest. In agriculture this is however not the case. Agricultural systems inherently loose nutrients by harvesting, but also by erosion, and leaching as a result of limited soil cover.

To maintain a balanced nutrient situation in which crops can prosper fertilisation is necessary. Fertilisation can be done by applying compost, organic fertilisers, chemical fertilisers, animal manure, green manure, etc.

Coffee generally responds quite well to fertiliser applications. When applying fertilizers, one has to realize that various factors determine the maximum possible yield: climate, variety and age of the coffee tree. Whether this maximum yield may be reached depends partially on the management of the crop, where important activities are pruning and stumping and weed, pest and disease control. If these practices are not done in a correct form, the maximum attainable yield will be lower than the maximum possible yield. Whether the maximum attainable yield can be reached, depends on the availability of nutrients to the crop. The soil type has a strong effect on this (as well as planting techniques, see chapter Soil requirements for coffee) but fertilisation can be instrumental in overcoming deficiencies of nutrients in the soil. Fertilisation, however, can NOT overcome 'faulty' management practices, e.g. when weeding or pruning is not done properly. This means that to make optimal use of the expensive nutrients, one should take care to apply the amounts of nutrients that are required for the maximum attainable yield and NOT for the maximum possible yield. To do so, good yield estimates are needed to determine the amount of nutrients that should be applied to achieve the maximum attainable yield under the conditions of soil, climatic and management conditions.

Nutrients and their functions

Nutrients are utilised by the plant for different functions. Some are vital for the uptake of water from the soils, whereas others have a function in the development of leaves or fruits. A closer look at the functions of nutrients and the symptoms the tree shows during shortages serves to improve the basis for fertiliser selection and correct applications (Table 14).

?

Why do leaves discolour under N deficiency?

Table 14: Primary nutrients, their functions and deficiency symptoms (pictures courtesy of Keith Chapman)

Primary nutrients	Used by the tree for…	Deficiency symptoms
N	• formation of chlorophyll • water uptake Deficiency shows by: • Leaf drop • Discoloration (yellowing) and rolling up of leaves (starting with older ones) • Dieback of tips	

During which stage of its live are phosphorus applications most important?

P	• Photosysnthesis • Respiration • Energy storage • Cell division Deficiency shows by: • Stunted growth • Pale leaves (starting with younger ones)	 
K	• Photosynthesis • Protein synthesis Deficiency shows by: • Discoloration • Necrosis on leaf edges	

Although primary nutrients are usually the ones lacking most, secondary nutrients can also be in short supply (Table 15).

Table 15: Secondary nutrients, their functions and deficiency symptoms (pictures courtesy of Keith Chapman)

Secon-dary nutrients	Used by the tree for…	Deficiency symptoms
Calcium (Ca)	• Root and leaf development • Affects uptake of other nutrients Deficiency shows by: • Leaf colour yellow from the centre outwards	
Magnesiu m (Mg)	• Central element of chlorophyll • Photosynthesis Deficiency shows by: • Brown, bronze discolouration of leaf sections from centre to edges	

Although this rarely happens, also micro-nutrients can be lacking. This phenomenon is mostly observed in recently planted coffee during dry weather (Table 16).

How likely do you think Fe deficiencies are on the red soils in Khe Sanh?

Table 16: Micro-nutrients, their functions and deficiency symptoms (pictures courtesy of Keith Chapman)

Micro nutrients	**Used by the tree for…**	**Deficiency symptoms**
Iron (Fe)	• Catalyst for chlorophyll formation Deficiencies show by: • Initially at young leafs; • Severe cases show yellow to bleached white discoloration with green veins	
Zinc (Zn)	• Necessary for chlorophyll formation; • Production of sugars Deficiencies show: • First at young leafs; • Leaf deformations; and • Yellow discoloration	

Boron (B)	• Germination of pollen • Transport of sugar and formation of proteins Deficiencies show by: • Stunted growth of young leaves; • Light green discoloration of young leaves • Reduced flowering	

Fertilizers and their nutrient contents

Nutrients, like N, P and K occur in many chemical forms. This can be in so-called organic forms or in an-organic or artificial forms.

Organic forms are produced by living organisms, where for example Nitrogen can be in the form of proteins (meat, egg-white, pulses), partially decomposed material (dung) or ureum (in urine). Another example is Calcium (Ca) that can be found in shells (of eggs or snails), in bones and in milk.

?

How do energy prices influence the price of fertilizers?

An-organic or artificial forms are created in chemical factories. Nitrogen, for example is taken from the air (which consists of about 80% of N) and by use of a lot of energy made into Ammonium-Nitrate, Ammonium-Sulphate (found in SA21%), Urea and various other forms.

Apart from occurring in different forms, the nutrients can also be in different concentrations, i.e. the amount of a nutrient that comes with a certain amount of fertilizer. In artificial fertilizers, the concentration of nutrients are indicated on the package, and sometimes reflected in the name. In most organic fertilizers, there is no such indication and concentrations may vary strongly, because of the origin of the product and of the way it was stored. In general concentrations of nutrients in organic matter are much less than in artificial fertilizers, partly because the organic matter contains a lot of water while artificial fertilizers are almost completely dry.

For historical reasons, the concentration of Nitrogen refers to single N, whereas for Phosphorus (P) the concentrations of the chemical form P2O5 are given and for Potassium (K) of the form K2O. In urea, generally 46% of N is found or 46 kg N per 100 kg of urea. In Ammonium-Sulphate 21%, this is 21 kg N per 100 kg of SA. In Phosphate 16.5%, there is 16.5 kg of P_2O_5 per 100 kg, and in Kali 58% 58 kg of K_2O per 100 kg.

To make matters even more complex, nutrient contents of agricultural products, like coffee-cherries, are expressed in single nutrients, thus N, P and K. When using crop nutrient requirements for calculating required fertilizer applications, it is needed to express all nutrients in the same unit. This requires to know that there is 0.44 kg P in 1 kg of P_2O_5 and 0.83 kg K in 1 kg of K_2O. This means that in 100 kg of Phosphate 16.5% there is only 7.2 kg of P, while in 100 kg of Kali 58% there is 48.1 kg of K. In Table 17 a list of contents of N, P_2O_5, P, K_2O and K for some fertilizers is given.

Table 17: Contents of nutrients in various fertilisers

Fertilizer	Nitrogen (kg per 100 kg fertilizer)	Phosphorus (kg per 100 kg fertilizer)		Potassium (kg per 100 kg fertilizer)	
	N	P_2O_5	P	K_2O	K
NPK (10-10-5)	10	10	4.4	5	4.1
NPK (16-8-16)	16	8	3.6	16	13.3
NPK (16-16-8-13S)	16	16	7.2	8	6.6
NPK (16-8-16-13S)	16	8	3.6	16	13.3
NPK (10-12-5)	10	12	5.2	5	4.1
Sa 21%	21	0	0	0	0.
Urea 46%	46	0	0	0	0.
Phosphate 16,5%	0	16.5	7.2	0	0
Kali 58%	0	0	0	58	48.1
Compost (estimate)	0.5	0.06	0.03	0.4	0.33
Coffee pulp (turned)	0.23	0.018	0.008	0.25	0.21
Coffee pulp (untreated)	0.17	0.026	0.011	0.16	0.13
Dung	0.45	0.55	0.24	0.61	0.51

Information about the contents of nutrients in fertilizer, together with their price, can be used to calculate the cost of 1 kg of each nutrient. This information can be used to calculate the cheapest way to fertilize a certain amount of nutrients. Choosing from NPK 16-8-16 at a price of 3,500 VND per kg, Urea 46% at 3,500 VND per kg, Phosphate 16.5% at 1,200 VND per kg and Kali 58% at 3,300 VND per kg, what would be the cheapest way to apply 150 kg of N, 10 kg of P and 170 kg of K?

First calculate the amount of fertilizer that is needed to fulfill the requirements of all the nutrients:

Scenario 1: Fertilising with NPK 16-8-16
From NPK 16-8-16 it is needed to apply:

150 / 0.16 = 937 kg for the N requirements;

10 / (0.08 * 0.44) = 568 kg for P; and

170 / (0.16 *0.83) = 1,280 for K.

Choosing the highest amount, because only then the requirements of all nutrients are fulfilled, the costs of fertilization would be 1,280 * 3,500 = **4.48 million VND**.

Scenario 2: Fertilising with single fertilisers
If all N should come from Urea, then

150 / 0.46 = 326 kg is needed, at a cost of 326 * 3,500 VND = 1.14 million VND.

If all P should come from Phosphate 16.5%, then

10/(0.165*0.44) = 275 kg is needed, costing 275 * 1,200 = 0.33 million VND.

If all K should come from Kali 58%, then

170/(0.58*0.83) = 353 kg is needed, costing 353*3,300 = 1.16 million VND.

Using single fertilizers the costs of fertilization would be: 1.14 + 0.33 + 1.16 million = **2.64 million VND**

If the choice would be to fertilize only NPK 16-8-16 or Urea + Phosphate16.5% + Kali58%, then total costs would be 4.48 million VND for NPK16-8-16 and 2.64 million VND for the combination of Urea, Phosphate and Kali. This difference is to a large extent caused by over-fertilization when using 1,280 kg of NPK 16-8-16. This causes oversupply of (1,280 – 937) * 0.16 = 54.8 kg N and of (1,280-568) * (0.08*0.44) = 25 kg P.

Is there a cheaper way to fertilize? To check this, calculate for the situation where there is no oversupply of any fertilizer when using NPK 16-8-16 and add the lacking nutrients from the single sources Urea, Phosphate and Kali.

Scenario 3: Fertilising with a combination of NPK and single fertilisers
The lowest amount of NPK that should be supplied is 568 kg for fulfilling the P requirements, costing 1.99 million VND. This means that only N and K are needed from other sources.

At 568 kg NPK 16-8-16, 568*0.16 = 90.1 kg N is applied; and

568*0.16*0.83 = 75.5 kg K,

leaving still 150-90.1 = 59.9 kg N to be applied; and

170-75.5 = 94.5 kg K.

This means 59.9/0.46 = 129.4 kg of Urea, costing 129.4 * 3,500 = 0.45 million VND, plus

94.5/(0.83*0.58) = 196.4 kg Kali 58%, costing 0.65 million VND.

In total, costs would be 1.99 + 0.45 + 0.65 = **3.09 million VND**.

This is still more costly than the 2.64 million VND when not using NPK 16-8-16. Apparently the costs per kg of nutrient from compound NPK 16-8-16 are higher than that from the single nutrient fertilizers. Mind you, this is an example only. For each situation regarding nutrient requirements and prices and contents of fertilizers the calculation should be performed again.

Reasons for applying organic fertilizers.
When using organic fertilizers to apply the required nutrients of the example above, large amounts are needed. Looking only at Nitrogen, for example, a requirement of 150 kg N per ha would need an application of

150 / 0.005 = 30,000 kg of Compost;

or more than 65,000 kg turned coffee pulp and more than 88,000 kg unturned coffee pulp. This requires a lot of expenses in labour and in transport. From the point of view of nutrients therefore, it makes financially much more sense to apply artificial than organic fertilizers. So why apply organic fertilizers? The main reason for doing so lies in the need to maintain a high enough percentage of organic matter in the soil which is needed to buffer the pH of the soil, to keep the CEC high and to keep the physical structure of the soil in good condition (see section Soil organic matter).

Why is maintaining an adequate CEC level so important, and how can this be done?

Application rates

Coffee nutrient requirements depend on several factors. Concerning the tree itself, requirements are influenced by variety, age and expected yield. Soil, weather, and shading conditions also play an important role. Therefore, the advice given in this section should not be considered as a blue print for fertilization. Rather it aims to serve as a guideline for determining required amounts.

Application during the first three years

During planting, a first application of manure or compost and fertilizer is required to give the new tree a good start. Especially Phosphate is important for root development during this phase.

During the first year no yield should be allowed on the tree. The tree needs all its energy to establish a sound structure and root system to start a productive live.

If you decide to use NPK in the first 2 years after planting, what would be a suitable composition?

After the second year a small harvest is permissible, but care should be taken that this crop is not too big, say no more than 1.5 kg fresh cherry/tree.

Production starts from the third year onwards and nutrient requirements change according to expected yield levels. As yield levels can be expected to vary between fields and crop years, so should nutrient applications.

Table 18 shows the recommended application schedule for the first three years.

Table 18: Nutrient requirements (kg/tree) during planting and the first three years afterwards

Year	Manure (kg/tree)	N (g/tree)	P_2O_5 (g/tree)	K_2O (g/tree)	Lime (g/tree)
During planting	5	9.2	49.5	5.8	300
1	0	23	16.5	11.6	
2	5	36.8	9.9	23	
3	0	46	16.5	52.2	200

Take care that the data in Table 18 represents nutrients not fertilizers. Table 21 explains how to calculate amounts of nutrients needed into amount of fertilizer to be applied.

After year 3 a set of general guidelines serves to calculate needed amounts of nutrients.

General guidelines

The first section of this chapter described how the influence of fertilizers on yields is only part of the story and that high yields are also the result of good husbandry and favorable climatic conditions. Taking this into account it makes sense to fertilize according to expected nutrient removal during yield and anticipated losses (i.e. those nutrients that do not end up in the cherry) after the tree reaches an age of 3 years. The following is needed for this:

1. a reliable yield estimation method;
2. knowledge of nutrient removal during harvest;
3. knowledge of nutrients needed for sustenance of the tree, that is growth of all plant parts but cherries, and losses incurred through eg leaching; and
4. ability to identify suitable field conditions for nutrient application

Yield estimation

Making an accurate estimation of yields is a painstaking job that involves counting the cherries on the trees. Unfortunately no reliable shortcuts are available. The best time to make yield estimate is just after the flowering and before the first fertilizer application when the trees are in the pinhead stage. Table 19 gives an example using 6 trees, however, to make a reliable estimation at least 30 randomly selected trees per ha should be assessed.

How to select trees randomly?

Table 19: Yield estimation example

Location	Fresh cherry weight (kg/1,000 cherries)
Huong Phung	0.96
Khe Sanh	0.99
Example for a farm in Khe Sanh with 4,000 trees/ha:	
Tree nr	**Nr of cherries**
1	4,254
2	5489
3	3,890
4	4,710
5	5,316
6	5,120
Average nr of cherries/tree	4,797 (=sum of all observations divided by number of counted trees)
Estimated yield	4,797 / 1000 * 0.99 = 4.75 kg/tree ; 4,000 trees / ha * 4.75 kg / tree = 19,000 kg cherry/ha

Nutrient removal

Analyses of over 500 samples over a period of two years in Khe Sanh and Huong Phung (Pinkert, 2002) have given good insight in the removal of nutrients during harvest (Table 20).

Table 20: Nutrient removal during harvesting in Khe Sanh and Huong Phung

Location	N (kg/100kg fresh cherry)	P2O5 (kg/100kg fresh cherry)	K2O (kg/100kg fresh cherry)
Khe Sanh	0.5	0.089	0.75
Huong Phung	0.55	0.089	0.75
Example: Farmer A in Khe Sanh expects a yield of 19,000 kg fresh cherry/ha 100 kg removes 0.5 kg of N 19,000 kg cherry/100kg = 190 190*0.5kg N = 95 kg N removed			

From Table 20 one can calculate how much a farmer with an expected yield of 19 Mt of fresh cherry per ha should at least apply to maintain a balanced nutrient status with regard to nutrient removal from cherries (Table 21).

Table 21: Minimum fertiliser application based on yield level, but excluding sustenance fertilization and losses

	Kg/100kg cherry	Calculation	Amount of fertiliser needed
N per 100 kg cherry	0.5	(19,000/100) *0.5= 95 kg N	**Urea 46%** 95 /0.46= **207 kg**
P_2O_5 per 100 kg cherry	0.089	(19,000/100) * 0.089= 16.9 kg P2O5	**Phosphate 16.5%** 17/0.165= **102 kg**
K_2O per 100 kg cherry	0.75	(19,000/100) * 0.75= 142.5 kg K2O	**Kali 58%** 142.5/0.58= **246 kg**

Sustenance fertilization and nutrient losses

Fertilisation for sustenance refers to those nutrients needed to maintain the tree. We already know how much nutrients are removed during the harvest, but we should also take into account how much of which nutrient is needed for the tree to maintain healthy leaves, branches and roots.

No hard data from Khe Sanh and Huong Phung on levels of sustenance needed and losses incurred are available. Information from other coffee producing areas indicates that the two combined can require up to 60% more on top of the calculated removal during harvest, depending on soil and weather conditions.

Table 22: Multiplication factors

Nutrient	Multiplication factor
N	1.375
P	1
K	1.235

For Khe Sanh and Huong Phung several assumptions (see Annex I) have led to a multiplication factor for N, P and K to calculate how much of each nutrient is needed on top of the amount that should be applied to compensate for nutrient removal from harvesting (Table 22).

In Table 20 the minimum amount of fertilizer is calculated. When we include the multiplication factors for N, P and K to account for sustenance, efficiency of application and nutrient recycling the amounts to be applied look different (Table 23).

Table 23: Fertiliser application needed to compensate for nutrient removal during harvest and tree sustenance

	Kg/100 kg cherry	Calculation	Multiplication factor	Amount of fertiliser needed
N per 100 kg cherry	0.5	(19,000/100) *0.5= 95 kg N	1.375	**Urea 46%** 95 * 1.375 /0.46= **238 kg**
P_2O_5 per 100 kg cherry	0.089	(19,000/100) * 0.089= 16.9 kg P2O5	1	**Phosphate 16.5%** 17 * 1 / 0.165 = **102 kg**

K_2O per 100 kg cherry	0.75	(19,000/100) * 0.75= 142.5 kg K2O	1.235	**Kali 58%** 142.5 * 1.235 / 0.58 = **303 kg**

Field conditions

An important factor is to decide when to fertilise, based on field conditions. A checklist can be used for this (Table 24).

Table 24: Fetiliser checklist for field conditions

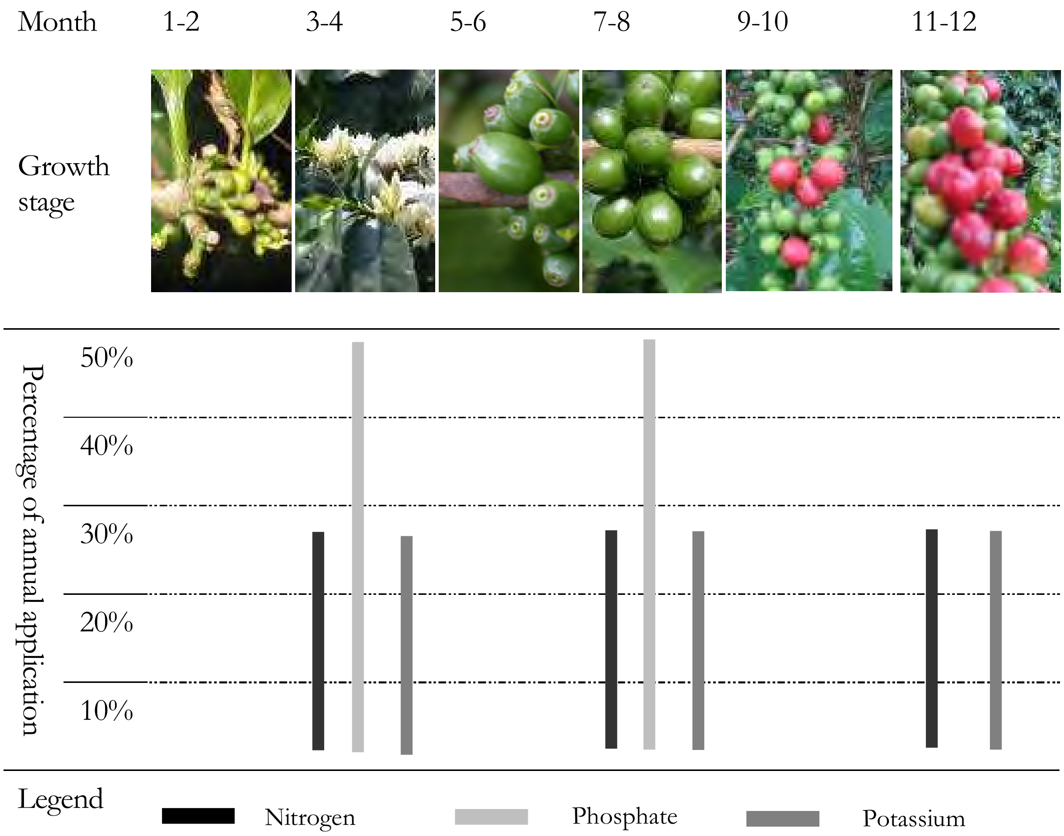
Field condition	Indicator	Yes	No
Soil humidity	In Khe Sanh: Can I make a ball of soil by hand that doesn't fall apart? In Huong Phung: Can I penetrate the soil with my finger?	☐	☐
Outside temperature	Below 30ºC?	☐	☐
Rain	Dry, but cloudy weather?	☐	☐
Weed infestation	Is the field clean of weeds, or have weeds been cut down?	☐	☐
Flowering	The tree has flowered already or will not start flowering in the coming two weeks?	☐	☐

A yes to all of these questions indicates suitable field conditions for fertilizer application. Of course not all conditions might occur at the same time. In that case at least soil humidity and temperature conditions should be met during nutrient application.

Timing of applications

Needs of the coffee tree vary over the year and depend on the age of the tree, expected harvest and weather conditions. For example, nutrient requirements will be greater during the filling stage then during the pinhead stage. Also, the type of nutrients in greatest demand vary with the seasons (Table 25).

Table 25: Seasonal nutrient application schedule for mature Arabica coffee



Application methods

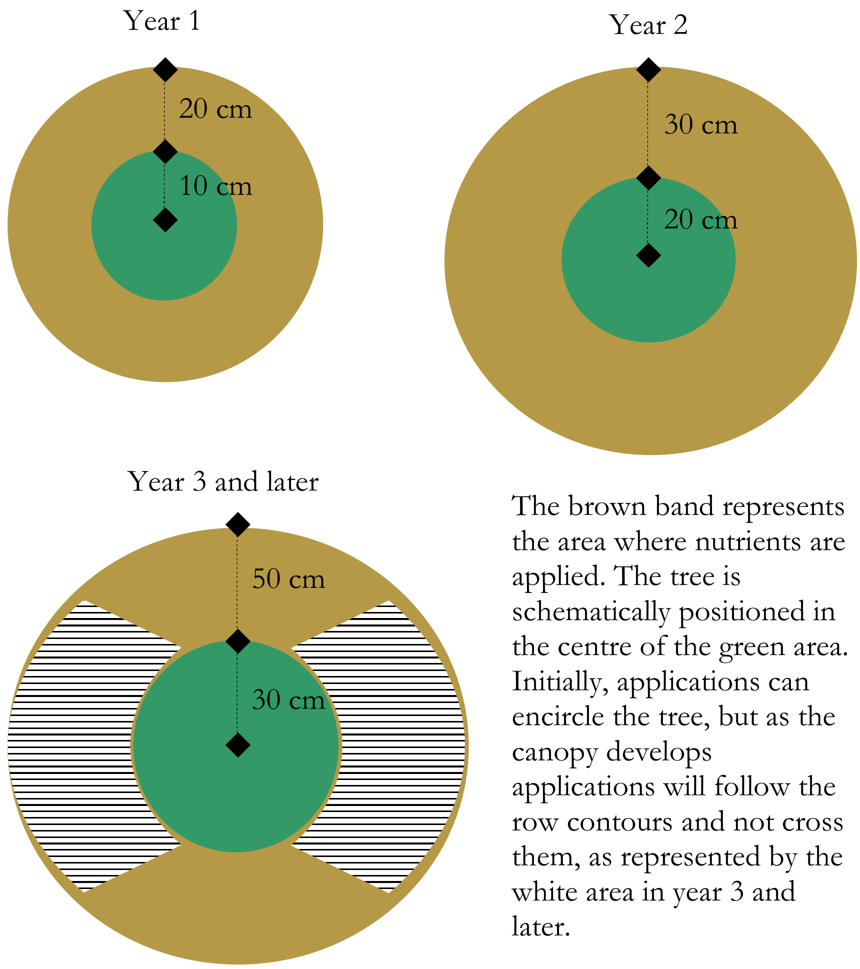
Already we calculated the total amount of nutrients needed for the whole field. However, we should also know how much we should apply per tree (Table 26).

Table 26: Calculation of amount of Urea per tree, based on yield removal calculation of Table 21

Total yield and amount of Urea needed	Nr of trees per ha	Amount of Urea per tree (kg)	Amount of Urea per tree (g)
19 Mt/ha of cherry requires 238 kg of Urea	5,000 trees/ha	238/5,000 = 0.048kg/tree	Or 48g per tree

Of course, one can not weigh the fertilizer for each individual tree. A good method to apply the right amount per tree is to take an old can and use a scale to determine how full the can should be to apply the required amount per tree.

When applying fertilizers or other sources of nutrients it is important to realize that the tree takes up nutrients with the hair roots. These roots are mostly found on the ends of the root system. The end of the root system roughly follows the canopy circumference. Therefore the actual position of the application changes over time according the development of the tree's canopy and root system (Figure 106).



The brown band represents the area where nutrients are applied. The tree is schematically positioned in the centre of the green area. Initially, applications can encircle the tree, but as the canopy develops applications will follow the row contours and not cross them, as represented by the white area in year 3 and later.

Figure 106: Nutrient application methods

In the field the application procedure consists of 4 steps (Figure 107). Step 1 consists of digging a shallow furrow following the contours of the canopy of the tree. The furrow is around 10cm deep. Step 2 is to apply the required amount of fertilizer. While step 3 consists of mixing soil and fertilizer before the furrow is covered in step 4.

Step 1: Creating a shallow furrow that follows the contours of the canopy

Step 2: Apply fertilizer

Step 3: Mix soil and fertiliser to get an even distribution

Step 4: Cover the furrow

Figure 107: Nutrient application with fertiliser

Alternatively, fertilizer applications can be done using animal traction. A cow is then used to plow a shallow furrow in between the rows close to the canopy. This will greatly reduce the amount of labour needed in step 1. However, care must be taken to avoid ploughing too deep as this might damage the root system.

Composting

This section deals with composting techniques. Described techniques are such that it allows farmers to produce compost from coffee pulp and coffee husk, on-farm with small financial investments.

Most coffee fields in Huong Hoa are medium to low on organic matter content in the topsoil. The importance of organic matter has been discussed in the chapter Soil requirements for coffee. Composting coffee pulp and applying it to the field is one of several ways to improve organic matter content, the others being the use of shadow trees and cover cropping. Composting is the process whereby natural decomposition of organic materials is accelerated under controlled conditions.

Compost also has limitations. Intensive cultivation with high yields removes a lot of nutrients from the field during harvest. Although compost contains nutrients such as N, P and k and several secondary elements, the contents of these are too low to completely replace fertilizers. For example calculations show that a farmer in Khe Sanh with 20Mt of cherry per ha needs to apply around 30Mt of compost to balance the nutrient status of his field after harvesting.

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What is the difference between compost and organic material?

Therefore, in intensive cultivation systems, compost should be seen as an addition to fertilizers aimed at enhancing soil properties such as moisture holding capacity, structure and nutrient buffering capacity (CEC), not as a fertilizer replacement.

Composting coffee pulp and husk

Each year in Huong Hoa 20 to 30,000Mt of fresh cherry is produced and processed. This amount of cherry contains around 3.5 to 5,000 Mt of green bean that are being sold both on the domestic market and for export. Therefore, coffee pulp that can be used for composting amounts to 16.5 to 25,000 Mt per year.

Figure 108: Coffee pulp

Care should be taken however, that compost is produced in an appropriate manner. Simply applying discarded coffee pulp to the field is not a good idea. This material may still contain **pathogens** (pathogens are organisms that cause diseases, for example the Coffee Leaf Rust fungus) that can affect the coffee tree. During composting the pulp is heaped. The breakdown process increases temperatures in the heap up to 70°C, killing a large portion of the pathogens. Additionally, organic acids from the fresh pulp may damage coffee roots if applied directly in the field.

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What kind of damage could the organic acids from raw pulp do to the roots of the tree?

The structure of the heap is important to achieve optimum decomposition. The heap should consist of several layers (Figure 109 to Figure 114):

1. The ground is first covered by a sheet of plastic or a layer of banana leafs to prevent excessive leaching of nutrients from the heap;

Figure 109: layer of banana leafs

2. a layer of small branches is deposited on top of the plastic/leafs to improve **aeration** (aeration is the entry of air into the heap). This layer is around 10cm thick;

Figure 110: Layer of leafs and branches for aeration

3. this is followed by a layer of fresh coffee pulp of 25 cm thick;

Figure 111: First layer of pulp

4. Sprinkle NPK, or single fertilisers and lime (any type will do) to speed up decomposition (micro-organisms responsible for decomposition use especially N);

Figure 112: Lime, Urea, Phosphate and Pottasium have been added

5. Optionally one can now deposit a layer of coffee husk, rice straw or grass; This will give a bit more structure to the heap and prevent it from falling apart.

Figure 113: Layer of grassy material

6. Apply another layer of fresh pulp, 25cm thick, sprinkled with NPK and lime;

7. Repeat steps 3 to 6 until the pile is around 1.5 m high; and

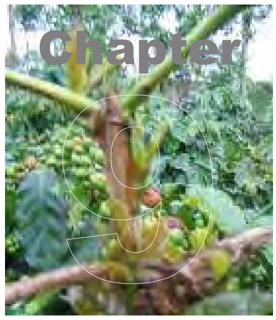
8. cover the heap with plastic or banana leafs to prevent rewetting of the compost. Note that each 3 layers of lime and fertilizer are visible.

Figure 114: Finished heap with banana leafs as cover

After around 2 weeks the heap can be turned, leaving the branches of step 2 in place and putting the cover of step 8 back in place. From this moment onwards the heap should be turned once a month. After 3-5 months the pulp has been composted and can be applied in the field.

Similar to fertilizing the compost should be applied in a band around the tree and lightly worked in the soil. Alternatively, animal traction can be used to work the compost in a furrow. This can save considerable time.

Depending on the transportation distance, most farmers in Huong Hoa need around 1 day for the application of 1 m^3 compost. Utilisation of animal traction can reduce the application time by as much as 30%.



Pruning and stumping

Pruning is an essential task to maintain strong and healthy trees. This chapter will tell you how to do it. In addition stumping will be discussed.

Objectives of pruning

Generally speaking the goal of pruning is to create well-structured, healthy trees that give good cherry yields over a long period of time. Or, to rejuvenate old trees by stumping. In more detail: the objectives are:

1. to avoid unnecessary competition for nutrients by removing unproductive wood;

2. to remove weak branches that will not yield, or only a little;

3. to avoid high humidity and fungus development through better air circulation;

4. to create better access to the core of the tree when spraying pesticide; and

5. to decrease the risk of the damage to the coffee trees' canopy during periods of heavy rain and/or wind.

Growth shapes

With pruning we try to reach a desired shape of the tree. Two main shapes are commonly found, single stem and multiple stem trees. Each has its distinct characteristics.

Single stem

This is the prevailing system in Quang Tri, favoured by many farmers because it yields high quantities of cherries over a longer period of time, requires less labour than the multiple stem system and allows for easier application of pesticides. The single stem system is primarily used for Arabica coffee (Figure 115).

Multiple stem system

The multiple stem system is used by some Arabica farmers (Figure 116), but is more commonly found in Robusta coffee. Use of the multiple stem system in Arabica is that in the first 3 to 4 years yields are higher than in the single stem system. However, yields from multiple stem trees will decline more rapidly after the initial peak.

Additionally, the commonly found planting density of up to 5,000 trees per hectare in Huong Hoa is not very suitable for the multiple stem system. When working with two stems per tree the maximum planting density for Arabica Catimor is around 3,000 trees per hectare. An advantage of the multiple stem system is that you can keep a minimum yield when the time for stumping (rejuvenating) has arrived. This is done by stumping a tree in two phases. In phase 1 one of the two stems is stumped. Two years later, when the stumped stem has been replaced by vigorous suckers which will be about to give fruit, the second stem is removed. Although low, a yield will be had every year.

Figure 115: Single stem tree

Figure 116: Multiple stem tree

The focus here will be on the single stem system, as this is the most commonly used.

Types of branches

The coffee tree has 2 types of branches that can be further subdivided (Figure 117):

1. Lateral branches:

   Lateral branches grow outwards from the main stem. These branches are the only branches that bear fruit. Lateral branches can be subdivided in two types:

a. Primary branches:

Primary branches are directly connected to the main stem. These branches are not regenerative.

b. Secondary branches:

Secondary branches are attached to the primary branches. Each primary branch has many buds, some will develop in flowers, others into secondary branches. The secondary branches also have buds that develop into flowers or more branches still. These branches are called tertiary branches.

?

When pruning, which type of branches would you favour over others?

2. Suckers

Suckers are branches that grow from dormant buds on the main stem. They grow quickly and vertically and do not bear fruit. Suckers, as their name indicates suck away copious amounts of water and nutrients that is not being put to any productive use. De-suckering is therefore an important pruning operation.

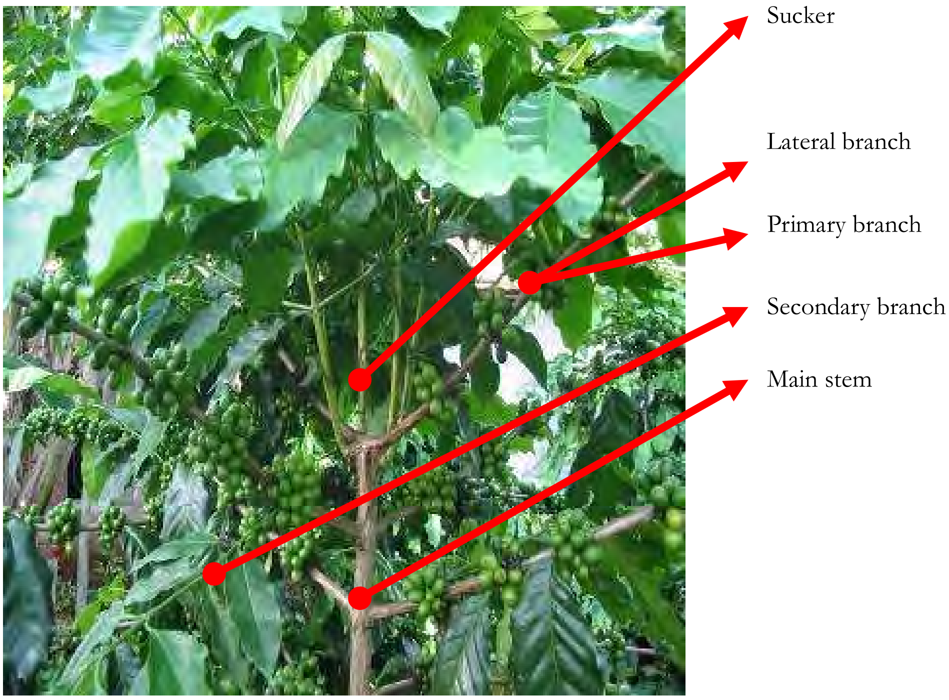


Figure 117: Branche types

Pruning requirements and techniques

Throughout it's entire life-cycle the coffee trees have pruning requirements. Requirements will change with increased age of the tree.

?

Why is it advisable to use pruning sissors?

First year

Pruning requirements in the first year after planting are very low and consist only of removing unnecessary suckers (Figure 118). Like their name indicates they suck a lot of moisture and nutrients away from the tree.

Suckers can appear at any given time of the year. Removing them is a recurring job that can be done at any time of the year. To avoid excessive competition for nutrients and water, suckers should be removed timely.

If any crop appears on one-year old trees the cherries should be stripped immediately for the same reasons as removing the suckers.

Figure 118: De-suckering 1-year old tree, the red mark indicates where to cut

Second year

Pruning activities in the second year determine the shape of the tree in the years to come. Closely linked with the shape is the potential for production and ease of harvesting. Pruning activities in this year are crucial and should not be skipped.

Several interventions may be needed at this stage:

Figure 119: Removal of branches touching the soil, red marks indicate where to cut

Remove all drooping primaries touching the soil up to a height of 30cm above the soil level (Figure 119).

Also all suckers should be removed to avoid unproductive nutrient and water competition with the primary and secondary branches (Figure 121).

Figure 120: Removing secondary branches close to the main stem

Figure 121: Removing suckers

The next step is to remove any secondary branches that are within 20cm of the main stem. Secondary branches so close to the stem receive little light and are typically low- or nonproductive. Additionally, removing them will create a "chimney" around the stem that facilitates ventilation (Figure 120).

A limited crop can be safely allowed on two-year old trees.

Third and following years

During the third and following years the basic shape that has been determined in the first and second year is being maintained by:

?

What is the best time of the year to prune?

- Remove all drooping primaries touching the ground up to 40cm above the soil level;
- Remove all the suckers;
- Remove the top at the desired height, commonly around 1.6m (Figure 122);

Figure 122: Removal of primaries, suckers and top

- Any long, drooping primary branches should be cut back to the nearest secondary branch (Figure 123);

Figure 123: Removal of long primary branches

- Primary branches in the top section should spaced at around 10cm (Figure 124);

Figure 124: Spacing primary branches and removing the top

- A maximum of 5 well-spaced secondary branches is allowed on each primary branch (Figure 124); and

Figure 125: Removing excessive secondary branches

- Finally all dead and weak branches are removed (Figure 126).

Figure 126: Removing weak and dead branches

After removal of weak and dead branches on the tree in Figure 126 there will not be many productive branches left. In this case it is better to rejuvenate the entire tree. This is done by selecting a sucker at the base of the tree that will be maintained and after a year can replace the main stem (Figure 127).

Figure 127: Rejuvenating the tree by using a sucker, the yellow circle indicates the sucker that will replace the stem

Stumping

Around 8 to 10 years after planting the vigour of the tree to produce new bearing wood decreases and it is time to start stumping. Traditional Arabica varieties can sustain yields for a much longer time of up to 20 years. However, highly productive varieties like Catimor loose vigour much earlier. With low pruning inputs or wrong pruning techniques, or low nutrient inputs this point may be reached after 5 to 6 years already (Figure 128, Figure 129 & Figure 130).

Figure 128: Low pruning inputs

Figure 129: Wrong pruning techniques

Figure 130: Low nutrient availability

Several approaches to stumping can be followed, each with its own merits and drawbacks.

Phased stumping

With phased stumping the tree is stumped over a two year period. At an age of around 6 to 7 years all branches on one side of the tree, preferably the eastern side, are removed. Of the newly developing suckers on that side two vigorous ones are maintained. After three months the most promising of these 2 suckers is kept and the other removed.

?

Why would one remove the branches on the eastern side of the tree and not on the western side?

Two years after pruning all the primary branches on the east side of the tree the new sucker has developed sufficiently and will bear a first crop. At his point the old main stem can be completely removed. Make sure the stem is cut at an angle of around 45 degrees to avoid water penetration of the stump which can stimulate fungal and bacterial infections.

The advantage of this system is that the tree continues to bear fruit throughout the transition from old to new bearing wood. However it requires more labour than the direct stumping approach.

Direct stumping

With direct stumping the entire stem is removed in one time. Again the stem should be cut at an angle of 45 degrees for the reasons mentioned in the previous section. The cut should be made around 10 to 15cm above the soil (Figure 131). Literature recommends a taller stump, but in Huong Hoa the seasonal winds from Laos result in too many broken sucker if the stump is taller. Stumping closer to the soil than this can result in increased infections by fungus and bacteria of the stump and a general reduction of regenerative capacity (Figure 132).

Figure 131: Stumped tree, note the slanted angle of the cut

The advantage of this system over phased stumping is that less labour is required. However, the field will be out of production for one year. This can be prevented by directly stumping a field in two phases. In the first phase, around year 8 to 8 50% of the field is stumped. In the second year, when the stumped trees start to bear fruit, the second 50% is stumped. A major drawback of this system is that the rejuvenated trees will have an age difference that results e.g. in different fertiliser requirements.

Figure 132: Stumping too close to the soil resulting in low regeneration

Taking care after stumping

After stumping a light tillage of the soil (not deeper than 10cm) is recommended for two reasons:

1. To cut part of the old root-system. This will reinstate the balance between roots and above ground matter. Furthermore it stimulates the formation of new hair roots; and

2. to loosen the soil that has been compacted over the years, allowing for a (leguminous) intercrop.

The intercrop can be harvested (Figure 133), but in the Huong Hoa area where organic matter content of the soil is generally low, it is recommended that the intercrop is worked in the soil again.

Figure 133: Coffee with spring onion

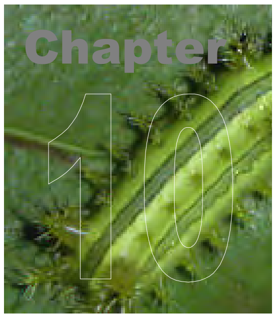
Figure 134: Sucker being maintained after stumping

After stumping an abundant number of suckers will grow from the stump, the majority of these have to be cut (with scissors!) swiftly before they grow too large. Depending on whether the farmer wants to use the single or multiple-stem system one (Figure 134) or more (Figure 135) vigorous suckers have to be selected.

With the prevailing winds come from the north, it is best too select a sucker on the north side of the stump to reduce the potential damage to the suckers from strong winds.

Immediately after stumping the field receives considerable more sunlight. Farmers who have not planted shadow trees and desire to do so, will find this a suitable period.

Figure 135: Several suckers on one stump



Pest and disease identification and prevention

*In Huong Hoa occurrence of pests and diseases is still fairly limited. Only leaf rust (*Hemileia vastatrix*) presents a serious problem, but not even every year. Other diseases occur, but their economic impact is up to now negligible. This chapter deals with the most common pests and diseases in Huong Hoa district.*

Pest and disease types

Four groups of pests and diseases can be distinguished, although the number will vary with the division criteria one applies. In this book the grouping criteria are:

1. Fungal diseases;
2. Bacterial diseases;
3. Nematodes; and
4. Insects and other pests

However, nematodes are not a problem in Huong Hoa, hence these will not be discussed here.

In some books nutrition deficiencies are also regarded as a disease. Although pests and diseases will occur more frequently in weakened trees that suffer from nutrition deficiencies, their direct link with fertilisation places these in the chapter Plant nutrition and fertilisation.

Successful pest and disease prevention starts at planting. A plantation that has been created carefully will be less susceptible to pests and diseases. Careful establishment centers amongst others on soil selection (Soil identification and improvement) but also planting distances have influence (Land preparation and planting) as well as fertilisation (Plant nutrition and fertilisation and Composting).

?

How could the selection of taproots during propagation and planting influence future pest and disease problems?

Three main fungus diseases occurring in Huong Hoa are, in order of frequency of occurrence: Coffee Leaf Rust (CLR), Brown eye disease and Black Spot Disease.

Coffee Leaf Rust

A tree infected by Coffee Leaf Rust shows symptoms on the leafs. If the conditions are right Coffee Leaf Rust can spread very quick and its economic impact in Huong Hoa and then especially in Huong Phung can be severe. The severance of the economic impact depends to a large extend on the time of infection and the overall health and vigour of the trees. Weak trees, such a caused by overbearing or under-fertilization, will display more problems. Coffee Leaf Rust was first described in present-day Sri Lanka in 1861. As a result of Coffee Leaf Rust outbreaks Arabica growing was abandoned in Sri Lanka 1867! Since those days Coffee Leaf Rust has spread around the world and is found in every coffee producing area, except Australia and Hawaii.

Symptoms

The first symptoms of Coffee Leaf Rust are yellowy circular spots on the underside of the leaves, after about a week these are covered by an orange powdery substance (Figure 137). Slowly these spots form larger circles. The upside of the leaf shows brown/yellow spots (Figure 136). On older leaves, the entire leaf area may be covered, but usually the leaf drops down before that stage is reached. Severe infections in combination with a poor nutrient supply can cause massive leaf shedding and enhance die-back. Other fungi can also develop on the leaf rust infected areas, for example *Verticillium lecanii* (Figure 138).

Figure 136: Coffee Leaf Rust infected leaf, upside

Figure 137: Coffee Leaf Rust infected leaf, underside

Figure 138: Verticillium lecanii on Coffee Leaf Rust infected area, an indicator of a humid climate

Development

Like all fungi, Coffee Leaf Rust spreads through spores (the yellow powdery substance found on the underside of infected leafs). Spores can be spread by wind, but also by any moving organisms in the field (including farmers!). For the spores to germinate liquid water is required. This explains why Coffee Leaf Rust hardly occurs during the dry season. The optimum temperature for germination is 20-25°C, with a maximum of 28°C. During temperatures below 15°C Coffee Leaf Rust does not develop.

?

Why is it important to wash clothes that have been worn in a field infected with Coffee Leaf Rust before using them again?

Suitable conditions for development of Coffee Leaf Rust are therefore wet days interspersed with dry and sunny spells, or foggy weather. Relative humidity should be around 80% or higher. In such conditions the germination process will take place in approximately 12 hours. The germ tube of the spore will extend into **stomata** (leaf openings, see also Leaves in Introduction to Arabica) of medium to old leaves (young leaves are not susceptible to infection) (Figure 139.4) **Sporulation** (dispersal of "seeds" of the fungal growth. Those "seeds" are called spores) of the new infection can occur already after 2 weeks (Figure 139.8). This is exacerbated by the relative low altitude of the growing area in Huong Hoa. If left unchecked and under highly suitable conditions Coffee Leaf Rust can infect huge areas in 1.5 to 3 months (Figure 140).

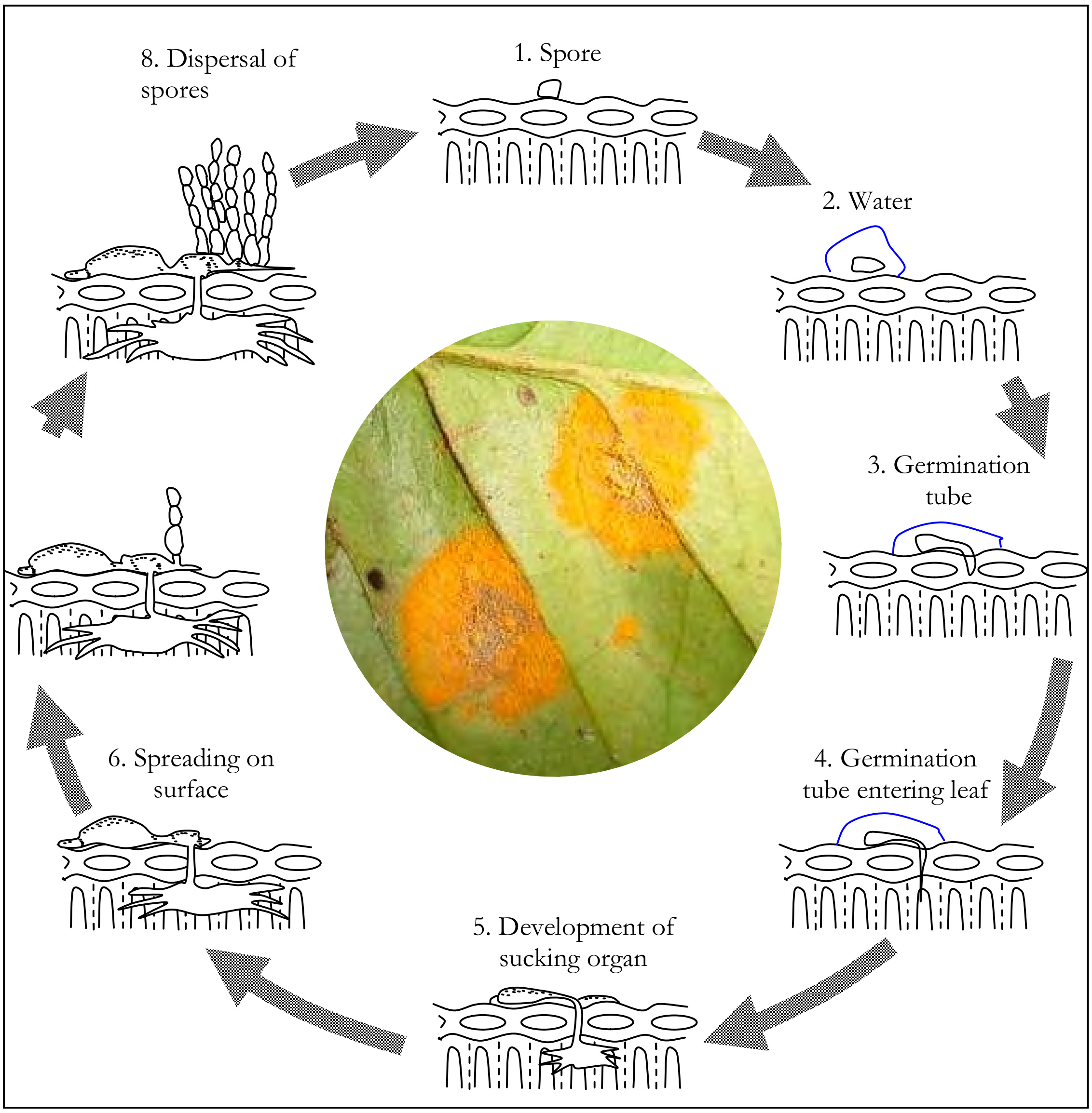


Figure 139: Fungus development

Figure 140: Result of severe Coffee Leaf Rust outbreak in Huong Phung, 2001

Prevention and treatment

The entire Arabica genus is susceptible to Coffee Leaf Rust. However, true to type Catimor is fairly resistant. This does not mean Coffee Leaf Rust can not occur in Catimor, only that when it does occur, the effects will be less severe as compared to other Arabica varieties.

The best way to prevent Coffee Leaf Rust from occurring is to have strong healthy trees. This attained by applying correct techniques of propagation, planting, weeding, fertilisation and pruning as described in previous chapters. If Coffee Leaf Rust still appears a first assessment of the severity is needed. In an otherwise strong plantation of trees small symptoms of Coffee Leaf Rust are not a reason to worry, but close observation on a bi-weekly basis is essential.

?

What does the leafrust infection in Huong Phung in 2002 tell you about propagation practices?

When the conditions are particularly suitable for Coffee Leaf Rust development, that is between 20 and 25°C with a high relative humidity, a preventive treatment with a copper based fungicide can be done. Copper based fungicides are only effective in from stage 1 to 3 (Figure 139). However, Coffee Leaf Rust only becomes visible to the human eye from stage 6 to 8 (Figure 139). In Huong Hoa, the time for application is from May to September. When spraying, care should be taken that especially the underside of the leaves is reached (farmers who pruned regularly will notice the benefits since pruning makes reaching the underside of the leaves easier!). In addition, the soils in Huong Hoa seem to have a low copper availability, so the application does more than only treat Coffee Leaf Rust.

If the disease becomes visible and continues to spread, and copper has no, or a limited effect, other fungicides can be used (Table 27). Also refer to section Pesticide application procedures for information on application methods and safety precautions to be taken.

Table 27: Fungicides, active ingredients and their use

<table>
<tr><th>Active ingredient</th><th>Commercial name</th><th>Use</th></tr>
<tr><td>Copper Oxychloride</td><td>Copper oxychlorua 30 BTN/WP</td><td rowspan="5">Prevention and in soils poor in copper some trace-element fertilization effect can be expected.</td></tr>
<tr><td>Copper Hydrocide</td><td>Champion 77 WP,
Funguran-OH 59 BHN (WP)</td></tr>
<tr><td>Benomyl 25% +
Copper Oxychloride 25%</td><td>Viben C 50 BTN</td></tr>
<tr><td>Kasugamycin 0.6% + Basic Cupric Chloride 16%</td><td>New Kasuran BTN</td></tr>
<tr><td>Zineb 20% + Copper Oxychloride 30%</td><td>Vizincop 50 BTN</td></tr>
<tr><td>Diniconazole</td><td>Sumi-Eight 12.5 WP</td><td rowspan="6">These fungicides should only be used when the disease has spread severely</td></tr>
<tr><td>Epiconazole</td><td>Opus 125 EC</td></tr>
<tr><td>Hexaconazole</td><td>Anvil 5 SC</td></tr>
<tr><td>Triadimenol</td><td>Bayfidan 25 EC
Samet 15 WP</td></tr>
<tr><td>Propiconazole</td><td>Tilt 250 EC</td></tr>
<tr><td>Tridemorph</td><td>Calixin 75 EC</td></tr>
</table>

Brown eye spot disease

Similar to Coffee Leaf Rust, Brown eye spot also manifests itself on the leafs. Although this disease can also occur on cherries. The disease is caused by the fungus *Cercospora coffeicola*.

Symptoms

Brown eye spot symptoms are normally found on leaves of young plants in the nursery garden, although it also occurs in mature trees. Occurrence in Huong Hoa is very much localised, with no economic impact to speak of. Infection is shown by brown lesions, ranging from 3 to 6mm in diameter (Figure 141). Massive infections can lead to leaf shed and loss in vigour of the tree, although this is only rarely occurs.

Figure 141: Brown Eye Spot infected seedling, two weeks after transplanting from the nursery

Infections of the fruit are shown as brown lesions on the fruit. In the early stage of fruit development the disease shows as a reddish circle on the unripe fruit. A rule of thumb is that reddish fruits that can hardly be popped open are infected with Brown Eye Spot disease (Figure 142).

Figure 142: Brown Eye Spot Disease affecting branches and cherries

Prevention and treatment

Brown Eye Spot is essentially a nitrogen deficiency. The deficiency makes the tree more vulnerable for Cercospora infection, which thus only highlights the underlying imbalance in fertilisation. Sudden changes in light intensity received by the tree, for example after transplanting seedlings from the nursery, underwrite this. Decent field management is normally sufficient to prevent Brown Eye Spot from occurring. If it does occur a copper treatment at the beginning of the rainy season can be used. However, although the copper treatment will reduce the proliferation of the fungus it does not remove the underlying cause, i.e. nutrient deficiency or lack of shade!

?

How does drought affect die-back?

Dieback

Several fungi are associated with Dieback. However, none of these is the true causal agent of the disease. Dieback is mainly a result of one or more sub-optimal growing conditions. Most common is a lack of nutrition (Figure 143), this can be strengthened in years with a heavy crop (Figure 145) or a dry year. Dieback can also occur as a result of other diseases such as Coffee Leaf Rust, or excessive exposure to sunlight or heavy fluctuations in temperatures.

Symptoms

Branches start dropping leaves and fruits from the branch tips inwards. Usually starting at the middle of the tree and slowly developing downwards and then upwards to the top of the tree. Finally, the young top-leaves will be shed. Ultimately the tree will die.

?

How can heavy crops such as pictured in Figure 145 be prevented?

Figure 143: Dieback in progress as a result of lack of nutrition and Brown Eye Spot disease

Figure 144: Dieback in a later stage as a lack of nutrition and Coffee Leaf Rust

Figure 145: Excessive crop, leading to Dieback after the harvest

Figure 146: Neglected garden with regenerating trees after Dieback in previous year

Prevention and treatment

Dieback is caused by poor management, excessive crops as a result of light exposure without sufficient fertilization, heavy temperature fluctuations, nutrient deficiencies, or severe moisture stress. All these issues can be handled with proper management in the field. Important topics are to ensure sufficient nutrient availability, regular pruning and if possible the use of a light shadow to regulate yield levels. In addition, two copper based fungicide applications can be done at the beginning of the rainy season to ensure sufficient micro-nutrient availability. A foliar fertiliser can also be used after the harvest in January and once more in February.

Figure 147: Light shadow cover regulating and stabilizing yields thus reducing occurrence of Dieback

Figure 148: Effects of Dieback, note that the lightly shaded trees are less severely affected

Black Spot Disease

Black Spot Disease is an unknown infection of the green bean with small black spots. Some Vietnamese sources attribute the occurrence of Black Spot Disease to a Boron deficiency. However, the complete absence of Boron deficiency signals in the leaves make this somewhat doubtful. Furthermore, extensive coffee quality research in 2002 (Pinkert, 2002) did not find any relation between amounts of macro- and micro nutrients in cherries and Black Spot Disease occurrence.

Symptoms

In the field no clear indications reveal if a cherry is infected. Otherwise perfectly healthy cherries can still contain Black Spot Disease infected green beans.

Figure 149: Black Spot Disease infected bean

Figure 150: Green bean sample with severe Black Spot

Economic impact

For the farmer the direct economic impact of Black Spot Disease is limited. No significant yield reductions have been detected. Indirectly farmers are affected economically. Coffee traders and roasters who buy coffee green bean first look at the appearance of the green bean to determine quality. Even though the brew of Black Spot Disease infected green bean does not have any additional cupping defects prices for such coffee will be lower because the green bean doesn't look nice. Lower export prices will result in lower local cherry prices.

Prevention and treatment

Presently, two trials are taking place in Huong Hoa, one in Khe Sanh and one in Huong Phung. As the cherries do not show any outward sign of Black Spot Disease infection, the hypothesis is that infection takes place during flowering. Therefore, different types of fungicide have been applied under controlled conditions from pre-flowering to pinhead stage. Whether this is effective in countering Black Spot Disease development has to be seen.

Pests

Pest problems in Huong Hoa are fairly limited with only 3 types of scales occurring more frequently. Occasionally some Stemborers are spotted. Although Stemborers are not causing major problems now their development has to be closely watched. In Kenya in the 1980s 60% of the national coffee tree population succumbed to Stemborers!

Brown scale

One of the primary hosts of Brown scale (*Sassetia coffea*) is coffee (all types are known to be hosting). Brown Scale is generally found in coffee trees older than 4-5 years.

Symptoms

Brown scale feeds on sap extracted from young leaves and shoots (Figure 151). It produces honey dew which in turn can attract ants. Ants use the honey dew as a food source and protect the Brown Scale from predators. The honey dew is an ideal base for the development of fungi, resulting in a black layer covering the affected leaves and shoots. Brown Scale is not very mobile and moves only from one plant to the other when the plants are touching [4]. Brown scale prefers hot and dry conditions, the use of shadow in the garden seems to hamper its development.

Figure 151: Brown scales

Green Scale

Similar to Brown Scale, Green Scale (*Coccus viridis*) is found on middle aged to old coffee trees, feeding on sap extracted from leaves and shoots (Figure 152). Occurrence is year-round but more evident in the dry season. Just as Brown Scale it prefers hot and dry conditions.

Figure 152: Green Scale

Prevention and treatment

Pesticides can be applied to control both Brown and Green Scales, although typically their economic damage is limited and does not warrant such an investment.. Furthermore, pesticides may kill natural enemies as well. In case of uncontrolled expansion that approaches damaging levels suitable pesticides that can be used are: Ofatox, Sumithion and Supracide. Only trees under attack should be targeted.

Coffee Mealy Bug

Coffee Mealy Bug (*Planococcus lilacinus*) was first described in 1905 in the Philippines. It primarily lives on fruit trees like coffee, cocoa and citrus. In Arabica it affects roots, branches, leaves and fruits. Up to now, economic impact of the Coffee Mealy Bug in Huong Hoa has been very limited (Figure 153).

Symptoms

Similar to the Scales, the Coffee Mealy Bug also excretes honey dew (Figure 154). This attracts ants and can lead to fungus development. When the leaves are attacked they can deform and growing tips of branches and shoots can die (Figure 155). Cherries are also vulnerable (Figure 156).

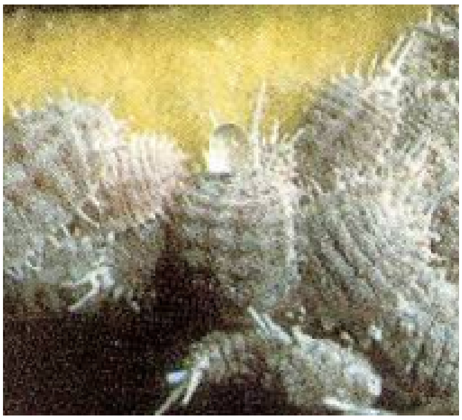


Figure 153: Coffee Mealy Bugs

Figure 154: Fungal growth on honey dew

Figure 155: Leaf deformation

Figure 156: Affected cherries

Figure 157: 2 Ladybirds looking for mealy bugs

Prevention and treatment

Coffee mealy bug has a wide range of natural enemies (Figure 157). Although chemical control can be successful, especially with stronger pesticides like Bi 58% (which is banned in Vietnam since 2004!) in principle biological control is still sufficient in Huong Hoa. Limiting the development of ants enhances the chances of success of natural enemies of the Mealy Bug, therefore clean weeding is recommended in gardens where Coffee Mealy Bug (and Scales) is developing.

Coffee Stem Borer

Two types of Coffee Stem Borer are present in Huong Hoa; red and white.

Red stemborer (*Xylotrechus quadripes*) is mostly active in un-shaded gardens where hot and sunny conditions prevail. Consequently, it is mostly occurring in the dry season. The adult have white wings with black spots. Typically, the adults emerge from August to October, but in Huong Phung this can be earlier. The adult lays eggs in crevices in the bark. After 6 to 9 days the larvae appear and bore into the tree eating their way to the tree top through the heartwood (Figure 159 & Figure 159).

Figure 158: Red stemborer adult (Picture courtesy Keith Chapman)

Figure 159: Red stemborer larva

White stemborer (*Zeuzera coffeae*) is a black and white beetle. It lays its eggs in the bark of the tree. White larvae feed on bark tissue, which splits as a result. At a later stage larvae may tunnel to all parts of the tree, including the root system (Figure 160 & Figure 161).

Figure 160: Adult of White stemborer

Figure 161: White stemborer larva (Source: ICO[5])

Presently, the Coffee Stem Borer does not have a major economic impact in Huong Hoa. However, other coffee areas in Vietnam have reported losses of up to 7% and on neglected plantations in India losses reached 20% [6]!

Symptoms

A clear symptom of Coffee Stem Borer is wilting trees (Figure 163 & Figure 164), or at a later stage of infestation, trees that easily snap just above the point of entry of the larvae (Figure 162).

Figure 162: Stemborer entry hole

Figure 163: First symptoms of red stemborer in mature coffee

Figure 164: Red stemborer damage in young coffee

Prevention and treatment

Cultural control of the Coffee Stem Borer is possible by shading the garden. In addition infested trees should be cut and burned as soon as possible to control spreading. Generally, as with all pests and diseases, weak trees seem to more vulnerable. Hence avoid planting young trees with twisted taproots.

?

Why does application of pesticides have limited effect on stem borers?

Pesticide application procedures

Three types of pesticides are available: herbicides, fungicides and insecticides. Herbicides are used by some farmers, especially in young coffee. During the first years after establishment of a new garden, weed pressure can be quite high. Herbicides can be divided in 2 groups:

1. Selective; and
2. Non-selective herbicides.

Selective herbicides work against one particular type of weed, while non-selective herbicides generally kills all plant growth.

Fungicides and insecticides can be grouped according to their types of action:

1. Preventive; and
2. Curative

As the name indicates, the first group is applied in advance of a pest or disease. This is done when conditions for the pest or disease development are favourable and the pathogen has been observed or is expected to occur (e.g. Coffee Leaf Rust in Huong

Phung). The second is applied when the pest or disease starts to approach unacceptable levels of damage to the crop.

Understanding the label

In Vietnam over 100 products are traded under different names and often with different characteristics. One thing they all have in common is user-instructions on the label (Figure 165). These should be followed at all times!

A product usually has different names:

1. the Common name: this is often a coinage of the name of the active ingredient, the part in the pesticide that does the job; and

2. the Trade name: this is the name under which the product is sold.

The active ingredient describes the chemical compound that makes the pesticide effective against certain pests and diseases. The amount of active ingredient is indicative for the strength of the pesticide. Do note that a pesticide can have more than one active ingredient: e.g. Ridozeb contains both Mancozeb and Metalaxyl.

The concentration of the active ingredient is represented by a number with a code:

Fastac 5EC Alpha-Cypermethrin

Fastac:	**Trade name**
5:	**g/ml of active ingredient per kg/l product**
EC:	**Code that indicates that Fastac is a fluid**
Alpha-Cypermethrin:	**Name of the active ingredient**

EC is not the only code that can be found on the box, bag or bottle. Others are: WP, BTN, BHN, SC and WG. In this EC and SC are fluid preparations, WP is similar to BTN and BHN and stands for a powder preparation. WG are granular products [7].

Common name:	A RIN 50sc
50:	Active ingredient is 50ml/100ml product
Sc:	the product is a fluid
Active ingredient:	Carbendazim
Production date:	24-03-04
Period of use:	3 years after production date
Crop types:	Coffee is indicated
Purpose:	Coffee Leaf Rust
Amount of product per ha:	For coffee: 0.5-0.8 l/ha; i.e. 5 to 8 bottles
Recommended concentration:	7-10ml product on 8l water
Amount of water per ha:	400-600 l/ha
Handling instructions:	Wear gloves, glasses, overalls, avoid spraying in surface water

Figure 165: Reading pesticide labels

Spraying equipment

Commonly farmers use small knapsack sprayers to distribute pesticides. (Figure 166, Figure 167) Although cheap and reliable they tend to deteriorate rather quickly. Deteriorated sprayers start leaking at the connections and it is not uncommon to see farmers with wet backs (and this is not only from sweating!). Needless to say this should be avoided at all cost!

Figure 166: Old knapsack sprayer with some leaking connections

Figure 167: New knapsack sprayer

Spraying patterns

Depending on the pest or disease that is targeted the spraying pattern has to be adapted (Figure 168). Spraying pattern refers to the droplet size and the coverage of trees. Adaptation can be done by adjusting the spraying nozzles (although the Chinese-made sprayers (Figure 167) have very limited adjustability) and by adjusting exposure of individual trees.

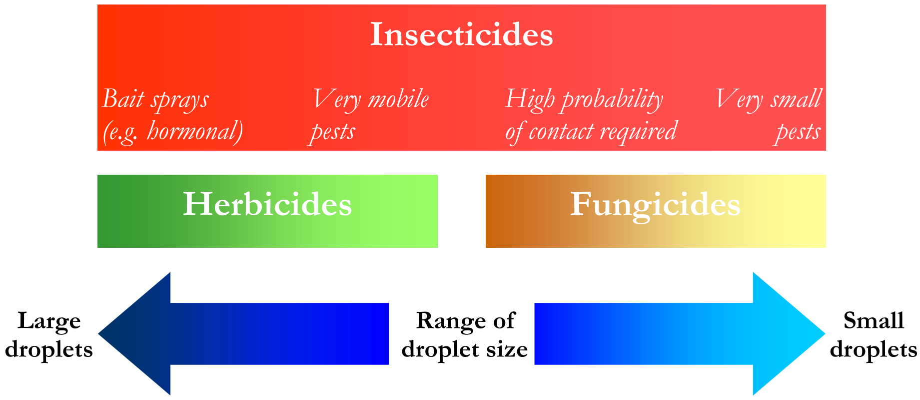


Figure 168: Relative droplet size in relation to pesticides

On the commonly used Chinese sprayer limited spray adjustment is possible by turning the retaining ring on the nozzles (Figure 169, Figure 170).

Figure 169: Nozzles adjusted to fine droplets

Figure 170: Nozzles adjusted to larger droplets

Figure 169 shows the nozzles adjusted for fungicide application, the spray is as fine as possible with this type of knapsack sprayer. Figure 170 shows the nozzles adjusted for herbicides and certain insecticides.

Personal safety during handling and application

The most important consideration when working with pesticides is that they are designed to kill living things. The capacity to kill or hinder the development of the body by a pesticide is called toxicity. Two types of toxicity are possible:

1. Acute toxicity

2. Chronic toxicity

How many people do you know that have had negative health effects from applying pesticides?

Acute toxicity means that effects of the contacting or inhaling the pesticide a single time will be felt shortly afterwards, or at last within 24 hours. This usually translates to irritated skin or burning sensations in the eyes (Figure 171, Figure 172).

Figure 171: Eye damage

Figure 172: Skin problems after exposure to pesticide

Chronically toxic pesticides show there effects only after repeated exposure to the product. These effects can take the shape of cancer, tumors birth defects, etc.

Both types of toxicity can also have systemic effects. A systemic effect is a delayed illness or injury to the body. Systemic effects usually affect the circulatory system, the nervous system, the kidneys or the liver. Most systemic effects are commonly associated with the chronic effects of pesticides. Examples of systemic effects include: blood disorders such as anemia or an inability to clot, nerve or brain disorders including paralysis, excitation, trembling, blindness, or brain damage, skin disorders, such as rash, irritation, and ulceration, lung and respiratory disorders, such as emphysema and asthma, liver and kidney disorders, such as jaundice and kidney failure.

Storage of pesticides

Due to their high toxicity pesticides should be stored out of reach from children and animals. A suitable option is to store pesticides in a separate building that can be locked, is well ventilated and not exposed to direct sunlight. Even better is to buy pesticides at the dealer on the day they are needed, thus avoiding on-farm storage altogether.

Figure 173: Fully protected!

Personal protection

The previous sections should have highlighted the importance of personal protection when applying pesticides. Naturally, wearing heavy protective clothing in a tropical climate is not very comfortable, but it seems preferable over brain damage.

In many countries users of knapsack sprayer operators are by law required to wear waterproof one-piece overalls when spraying. As complete over-alls may not always be available locally raincoats and trousers are a reasonable alternative (Figure 173).

Gloves should also be worn. However, only plastic gloves should be used as leather and cotton are too porous and don't fully prevent the pesticide from coming in contact with the skin.

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Which parts of the body take up pesticides most easily?

Boots should be rubber or plastic and the rain trouser has to fall over the boots to avoid entry of spray drip on the boots.

Protection for the head has to be plastic as well. The hood of the raincoat can be used, or else a construction hard hat. The eyes should be completely covered by glasses. Sunglasses do not suffice because spray drift can enter from the sides!

After use all the protective materials should be thoroughly washed with soap and dried in the shade (direct sunlight breaks down the material).

Needless to say during the handling drinking, eating and smoking should be avoided!

During application it is better to walk backwards, thus avoiding any contact between the body and sprayed foliage.

Pesticides and health

Pesticides can enter the human body through breathing, drinking, swallowing and directly through the skin. On parts of the body where the skin is thin, this danger is even more acute. Such parts are the insides of elbows and knees, groin and back. Entry of pesticides through the groin and back is even worse because several vital organs such as liver and kidneys are located close by. Because of the ease with which pesticides can enter human bodies, several of the most dangerous active ingredients have been banned internationally. Table 28 shows those pesticides that are commonly used in coffee in Vietnam. Listing pesticides according to Trade name and active ingredient, the table shows 6 characteristics. These are:

1. **PAN bad actor**: PAN stands for Pesticide Action Network. This organsiation evaluates dangers of pesticides and informs users and society about it. PAN bad actors are chemicals that are one or more of the following: highly acutely toxic, cholinesterase inhibitor, known/probable carcinogen, known groundwater pollutant or known reproductive or developmental toxicant.

2. **Acute Toxicity**: This refers to Acute toxicity refers to the immediate effects (0-7 days) of exposure to a pesticide. Highly acutely toxic pesticides can be lethal at very low doses. Narrative toxicity categories (Danger, Warning, Caution) are based on the LD_{50}, the dose (in milligrams of substance per

kilogram of body weight) that kills 50% of the test animals in a standard test, through either oral or skin exposure routes. For inhalation exposures, the LC_{50} is used--the concentration in air in mg per liter that kills 50% of the test animals.

3. **Carcinogenicity**: refers to the ability of a pesticide to cause cancer. Absence of a pesticide on the carcinogenic list does not necessarily mean it doesn't cause cancer, but may signal that it has not yet been evaluated!

4. **Cholinesterase inhibitor**: Proper functioning of the nervous system requires an enzyme called cholinesterase (ChE), which facilitates the transmission of nerve impulses. ChE-inhibiting pesticides disable this enzyme, resulting in symptoms of neurotoxicity---tremors, nausea, and weakness at low doses; paralysis and death at higher doses. Most of these pesticides are insecticides with a similar mechanism of action in both insects and humans.

5. **Developmental or reproductive toxin**: Some pesticides are known to cause birth defects or interfere with normal development

6. **Endocrine disruptor**: Many pesticides are capable of interfering with the proper functioning of estrogen, androgen and thyroid hormones in humans and animals. These substances are called endocrine disruptors. Exposure can cause sterility or decreased fertility, impaired development, birth defects of the reproductive tract, and metabolic disorders.

Those pesticides listed in bold are the so-called bad actors, these are best avoided because of potentially severe health effects on humans. Also within Utz Kapeh the use of these pesticides is not recommended, although not prohibited. Utz Kapeh also states that producers should follow national laws regarding pesticides. This means that farmers in Vietnam are not allowed to use Bi58 because it is banned nationally.

Table 28: Commonly used pesticides and their dangers for human health

Trade name	Active ingredient	PAN Bad Actor	Toxicity	Carcinogenicity	Cholinesterase inhibitor	Developmental or reproductive toxin	Endocrine disruptor
funguran oh 50 wp	copper hydroxide	No	slight	?	no	?	?
Danawin	Difenoconazole	No	slight	possible	no	?	?
round up	Glyphosate IPA salt	No	?	?	no	?	?
Bi 58	**Dimethoate**	**Yes**	**high**	**possible**	**high**	**high**	**?**
Vicarben 50 hp	Carbendazim	No	slight	possible	no	?	suspected
Dibamirin 5EC	Cypermethrin	No	?	possible	no	?	?
Supracide 40EC	**Methidathion**	**Yes**	**high**	**possible**	**high**	**?**	**?**
Vifosat	Glyphosate IPA salt	No	?	?	no	?	?
DiMix-Top	**Diazinon**	**Yes**	**moderate**	**?**	**high**	**?**	**?**
DiMix-Top (lso) (l)	**Isoprocarb**	**Yes**	**moderate**	**?**	**high**	**?**	**?**
Boocdo	copper sulphate	No	moderate	?	no	?	?
Ofatox	**Fenitrothion**	**Yes**	**moderate**	**not likely**	**high**	**?**	**suspected**
Ofatox	**Trichlorfon**	**Yes**	**moderate**	**high**	**high**	**?**	**?**
Oxitos	N.A.	?	?	?	?	?	?
Suprathion 40EC	**Methidathion**	**Yes**	**high**	**possible**	**high**	**?**	**?**
Vidithoate 40ND	**Dimethoate**	**Yes**	**high**	**possible**	**high**	**high**	**?**
Sunfatdong	copper sulphate	No	moderate	?	no	?	?
Ba Sa	**Fenobucarb**	**Yes**	**moderate**	**?**	**high**	**?**	**?**
Kali 58%	K2O	?	?	?	?	?	?
Bini 58 40EC	**Dimethoate**	**Yes**	**high**	**possible**	**high**	**high**	**?**
Bi 58 40EC	**Dimethoate**	**Yes**	**high**	**possible**	**high**	**high**	**?**
trebon 10 EC	Etofenprox	No	no	possible	no	?	?

Harvesting and quality

Numerous factors in the field influence the quality of a cup of coffee. This chapter discusses the most important factors.

Introduction

High quality coffee is demanded and well paid for by international traders and coffee roasters. Generally, Arabica coffee prepared by the wet method receives the best prices on the world market. Although the final quality of the green bean depends to a large extend on the processing practice, field management also has influence. Here, farmers have an important role to play. Although a bad quality of green bean may not seem a problem for farmers, but when the exported coffee is rejected, the competitive power of the exporting company will become less, which will make it more difficult to export coffee and obtain a good price. In the end, this will affect negatively the price that farmers receive.

Six main factors that influence coffee quality on field level can be distinguished:

1. Variety
2. Climate
3. Soil
4. Nutrition
5. Pest & disease
6. Harvesting

Variety

The most common Arabica variety in Huong Hoa and the rest of Vietnam is Catimor. Besides Catimor older varieties like Bourbon and Typica can still be found. However these are seldom grown commercially with farmers preferring modern, high yielding varieties. In terms of cup characteristics the old varieties are usually considered superior. Some properties of common varieties in Vietnam are:

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What has been the main consideration for promoting Catimor in Vietnam?

- Catimor: A true to type Catimor tree is resistant to Coffee Leaf Rust and can survive extended periods of drought. From a cultivation perspective it is an easy tree, but with sub-optimal management yields deteriorate rapidly. Its' acidity, body and aroma are lesser valued by traders and roasters than e.g. Caturra and Bourbon types.

- Caturra: is a mutation of Bourbon with high yields and fair quality. It does require intensive management, more so than Catimor.

- Bourbon: has lower yields than most other varieties but with excellent cupping qualities when grown at higher altitudes.

Climate

Climate is an important factor in the quality of coffee. The elevation of Huong Hoa is at around 600m above sea level sub-optimal for Arabica cultivation. This however, is to some extend compensated by Quang Tri's latitude of 17° north. Soil plays an important role in the quality of coffee.

Figure 174: Lack of nutrients

Figure 175: Beans from such cherries

Extended dry periods have a negative influence on the quality of coffee. The tree can only take up nutrients in soluble form and a lack of water, especially during the filling stage will result in underdeveloped cherries that take a long time to ripen or do not ripen at all (Figure 174, Figure 175).

Similarly, excessive rain during the final days of ripening also has detrimental effects on quality. It causes the cherries to pop open and speeds up drying on the tree. Besides that, without the protection of the skin the cherries are easier infested by insects, fungi and bacteria feeding on the mucilage.

Big differences between day and night temperatures during ripening have a positive effect on quality, resulting in less spongy beans.Climate can be influenced by the use of shadow trees. The use of shadow at the elevation of Huong Hoa results for Catimor in better body and acidity, but aroma is influenced negatively. Overall, well-managed shadow is expected to better cupping quality.

Soil

Ideally Arabica is grown on a soil with a pH from 5 to 6. In Khe Sanh soil pH is around 4.8, in Huong Phung pH is even lower at around 4.5. The lower the pH, the more difficult it is for the tree to take up nutrients. Top soil organic matter content should be around 3%, in both Khe Sanh and Huong Phung it is lower, ranging from 2 to 2.5%. Although difficult to pin the effects of this down to quality aspects, it can be stated that better nutrient uptake will result from improved pH and organic matter content, leading to less defect beans.

Nutrients

As outlined in "Soil" and "Climate" shortages of nutrients lead to increased amounts of defect beans. However, oversupplying nutrients also has a negative effect on quality.

Excessive application of N fertiliser (Urea, SA, etc) will not only damage economic returns on investment, but also result in a higher caffeine contents. This leaves a more bitter aftertaste of the coffee brew.

Too much Potassium causes a harsh taste of the coffee brew.

In general: to produce good quality coffee, a well balanced mix of nutrients is needed, applied in regular intervals (3 to 4 times a year), rather than large amounts at once. In the field deficiency signals from the trees already give a good indication of the quality of the coming crop.

Harvesting

Harvesting techniques can be grouped into mechanical and manual approaches. In countries where wages are high such as Australia and Brasil mechanical harvesters are used, but most producing countries harvest manually. Manual harvesting can be either selective picking or strip picking. The use of one technique over the other depends on many factors, availability and cost of labour, cherry price and uniformity of flowering and thus in ripening of the crop being the most important.

During harvesting it is important to pick only red cherries. Green, dried and overripe cherries lead to different quality defects. To stimulate selective picking it would be good if processing companies stimulated farmers by paying premiums for the absence of defects, rather than applying discounts from a standard price for defects. This is unfortunately not yet the case in Huong Hoa.

Figure 176: Red and yellow cherries

Figure 177: Parchment

Ripe cherries

Ripe cherries have a red or yellow colour, depending on the variety. Ripeness can be checked by squeezing the cherry between thumb and index finger, when the bean pops out the cherries of that colour are ripe.

Green cherries

Green cherries should not be picked because they are:

1. More difficult to process; and result in

2. light brown bean colour after roasting, green grassy off-taste and general low quality.

Figure 178: Green cherries

Under-ripe cherries

Late in the harvesting season, green cherries lose their green colour without really ripening. These cherries pulp relatively easy, but will also give a green, grassy off-taste and should therefore not be picked.

Over-ripe cherries

Overripe cherries should not be picked (Figure 179). Often they are already fermenting on the tree leading to very bad off-tastes. A handful of over-fermented beans can spoil the quality of an entire container green bean. Ripe cherries that take too long to be processed will also lead to over-fermented beans. It is very important to transport cherries to the factory as soon as possible after harvesting. If this is not possible one can slow down the fermentation rate, and thereby the rate of quality loss, by evenly spreading out the cherries around 10cm thick. Of course the cherries should not get in direct contact with soil, dogs, chicken, motorbikes, etc.

Figure 179: Over-ripe cherries

Figure 180: Fermented beans from over-ripe cherries

Dried cherries

Dried cherries, either on the tree or fallen down on the soil (Figure 181), should not be picked. Especially fallen cherries as they pose a health risk because of bacteria infection and development of moulds and Ochratoxin A which is known to cause cancer.

Figure 181: Dried cherries

Figure 182: Over-fermented beans from dried cherries

Calculation examples

The calculation examples explain why it makes sense to harvest as selectively as possible.

Scenario 1: Picking green cherries

Generally speaking 1kg of ripe coffee cherry contains 850-900 fruits. 1 kg of green cherries contains 1150 to 1200 fruits, a difference of around 24%.

Samples in Khe Sanh showed that farmers rarely come below a value of 10% green cherries in any given shipment of cherries. In the present pricing system, green cherries are discounted from the total amount and therefore not paid.

Suppose farmer A has a "green percentage" of 14% and a total yield of 20 tonnes (t) that she sold for 1,800VND/kg:

20t * 14%=	2.8t green
Now suppose that 80% of this amount of green cherries could have been harvested ripe with more selective picking:	
2.8t * 80%=	2.24t ripe
Extra benefit:	
2.24t * 1000=	2,240kg
2,240kg * 1,800=	**4,032,000 VND**

Form this example the gross increase is 4,032,000 VND. After discounting the extra labour needed for harvesting 2,352,000VND remains.

2,240kg / 40kg/man-day=	56 man-day
56man-day*30,000VND/day=	1,680,000VND extra labour cost
4,032,000-1,680,000=	**2,352,000VND extra benefit**

Scenario 2: Picking over-ripe

Usually another 10-15% of a shipment contains over-ripe cherries. Over-ripe cherries are around 18-20% lighter than ripe cherries.

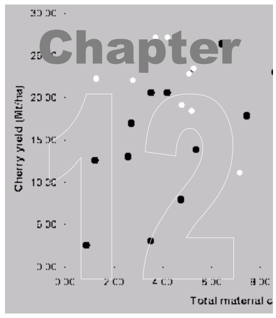
Suppose farmer A had another 5% over-ripe:

20t * 5%=	1t over-ripe
Now suppose again that 80% could have been picked ripe:	
1t * 80%=	800kg
Extra benefit:	
800kg *1,800VND=	**1,440,000VND**

When we again assume that one worker picks 40kg per man-day the net benefit is considerably smaller than in the previous example:

800kg / 40kg/man-day=	20 man-day extra labour
20 * 30,000VND/man-day=	600,000VND extra labour cost
1,440,000-600,000=	**844,000VNd extra benefit**

In conclusion, selective picking of cherries is vital for good quality coffee. It does not only pay because of the better prices received at the factory, but also through, albeit slightly, increased yields.



Fieldbook

Quantification of management of the field is useful to farmers because it allows for accurate analyses of performance and can be used to identify areas for improvement. The Fieldbook facilitates quantification and this chapter explains how.

Rationale

Each year farmers have to make tough decisions on how much to invest when in the coffee garden. Especially in intensive cultivation systems such as in Huong Hoa, the levels of investment for fertilizers and labour are considerable. When such large sums of money are being used it is important for farmers to have a reliable and **quantitative** (a way of describing something so that it can be counted or measured. For example a high yield is not a quantitative statement, but a yield of 25Mt/ha is) analysis of their management. The term quantitative is used for describing something such that it can be counted or measured. For example a high yield is not a quantitative statement, but a yield of 25Mt/ha is. For this purpose the Fieldbook can be used.

Approach

When using the Fieldbook a farmer, or group of farmers, records for one or more fields on a periodic (preferably daily) basis all the inputs in terms of materials (such as fertilizer and pesticides), labour (both from the family and hired) and equipment and prices paid for each. Also all the outputs (for example fresh coffee cherry) and the price at which they were sold of this field are recorded.

This information can then be put into the computer using a dedicated software package. After the harvest the software can be used to make an analysis of the year's production. This analysis can be done on a per field, per ha or per tree basis and is presented both in tabular form and graphically. A wide variety of analyses can be made, some examples are:

- physical relations (for example N-application and yield)
- Labour use (labour for pruning against yield)
- Economic parameters (gross benefit, income, material costs, labour costs against any other parameter).

Results

While a wide range of results can be analysed, this section will only highlight some examples in 2 categories.

Biophysical analysis: comparison between forms of management and years

On the fields of three farmers in Quang Tri, comparative experiments take place, where each of these fields is split in two parts. Both are managed by the farmer, according to his own decisions, with one exception: on one part, an 'alternative' fertilization is tested, following suggestions by the project team. In the field of one farmer in Khe Sanh, the alternative management in 2002 gave different results compared to the farmer's management: cherry production was 10 tons per ha higher and more synchronised in time (compare open circles and closed circles for 'alternative' and 'farmer' management, respectively, in Figure 183).

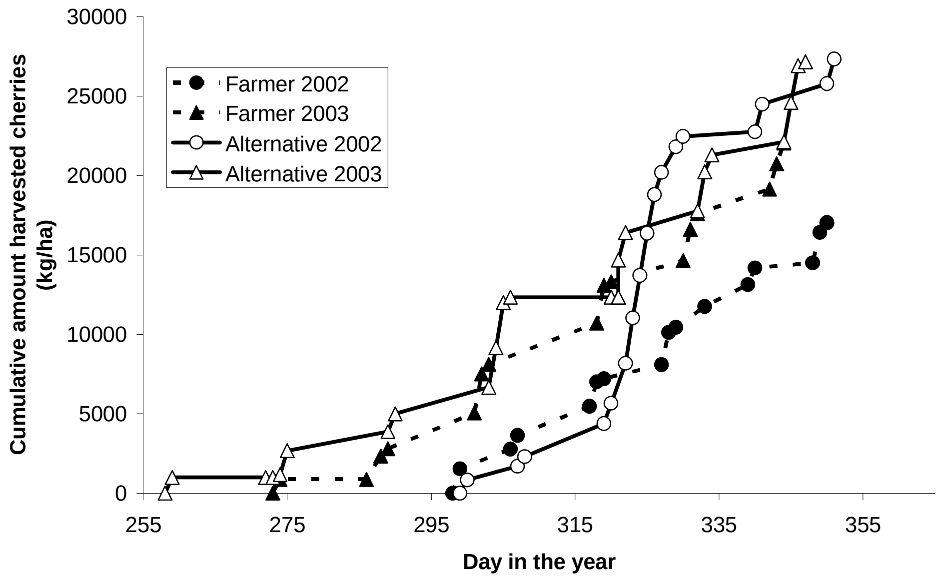


Figure 183: Cumulative amount of harvested fresh cherries according to year (2002, circles; 2003, triangles) and management (farmer's fertilization, closed symbols; alternative fertilization, open symbols) in a particular field in Khe Sanh

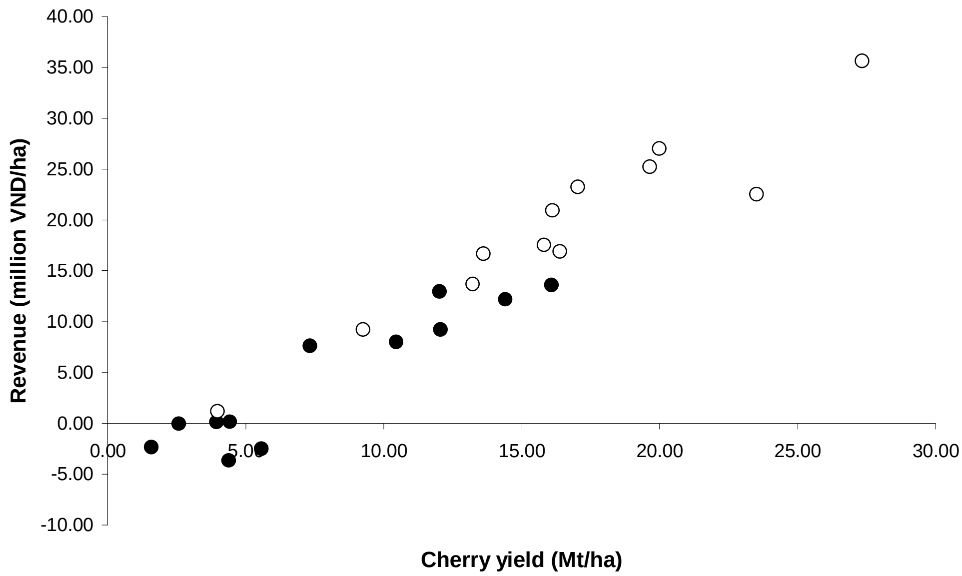
Although the farmer enjoyed the higher yield, he disliked the synchronization, as this made it more difficult for him to do the harvesting in his other fields with the limited labour force available. In 2003 no big differences were observed in performance of the two forms of management (open and closed triangles, Figure 183). This is mainly related to the smaller differences in amounts and timing of N application between the 'farmer' and 'alternative' management in 2003 (Table 29). Due to drought, the suggested alternative fertilization schedule could not fully be executed as planned in 2003.

Table 29: Time and amount of Nitrogen fertilization in 2002 and 2003 in the plots with full farmer manage¬ment ('Farmer') and with an alternative fertilization ('Alternative'), for one specific farmer in Khe Sanh

Management	2002		2003	
	Day	N (kg/ha)	Day	N (kg/ha)
Farmer	≈150	366	142	110
	350	77	272	77
Alternative	≈150	366	225	81
	194	57	321	96
	266	142		

Economic analysis: comparison between farmers

Coffee farmers in Quang Tri are generally profit maximisers: yield is less important than income. Therefore, they are extremely interested in the economic performance of their fields. To express this performance, the revenue achieved at each field is calculated according to: $R = G - C = Y \cdot P - C$, where R= revenue, G = gross income, C = total costs of inputs used, Y= yield of cherries, P = price of cherries. In 2002 and less so in 2003, a strong and positive relation existed between yield and revenue (Figure 184).



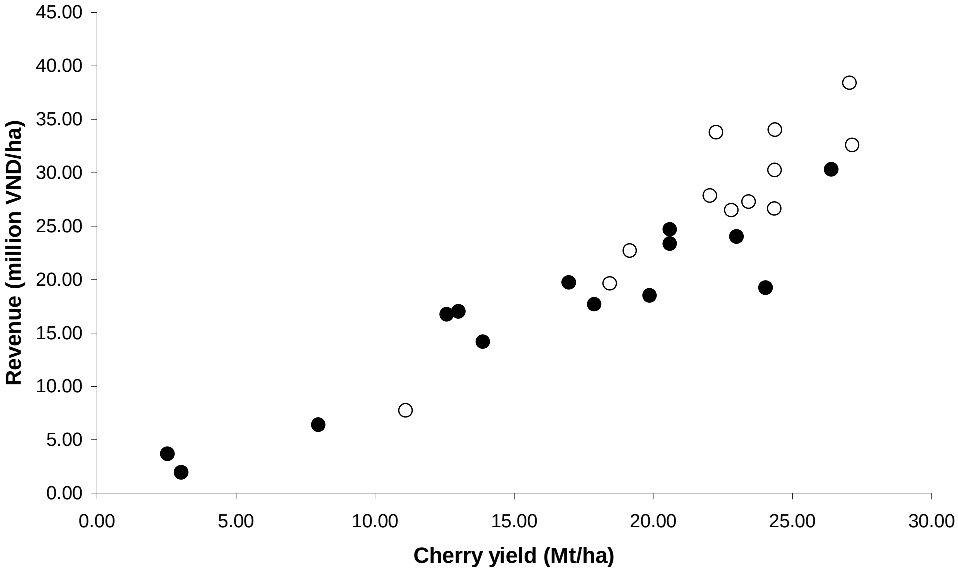
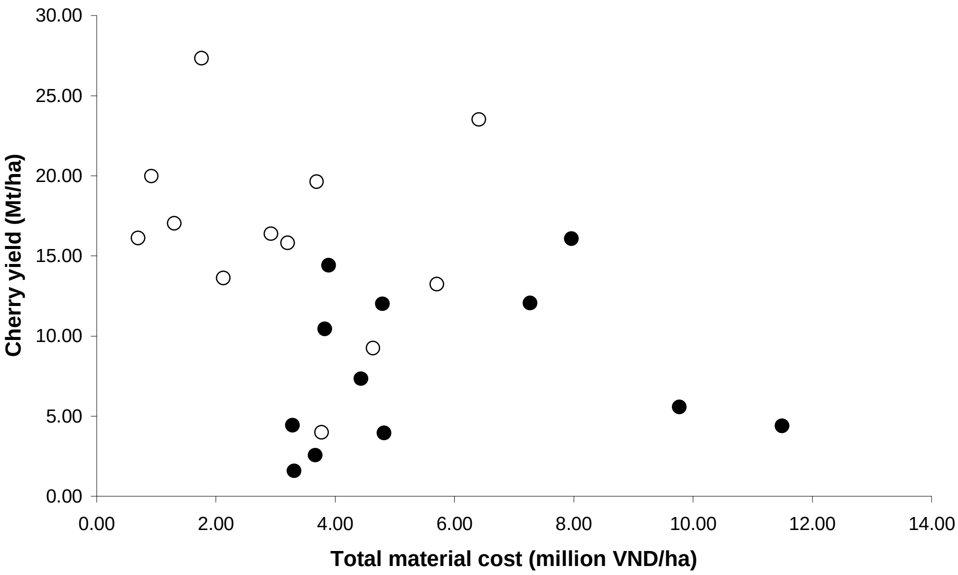


Figure 184: Revenue of individual fields in relation to cherry yield, for two years (2002, top, and 2003, bottom) and two locations (Khe Sanh, open dots and Huong Phung, closed dots). Data are shown on a per ha basis to allow comparison.



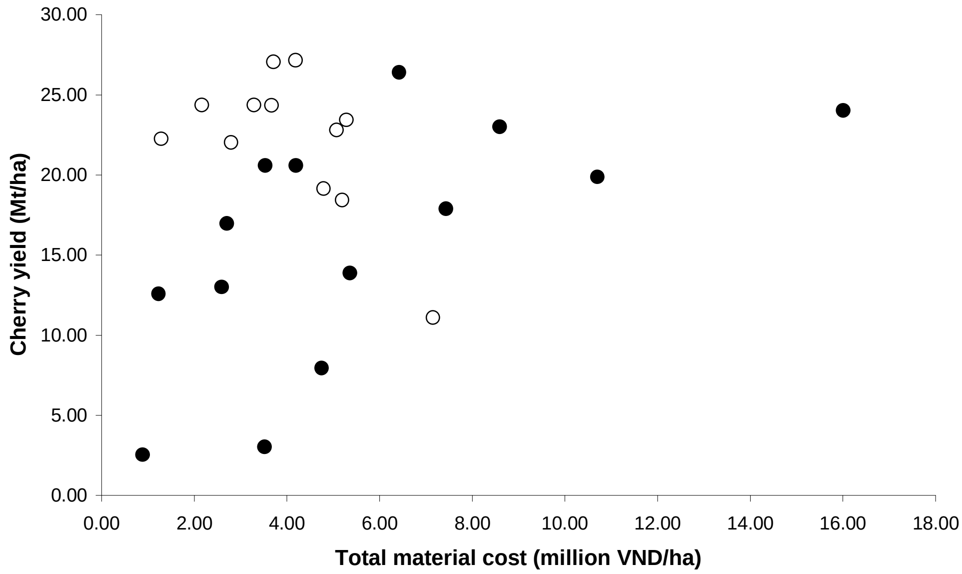


Figure 185: As Figure 184 for relation between total costs of materials used and cherry yield.

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What could be an explanation for the weak link between material costs and yield (figure 186)?

There is a difference between the two locations: farmers in Huong Phung, with less fertile soils, younger crops and poorer infrastructure have in general lower yields and lower revenues at similar yields than their colleagues in Khe Sanh. Also, considerable variation exists in the yield-revenue ratio between farmers within each location: especially in 2003, some fields with lower yields had higher revenues and different fields with similar yields showed different revenues. This results mainly from the lack of relation between total costs for material used and yield (Figure 185).

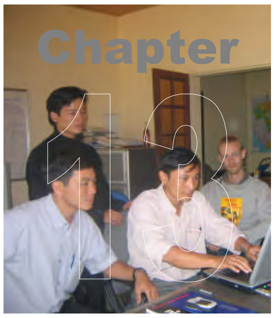
The reasons for this lack of relation are probably twofold:

1. Nutrient management is not always adequate: nutrients are often not applied in a proper mix nor in a proper timing and frequency

2. Other management activities, especially pruning and weeding, are often not conducted properly

Final notes

The Fieldbook software is freely available to anybody who is interested. As of August 2005 the approach is used in by one company and two projects in Vietnam and another project in Peru. For more information please refer to our contact details on the cover page of this book.



Investment calculation

The decision to establish a new coffee field should be based on a sound investment calculations that take not only the direct establishment costs into account but also expected investments during the first years of operation and anticipated returns. This chapter gives some examples and explains how to make such calculations.

Approach

Any investment analysis should take into account the not only the establishment costs for the field, but also the maintenance costs during the trees life. The difference between the costs for establishment and maintenance and expected returns from yield should be the basis for the decision whether to plant new coffee or not.

Table 30 gives a standard cost calculation for the establishment of 1 ha of Arabica. All prices are based on the 2004 level in Huong Hoa. Needless to say prices change, so please check if prices used here are still valid when you are making a calculation.

Calculation example

This example is based on the establishment of 1 ha of Arabica with 5,000 trees per ha. Windbreaks are not yet present and an additional 1,000m^2 is used for that bringing the total land area to 1.1ha or 11,000 m^2. The cost for land purchase has not been included as prices vary considerably even within a small area as Huong Hoa. It is assumed that the land used has not been cultivated before and is presently under imperator grass (*Imperata cylindrical*). A cover crop is incorporated to prevent erosion and supply extra organic matter to the topsoil. All labour has been valued, and no distinction has been made between hired and household labour. The reason for this is that if the farmer had not been working in this field s/he might have worked at another activity receiving comparable wages.

Table 30: Cost calculation for the establishment and first 6 months of maintenance of 1ha Arabica

Nr	Inputs	Unit	Nr of units/ man day	Total nr of units	Nr of man days	Cost per unit (VND)	Total cost (*1,000 VND)
I	**Soil preparation**						
1	Clearing	m^2	400	11,000	27.5	20,000	550
2	Burning	m^2	2000	11,000	5.5	20,000	110
3	Topsoil turning	m^2	100	11,000	110	20,000	2,200
4	Field layout	m^2	2500	11,000	4.4	20,000	88
5	Digging planting holes (50cm*50cm*50cm)	Hole	100	5,000	50	20,000	1,000
6	Liming	m^2	5000	11,000	2.2	30,000	66
7	Manure distribution	m^3	1	25	25	20,000	500
8	Phosphate distribution	Kg	500	1,500	3	20,000	60
9	Mixing fertilizers and manure	Hole	200	5,000	25	20,000	500
	Subtotal soil preparation				**252.6**		**5,074**
II	**Planting**						
1	Coffee seedling distribution	Bag	1000	5,000	5	20,000	100
2	Planting	Bag	200	5,000	25	20,000	500
3	Digging planting holes for windbreak (30cm*30cm*30cm)	Hole	250	1,000	4	20,000	80
4	Transportation, distribution and planting of	Bag	200	1,000	5	20,000	100
5	Digging planting holes for shade trees (30cm*30cm*30cm)	Hole	200	200	1	20,000	20
6	Distribution and planting of shade trees	Hole	200	200	1	20,000	20
7	Planting second windbreak	Labor			4	20,000	80
8	Planting/sowing cover crop	Labor			10	20,000	200
	Subtotal planting				**55**		**1,100**
III	**Maintenance during first 6 months**						
1	Weeding whole field two times	m^2	400	11,000	27.5	20,000	550

2	Weeding planting holes	m^2	500	10,000	20	20,000	400
3	Fertilizer application (N + K)	Hole	500	6,200	12.4	20,000	248
4	Replacement of dead & weak trees (10%)	Hole	50	620	12.4	20,000	248
5	Plant hole maintenance	Hole	200	5,000	25	20,000	500
6	Spraying herbicide	Labor			10	40,000	400
7	Clearing around field	m^2	500	2,000	4	20,000	80
	Subtotal maintenance during first 6 months				**111.3**		**2,426**
IV	**Materials and equipment**						
1	Bush-hook	Nr		4		40,000	160
2	Hoe	Nr		4		25,000	100
3	Other hoe	Nr		4		20,000	80
4	Basket	Nr		4		15,000	60
5	Knives	Nr		2		10,000	20
6	Knapsack	Nr		1		80,000	80
7	Buckets	Pair		1		50,000	50
8	Other knives	Nr		4		10,000	40
9	Bags for transport of seedlings	Bag		5,500		600	3,300
10	Bags for transport of shade trees	Bag		220		400	88
11	Bags for transport of windbreak trees	Bag		1100		400	440
12	Seeds for cover crop / temporary windbreak	Kg		3		50,000	150
13	Manure	m3		25		140,000	3,500
14	Lime	Kg		1,500		50	75
15	Phosphate fertilizer	Kg		1,500		120	180
16	Nitrogen fertilizer	Kg		100		3,000	300
17	Potassium fertilizer	Kg		50		2,500	125
18	Copper	Kg		2		25,000	50
19	Good lime (with copper used as a fungicide)	Kg		2		10,000	20
20	Sumithion	bottle of 0.5l		1		80,000	80
	Subtotal materials and equipment						**8,898**
	Total labours days and cost				**418.9**		**17,498**

After establishment of the garden an assessment has to be made of the expected benefits during the economic life of the coffee tree. In this case the assumption has been made that the coffee will remain productive for at least 10 years. Annex II shows the detailed calculation, while Table 31 summarizes the outcomes. Again all labour has been valued at 20,000VND/day and an average cherry price of 1,900VND/kg has been assumed.

Table 31: Summary of cost benift calculation of 1ha of Arabica, productive lif eof 10 years at a planting density of 5,000 trees/ha

		Year 1 (*1000 VND)	Year 2 (*1000 VND)	Year 3 (*1000 VND)	Year 4 (*1000 VND)	Year 5 (*1000 VND)	Year 6 (*1000 VND)	Year 7 (*1000 VND)	Year 8 (*1000 VND)	Year 9 (*1000 VND)	Year 10 (*1000 VND)
Costs	Labour	8,600	5,500	7,900	7,988	10,240	8,105	12,117	12,696	8,608	13,158
	Material	8,898	2,775	6,490	1,709	5,976	2,828	5,819	6,973	4,388	7,082
	Subtotal	*17,498*	*8,275*	*14,390*	*9,697*	*16,216*	*10,933*	*17,936*	*19,669*	*12,997*	*20,240*
Benefits	Cherries sold	0	2,850	9,500	15,200	30,481	26,600	31,387	42,636	17,436	43,700
Balance		**-17,498**	**-5,425**	**-4,890**	**5,503**	**14,265**	**15,667**	**13,451**	**22,967**	**4,439**	**23,460**

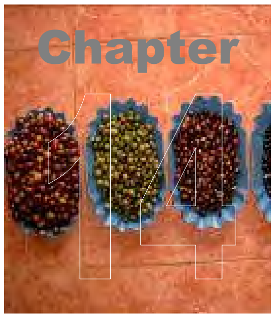
In this calculation the benefit over a period of 10 years amounts to 71,967,249VND/ha. However, this example does not take any capital costs into account, nor the purchase of land. When all capital for the establishment of the field has to be borrowed at 1%/month and the land purchased at 10,000,000VND/ha the outcome is different (Table 32).

Table 32: Cost benefit calculation when all investment capital has been borrowed at a rate of 12% per year.

		Year 1 (*1000 VND)	Year 2 (*1000 VND)	Year 3 (*1000 VND)	Year 4 (*1000 VND)	Year 5 (*1000 VND)	Year 6 (*1000 VND)	Year 7 (*1000 VND)	Year 8 (*1000 VND)	Year 9 (*1000 VND)	Year 10 (*1000 VND)
Costs	Land purchase	10,000	0	0	0	0	0	0	0	0	0
	Labour	8,600	5,500	7,900	7,988	10,240	8,105	12,117	12,696	8,608	13,158
	Materials	8,898	2,775	6,490	1,709	5,976	2,828	5,819	6,973	4,388	7,082
	Subtotal	27,498	8,275	14,390	9,697	16,216	10,933	17,936	19,669	12,997	20,240
Capital	Loan	27,498	37,423	52,957	58,645	66,117	53,530	50,633	43,915	18,365	22,593
	Interest	1,650	3,994	5,491	6,456	6,961	5,768	5,000	4,090	1,424	1,497
	Total cost	29,148	41,417	58,449	65,101	73,078	59,297	55,633	48,004	19,789	24,090
Income	Reimburse ment	0	2,850	9,500	15,200	30,481	26,600	31,387	42,636	17,436	43,700
	Remaining debt	29,148	38,567	48,949	49,901	42,597	32,697	24,246	5,369	2,354	0
Balance		-29,148	-35,717	-39,499	-34,701	-12,116	-6,097	7,141	37,267	15,082	0

In this scenario where all capital has been borrowed at 12% per year, the farmer gets an income only in year 7 when the balance becomes positive. For each year the farmer has to borrow additional costs to cover the year's operational expenses. Only the carry-over debt of the previous year is valued at 12%, the borrowing for the operational costs typically takes place halfway the year when the largest expenditures take place and is valued at 6%. In conclusion growing coffee when all capital has to be borrowed does not seem like a sound investment.

The total amount for establishment and maintenance during the first 6 months after establishment is 17,498,000 VND. To complete the analysis we should now look at the maintenance costs and expected benefits during the expected lifetime of the coffee tree.



Farmers' research

Although the implementation and analyses of research is typically a job for scientists, farmers can certainly contribute to the generation of knowledge on coffee. This chapter will detail how farmers can setup simple trails in their own fields to improve field management.

Rationale

During the first year Farmer Field School training is quite general. In the second and last year of the training knowledge and skills are deepened with more focus on analysis and problem solving approaches for coffee. An important matter in this respect is the ability of farmers to be able to implement, execute and analyse experiments on their farm. Although Vietnam has a good infrastructure of coffee related research, these institutions can not always match the local conditions of farmers in their field trials. Therefore, farmers who want to improve their management should be able to investigate alternative practices in their own fields.

What is science

To answer this question it is important to look at some aspects that scientists have in common, but that are not limited to scientists only. Primarily science is driven by curiosity to understand the world around us. Also, science is of an observing, hypothesizing and analysing nature. For this the scientist has several tools at his disposal, for example: research methods, statistical methods and computers to make calculations, etc.

Although the farmer often doesn't have these tools, they often do have the curiosity and drive to understand what is happening in the field.

Principles of farmers' research

To conduct a field test several steps are necessary (Figure 186).

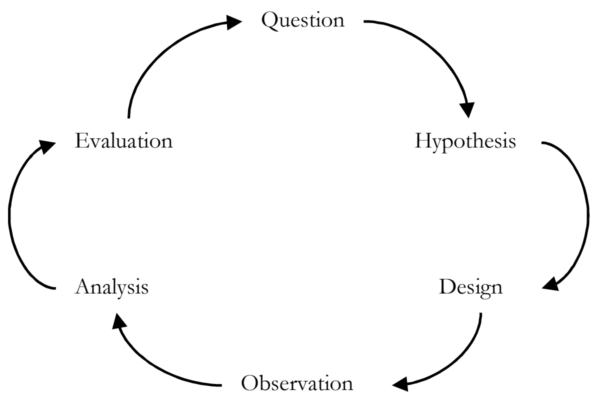


Figure 186: Learning cycle for on-farm research

The figure represents a learning cycle, adapted for field use. It shows 6 essential steps when doing a field research.

In more detail:

Question

As farmers, before we can be "scientists" we have to observe our fields and formulate questions about things we see but do not understand. To assist in formulating these questions after field observations we can use a "Topic selection matrix

Table 33: Research topic selection matrix

Problem	Current practice	Potential for improvement	constraint	Suggested topics
Leafs drop down after harvest	2 times fertilising per year	More times fertilising per year	Cost Extra labour Drought	Compare 2 and 3 times fertilising
Soil seems to become hard over time	Little or no compost or organic manure applications	Increased application of organic materials	Cost Extra labour Availability of organic material	Compare 100% chemically fertilised plot with organic and chemically fertilised plot
People have very different applications of P2O5	Some apply 300kg/ha/year, others only 50kg/ha/year	Optimising of P2O5 applications	None	Compare different amounts of P2O5 applied
Pruning takes a lot of labour, not all trees are pruned properly	Too little pruning	More pruning	Cost Extra labour	Compare present pruning frequency with increased frequency
Etc.				

The Topic selection matrix is meant for farmers who wish to conduct a field experiment, not a detailed study into specific issues such as development of taste profiles of shade-grown Arabica *Catimor*.

Hypothesis

After using the Topic selection matrix to identify a problem that requires further research, farmers have to work out a hypothesis. A hypothesis is the idea that you are going to test. For example, a scientist who will test the use of urea might have as a hypothesis: "The use of more urea leads to higher yields". This is a single hypothesis and does not take other connected issues into account. For example, application of more urea can lead to more weeding, additional labour for application, etc. Changing one aspect of your management might well have influence on several other aspects, either directly or indirectly.

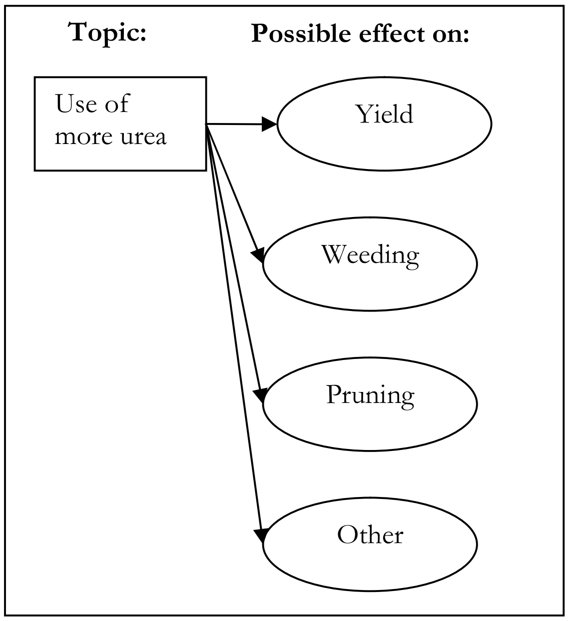


Figure 187: Influences of proposed change on other field issues

When making a hypothesis it is better also to think about other issues that can be affected by the proposed change (Figure 187).

Using more urea can also lead to more weed growth, resulting in higher labour requirements for weeding. Or it can lead to stronger growth of shoots, leading to more pruning labour.

To avoid the single hypothesis we can use the "Idea matrix" (Table 34). The "Idea matrix" is prepared after a topic for research has been identified and considers all the possible effects of the research. In the first column the farmers write down the possible influences of the research topic on other aspects. In the second column write down the source that mentioned the effect and in the third column write down the need to take this effect into account.

Table 34: Idea matrix on the use of more Urea

Idea	Source	What do WE think about each idea (should we test it?)
Increase of urea will lead to higher yields	Extension officer	Not convinced, needs to be tested locally
Weeds will increase when using more urea	Experience of one farmer	Needs to observed
Increased urea leads to more shoots and more pruning	Other farmers	Probably, need to observe
More labour and money is needed to apply more urea	Calculation of farmers	Needs to be tested
More urea will lead to pollution of water	Television	Maybe, but how to observe?

The idea matrix shows us that several other factors can be influenced by the application of more urea. Some of these factors we can easily observe or test in the field, whereas others are outside our skills.

As such the idea matrix serves as a central part of the research, showing us which ideas we have to take into account. After completion of the study each idea in the matrix is evaluated to see whether or not the idea was correct.

Design

The best design for a field experiment depends on the topic and the local conditions, hence no standard recipe for design can be given. Therefore, it is important to understand the principles of field design to allow for optimal design in a given condition.

Three principles are important when designing field experiments (Figure 188): natural variation, bias and simplicity. If you consider these principles you will be able to design better experiments.

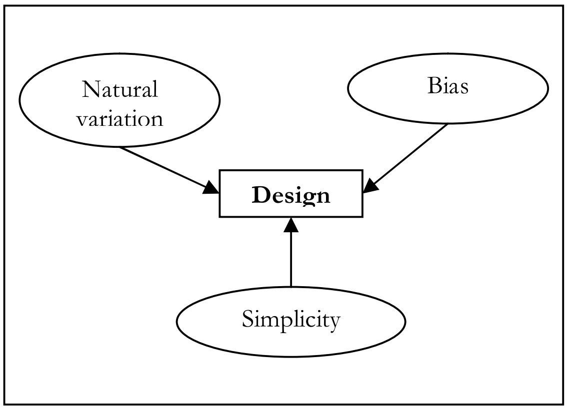


Figure 188: Research design considerations

Natural variation

Natural variation is the variation that you will find in any field and between different plants. These variations can be local differences in plant health, soil fertility, water table level, occurrence of shadow trees, etc.

A field experiment tries to compare different treatments under the same natural conditions. For example: more urea applied compared to the normal practice.

All these variations can influence the experiment. It is very important when selecting a plot to conduct the test to strive to keep the natural variation as small as possible.

To determine the amount of natural variation farmers can observe the field and draw simple maps of the variations (Figure 189)

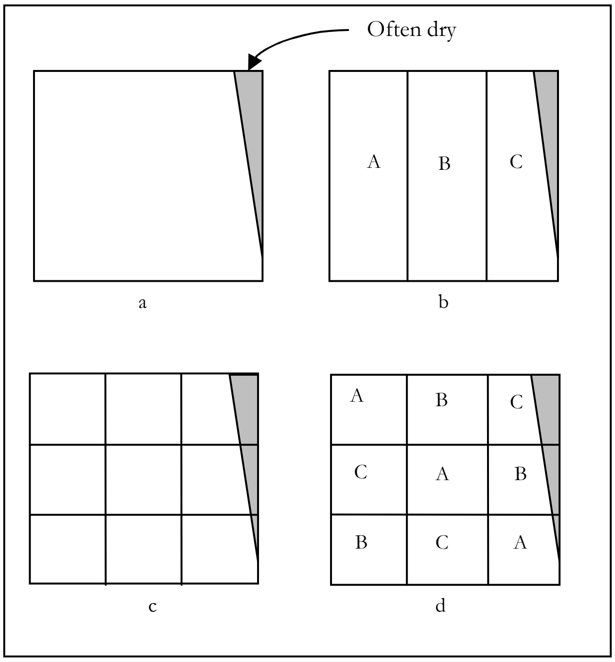


Figure 189: Plot design taking natural variation into account

1. When designing a field experiment it is of the foremost importance to select a field as uniform as possible to minimize variation.

2. Suppose we select field a, the whole field has a good moisture standard, except the grey area which is regularly too dry. This is one obvious source of variation, but there might be several others not so easily visible.

3. To design a field experiment on the use of urea we could divide the field in three plots like in figure b: plot A treatment with 100kg urea/ha; plot B treatment with 150kg urea/ha and plot C treatment with 200kg urea/ha. Would this give reliable test results?

4. The dry area will negatively influence our results, because the coffee trees will have more difficulty taking up the urea we apply in that area. It would be better if we replicated each treatment like in figure c.

Why is replication so important to achieve reliable test results?

Replications of treatments should be distributed evenly over the field (figure d). In that way the average of the results of each treatment will give a more reliable result. For small field experiments it is recommended that the treatments do not border each other.

Bias

A treatment plot that is bordered by a plot with another treatment may well receive influence from this other treatment (Figure 190). This is called bias.

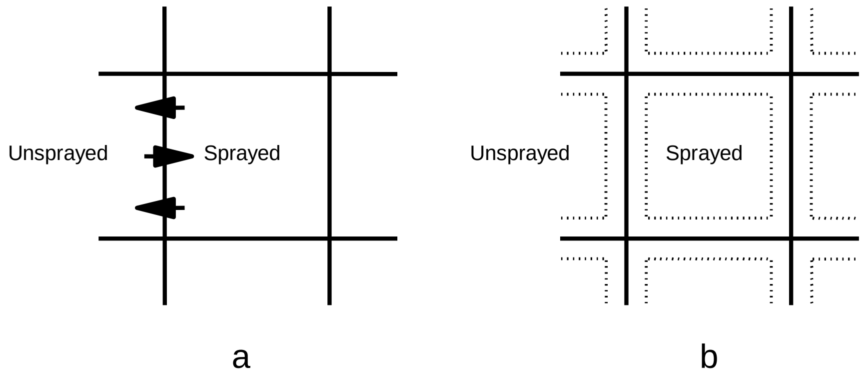


Figure 190: Biased pesticide application experiment

Bias occurs when one treatment is influencing a neighbouring treatment, causing a lower reliability of results.

Figure 190a shows a pesticide spraying experiment, in a setup where the treatments directly border each other and the unsprayed treatment can easily receive spray drift from the sprayed treatment.

?

Would you expect bias in an experiment on fertilisers, or plant spacing?

To overcome bias we can do several things: we could increase the plot size, such that with a similar bias the influence of it on the results would be lower. Large plot size is therefore more important in a spraying experiment than in a pruning experiment. We could also work with borders along the plots (Figure 190b). We would then only sample the inside area of each plot and not the border where the influence of bias would be greatest.

Simplicity

The design of any field experiment should be kept as simple as possible. The more factors are changed in an experiment the more difficult it becomes to contribute results to specific changes. For example if we change both urea and kali applications in a test and find differences in yield we will not know whether this is because of the change in urea application or kali.

The design of a simple test for urea would have to take several factors into account:

First, the experiment should only address one factor at a time, e.g. the influence of increased urea application.

Secondly, the number of treatments (that is different applications of urea in the experiment) should be limited. Only 2 to 4 different treatments should be considered at a time with one control treatment. The control treatment could be the present practice, thus allowing to check whether the alternatives are better or worse. Any more treatments will make the analysis of the results unnecessarily complicated.

Thirdly, the number of replications is important to achieve reliable results because it will decrease the influence of natural variation. A so-called 3 by 3 experiment, with 3 treatments and 3 replications is a good compromise between reliability, ease of observation and variation.

Observation

What should be observed? How should observations be made? When should observations be made? These considerations require careful planning by farmers.

To determine **what** should be observed (what kind of observations should be made) we can use the Idea Matrix in which we already identified the different components of the field that need to be considered in our study. If we expect that increased urea will have effect on any other issue (weeds, pruning, etc.) these components should be observed.

How to make observations depends on what is practical and what is accurate. Growth of new shoots as a result from different urea applications, for example requires observations of individual trees, while yield measurements are best taken by weighing the harvest of a treatment. In cases where not all possible observations can be done (such counting all leaves on all trees), a sampling schedule has to be made. For example, to indicate which trees will be sampled and on each tree, which branches. This has to be determined beforehand, because human beings generally have a preference for sampling the situations that are most similar to what we want to get out of an experiment.

Whatever we observe, our samples should give us a reasonably accurate estimate from each replicated plot, realising that there is variation between plants, and between the different parts of each plot. A representative sample consists of a number of observations; and this number depends on the type of observation. In case of individual plant observations (with clear variations between plants) a sample must consist of at least 10 plants per treatment in order to be representative. But for large yield measurements (e.g. 5 x 5 m), it is best to weigh the entire crop from each plot.

When to make observations depends on the type of observations. Yield measurements are taken at crop maturity or at harvest, while observations on weeds may be most important during the early crop stages. Observations on insects, diseases and plant development are ideally made weekly during the entire season because their incidence and condition change.

These three aspects –what, how and when to observe– can be planned using an Observation Matrix that is based on the Idea Matrix (Table 35).

Table 35: Observation matrix

What should we observe?	**How** should we observe?	**When** should we observe?
Yield	Harvest treatment plots separately	At harvest
Weeds	50 x 50 cm samples, and Fieldbook records	Weekly during first 5 weeks after application
Nr of new shoots	Observe 5 trees per treatment	Weekly
Labour for pruning	Record in Fieldbook	Weekly
Inputs	Calculate and record costs from Fieldbook	When inputs are made

Different types of observations produce a complexity of records. Separate records should be kept per treatment, and records of each sampling occasion should be summarised. At the end of the season, records could be summarised over all sampling occasions (to produce a seasonal *average* of, say, pruning labour; or the seasonal *maximum* of new shoots) to allow for easy comparison between treatments. The average is calculated by summing

For record keeping it is advised to keep a Fieldbook as discussed in the previous chapter, for each treatment.

Analysis

Replications are necessary to quantify natural variation. Each measurement from a replication of the same treatment will give different results because of variations in the field. However, the averages of the replications of 1 treatment can give a reliable result for this treatment.

Not only is the average important, it is also vital to understand the differences between measurement results of the same treatment. If measurements of 1 treatment are spread over a broad range these results are suspect because they indicate too large an influence of natural variation.

However, it is quite difficult to decide whether a number of measurements are too much spread out. Therefore the overlap test has been developed to compare variance between test results. Without an analysis of variances we might draw faulty conclusions. The overlap test allows for statistical analysis by farmers in a very much simplified manner.

The overlap test has 2 steps:

1. Is the difference between treatments large?
2. Is there any overlap between minimum-maximum ranges of treatments?

In step 1 the averages are calculated of each treatment (Table 36). We can then determine whether the differences between treatments are small or large.

Table 36: Yield analysis of urea experiment

	Yield kg/ha			
Treatment	**Replication 1**	**Replication 2**	**Replication 3**	**Average**
Urea: 100kg/ha	8,000	11,000	11,000	10,000
Urea: 150kg/ha	13,000	15,000	17,000	15,000
Urea: 200kg/ha	17,000	16,000	19,000	17,333

In step 2 we examine how variable or uniform the treatments are. For each treatment we determine the minimum and the maximum value of the measurements. If the minimum and maximum between different samples are close together the variance is limited. If the minimum and maximum are far apart they are likely to overlap with the results of another treatment. In that case we conclude that the results are not different, at least there is room to doubt that they are different.

Performing step 2 is easier when one draws the results. For this, draw a horizontal line with a scale covering the values of the yields of each treatment. Now determine where the minimum and maximum value for each treatment is located. Connect the points resembling the minimum and maximum of each treatment with each other. Determine whether the lines overlap.

At first glance it seems that applying 200kg/ha of urea gives better results than applying 150kg/ha. Still, we should check for overlap (Figure 191) and this gives us a different result.

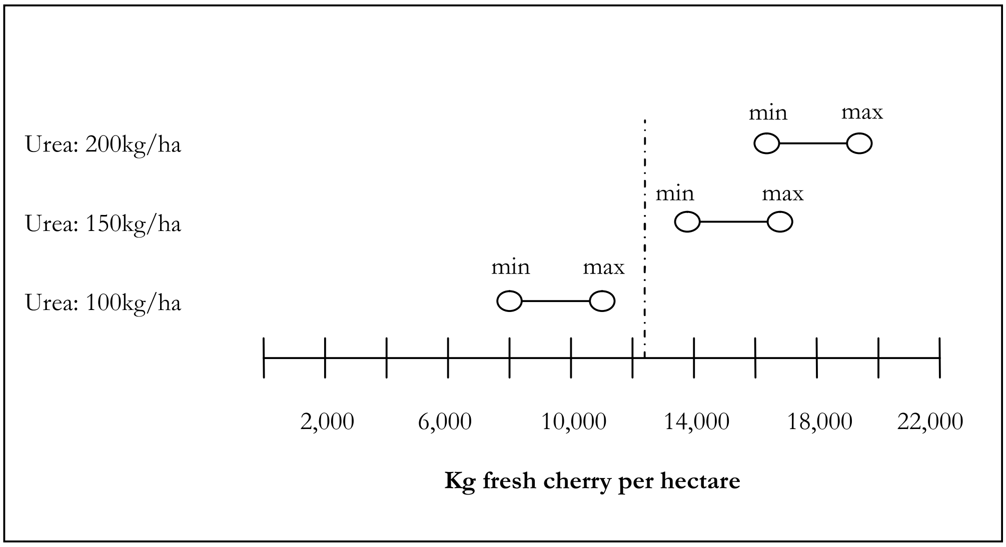


Figure 191: Overlap analysis of yield results

From

Figure 191 we can conclude that: 150 kg/ha of urea gives a higher yield than 100 kg/ha. However, there is no large enough difference between applying 150kg/ha and 200kg/ha, because the lines connecting the minimum and maximum of these two treatments overlap. So, even though the average yield in the application of 200kg/ha is higher than the 150kg/ha treatment the difference is not convincing and might be because of natural variation in the field.

Evaluation

Apart from the yield results the idea matrix contained several other issues that needed to be observed such as weed growth, pruning input and growth of new shoots. The averages or totals of these issues need to be summarised in an evaluation matrix (Table 37). This will help to clarify the impact of different urea applications beyond that of yield only.

Table 37: Evaluation matrix

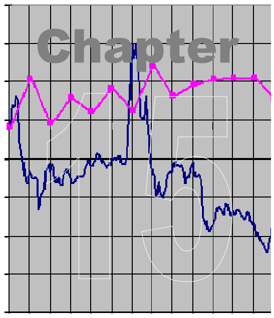
Ideas to be tested (at the start of the study)	Results: Treatment 1: 100 kg urea per ha	Results: Treatment 2: 150 kg urea per ha	Results: Treatment 3: 200 kg urea per ha	Conclusion
Increased use of urea will increase yield of coffee	10,000kg	15,000kg	17,333kg	Urea increased yield but no clear difference between 150 & 200 kg
Weeds increase with more urea	9 weeds per sample	10 weeds per sample	15 per sample	True, especially at the highest dosage
Growth of new shoots will increase with increased urea	6 new shoots per tree	8 new shoots per tree	11 new shoots per tree	Adding more urea increased nr of new shoots
With increased urea, more pruning labour will be required	Fieldbook records did not indicate a major difference, but next year should also be observed			Studies on pruning are required
More labour and money is required to apply the extra fertilizer	No extra inputs	Extra inputs 400,000VND/ha	Extra inputs 700,000VND/ha	Most extra inputs required at 200 kg urea

It is now up to the participants to explain the different results. Do bear in mind that the example showed us that applying 200kg/ha of urea did not show a convincingly different result in yield and therefore the extra costs and benefits from this treatment do not have to be calculated. Only the treatments of 100 and 150kg/ha showed difference.

Now that the experiment has been concluded two questions need to be asked:

1. What aspects remain unclear; and
2. what additional experiments do we need?

The answers on these two questions can lead to new experimentation.



Coffee world market

A regular statement by coffee farmers is that the price of coffee is too low. Although most farmers in Huong Hoa still make profits, less efficient farmers and those in marginal areas have a hard to time to break even on their production costs. This chapter explores the underlying mechanisms that determine global coffee prices.

Introduction

Although hard to influence from farm-level, the world market price for coffee is certainly influencing the lives of coffee farmers around the world. Despite its remote location Huong Hoa coffee farmers notice world market influence as well.

Coffee market

Coffee is produced in over 70 countries with Brazil, Vietnam, Columbia being the largest producers. Of all the coffee traded annually around 65% is Arabica, the rest is Robusta. Vietnam is the largest Robusta producer with a share of 25% of global production, while Brazil has a share of around 31% of total production. However only since 1999 did Vietnam gain such importance in the world market. Previously, Vietnam and the Asia-Pacific region had a much smaller share (Figure 192).

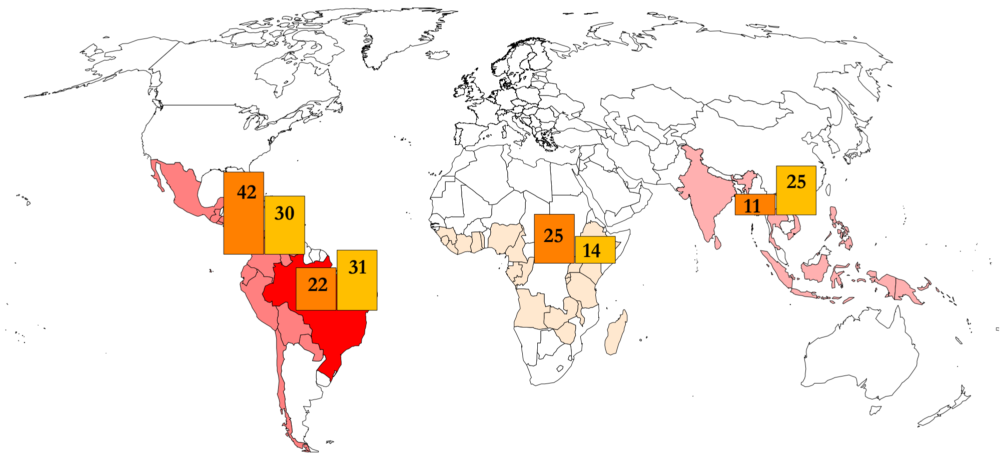


Figure 192: Production by region in percentage of global production, 1982 on the left and 2001 on the right (Data source: ICO)

Why did the share of the Asia-Pacific region increase so strong?

There is a clear regional distribution between Arabica and Robusta by region (Figure 193 & Figure 194).

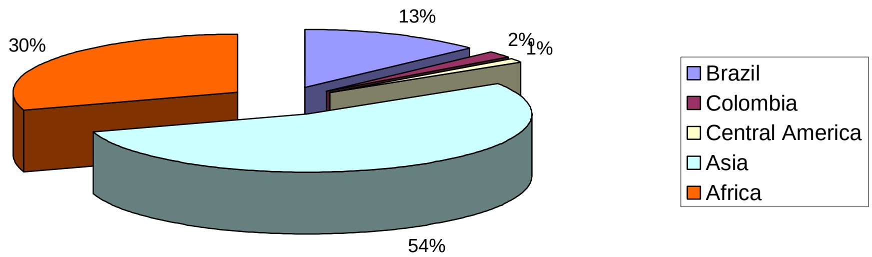


Figure 193: Production share by region for Robusta

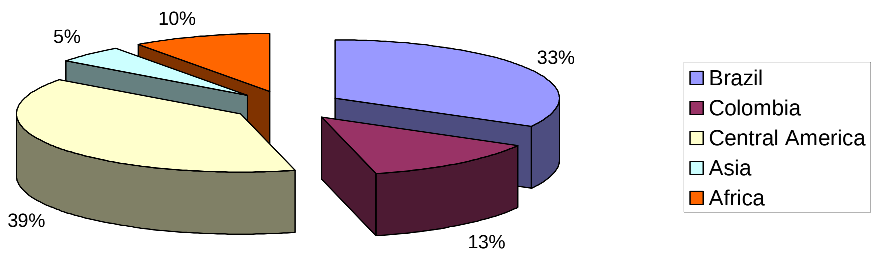


Figure 194: Production share by region for Arabica

Consumption

Coffee is consumed largely in the western world. Different countries have different tastes. In Europe, southern countries mostly drink Robusta, whereas the countries to the north use more Arabica. Between them, Europe and North America (including Canada) consume nearly 80% of the world's coffee (Figure 195)!

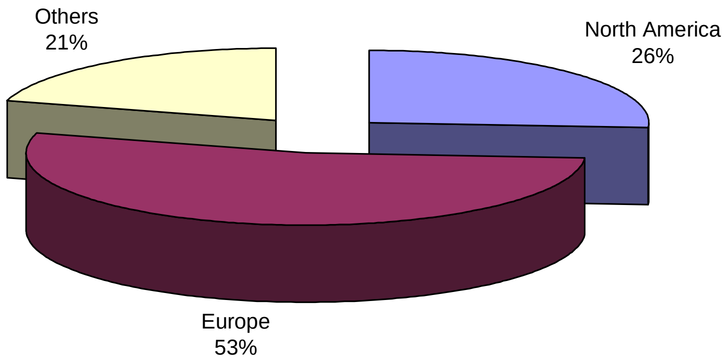


Figure 195: Coffee imports by region, 2004

As seen in Figure 193 and Figure 194 production of Arabica and Robusta is taking place in distinctly different regions. South and Central America are typical Arabica countries, although Brasil's Robusta production has been increasing lately. Whereas Africa and Asia are well-known for their Robustas. Consumption follows a similar pattern. In that specific countries have different perceptions of qualities and tastes (Figure 196).

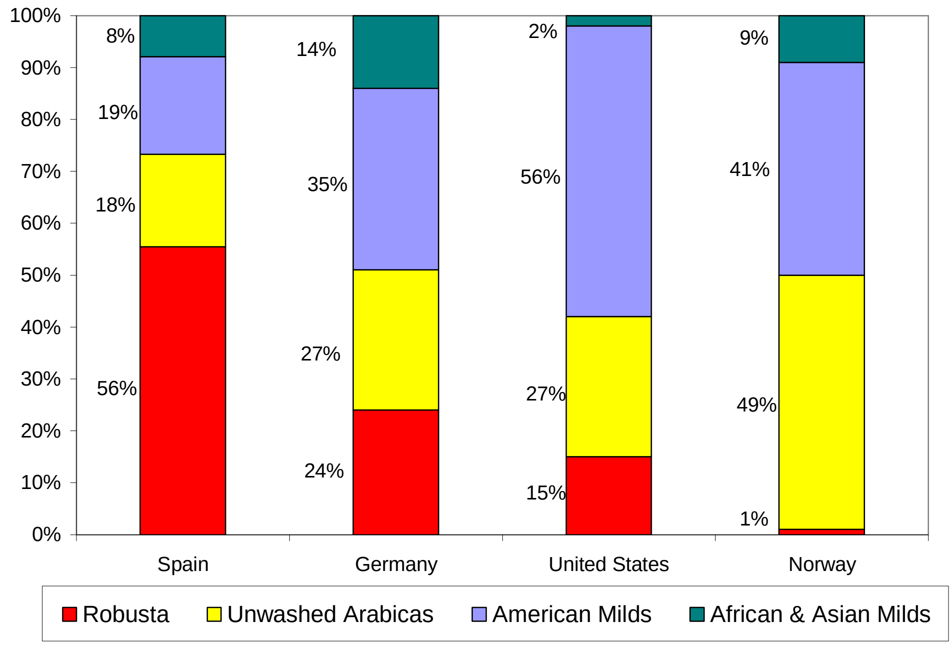


Figure 196: Imports of Spain, Germany, United States and Norway by coffee types. Red represemts Robusta, all other colors are different Arabica types (Source: Jan von Enden).

Coffee price

The price every coffee farmer receives is influenced by numerous factors. Three important factors are: the local buying price which is linked to the quality of the cherries, the amount of coffee available in the area and the demand for this coffee from local processing companies.

The demand from processing companies is in return influenced by the demand from exporting companies and traders.

The demand from exporters and traders is influenced by the demand of the world market, i.e. importing countries, and the availability of coffee worldwide to satisfy this demand and exporting and importing countries' policies.

In general the three most important factors influencing world wide availability of coffee, and therefore its' price, are:

1. The production levels of Brasil and Vietnam, the largest producers in the world;

2. Political agreements on limiting or stimulating production in, or between key producing countries such as Brasil, Columbia and Vietnam; and

3. Agreements such as ICA (International Coffee Agreements) which aim to limit production

The following graphic shows the linkage between significant events in the last 23 years of coffee trading, coffee production and coffee prices.

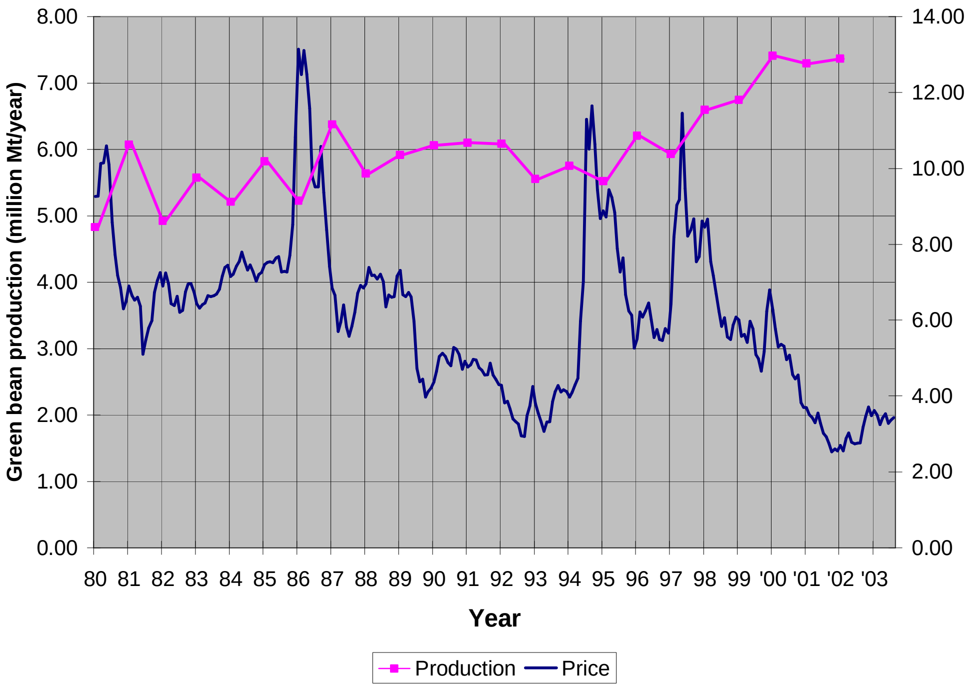


Figure 197: Price and production levels for Arabica from 1980 to 2003. Price levels are calculated in VND per kg fresh cherry with a conversion factor of 6.5 from fresh cherry to green bean where 1USD = 15,700VND. (Data source: ICO)

The heavy price fluctuations are closely linked to production and global events:

1978-1981 During this period the *Bogota group* was active on the futures markets of London and New York. Brasil and Columbia subscribed to organisation, which aimed to stabilise coffee prices by buying excess stock on aforementioned markets. Eventually, a huge production surplus evolved (at this time there were no international quota in force) and the *Bogota group* could no longer support prices in this way. The accumulated stocks were released on the market and the price crashed.

1980-1981 Consuming nations reacted and an international agreement (ICA, International Coffee Agreement) was put together in 1981, in which the producing countries were expected to regulate their production and consuming countries paid a higher price for coffee.

1985-1998 In 1985 there was a drought in Brasil and prices soared. In the late 1980's the ICO agreement was suspended because it caused overproduction by paying too high prices to producers. By 1991, prices had declined significantly, because of producers' stock being released on the market. Big harvests at the origins added to the pressure. In 1994 the prices rose again due to two big frosts in Brasil. In 1997, the effects of El Nino send prices up again.

From 1997 onwards a steady production increase and use of new processing techniques has had a tremendous influence in the price. Three trends were responsible for this:

- In Brasil the coffee tree population increased by 37% over a five-years period from 1993/'94 onwards.
- Vietnam's production increased 800% in the decade from 1989 to 1999.
- Central America increased production with 10% from 1997 to 1999/'00
- International roasters have been able to use more and cheaper Robusta in their blended coffees (see also chapter After export) due to new steaming techniques that remove part of the harsh flavour of Robustas.

National level price influences

The price at national level is naturally heavily determined by global developments, e.g. the harvest of Brasil. However, local events are also important.

Generally, the coffee trade in Vietnam seems unbalanced with high shares of the export values going to farmers (on average the farmagte price for coffee in Vietnam was 96% of the export value in 2003 [8]!). Reasons are numerous, the most important are:

1. Exporters in 2003 received 2% export subsidy on the value increase of exports compared to the previous year;
2. An abundance of local traders that take large risks by betting that prices will increase further after having bought coffee, especially during periods of high prices. This is illustrated by traders who in 2006 in Huong Hoa are buying cherries that have dropped during harvest and are picked up weeks or even months later and sold at relatively high prices.
3. For some traders/companies low profit margins on coffee are acceptable to earn foreign exchange. This foreign exchange is than used to import goods (for example motorbikes from Thailand) that can be sold at such profits that the losses or low margins on the coffee operations can be easily off-set.

Regional level

The local coffee price is determined by:

- The availability of coffee, i.e. the harvest level:

In a year with less coffee harvested for whatever reason such as coffee leaf rust outbreak, the local price is likely to increase as the three companies will be outbidding each other to get the largest possible share of the harvest. This in order to reach their "bonus" quota.

- Exporting and trading position of each of the three companies:

The trading position of each of the companies reflects the price they can afford to pay to farmers. When a company has good export contacts abroad, the price it receives for its' product can be higher than a company without these contacts.

Why is it interesting for farmers to sell to more than one exporter in the area?

- Price discussions between the three companies:

Of course, when the amount of coffee is limiting and companies start bidding against each other, as happened in Huong Hoa in 2002 and again in 2005 when the price paid to farmers was actually higher than the calculated world market price for cherries, the companies might strike an agreement to maintain a set price and refrain from increasing this.

Certificates

As seen in the previous chapter coffee prices are highly volatile and are next to impossible to influence from the field level. Farmers do have some price increasing options though. Quality and efficiency has been discussed already. Another option is certification of coffee, such as the Utz-Kapeh certificate. This chapter discusses such topics.

Development of coffee certificates

As early as the 1960's several organisations, including Oxfam, started to buy and sell coffee under terms with producers that would now be referred to as fair-trade. The fair-trade organisation is a common name for a group of organisations that share a common purpose. They buy products from producers in developing countries at guaranteed minimum prices. These prices are often much higher than real market prices. However, not everybody can deliver to a fair-trade organisation. Only those groups of producers that have a certificate are allowed to sell.

During the late 90's when coffee prices crashed (Figure 197) Non-Governmental-Organisations (NGOs) held many media campaigns to make coffee consumers aware of the difficult situation that many coffee farmers faced as a result of these low prices. In these campaigns the big roasting companies such as SaraLee-Douwe Egberts and Kraft were blamed for causing this difficult situation. The NGO's said that the big companies paid too low prices to coffee farmers. This resulted in a growing consumer demand for sustainable coffee, that is a coffee produced without social, environmental and economical problems as occurred, and continue to occur, during the coffee crisis. Needless to say coffee prices play a pivotal role in this, without a decent income said problems will not be solved.

From the example of fair-trade numerous other organisations emerged during this period with various objectives. Some organisations issue certificates that focus on environmental standards, others mainly address social issues and again others have a combination of these standards.

Major certificates

?

Using 5USct/lb as premium for Arabica, how much would this be in VND per kg fresh cherry?

Utz-Kapeh

Figure 198: Utz-Kapeh logo (Source: Utz-Kapeh)

Utz-Kapeh started in 1997 in Guatamala, Middle-America, as a collaboration between Guatemalan coffee farmers and Ahold, a Dutch coffee retailing company with its own coffee roaster. Utz-Kapeh has their own Code of Conduct describing the practices to which producers and buyers of Utz-Kapeh certified coffee should adhere. Improved coffee prices for producers are not fixed in Utz-Kapeh, but buyers and sellers who are both registered with the organisation agree to allow a so-called sustainability differential on top of the world market price. This means that the seller can request a negotiable premium on its' coffee when selling, this premium can be up to 7USct/lb green bean.

Bird-friendly

The Bird-friendly coffee certificate is issued to Latin-American farmers that grow organic coffee under shadow trees. The idea is that this production system conserves the environment and provides a good habitat for birds. Consumers of bird-friendly coffee, mainly in the USA, pay higher prices for this coffee.

Figure 199: Bird-friendly coffee logo (Source: BFC)

Fair Trade

Figure 200: Fairtrade logo (Source: FT)

Fair Trade Certification is an alternative approach to the coffee market that puts more of the profit in the hands of coffee farmers. Coffee companies that import and roast Fair Trade coffee guarantee farmers a minimum "floor price" of $1.26 per pound. This can be as much as a three- or even four-fold increase in what some farmers might otherwise receive for their crop.

Rainforest Alliance

The mission of the Rainforest Alliance is to protect ecosystems and the people and wildlife that depend on them by transforming land-use practices, business practices and consumer behavior. Through the certification program, the Rainforest Alliance seeks to reverse the intensive management systems required by industrial coffee hybrids and encourage the sustainable production and harvesting of beans.

Figure 201: Rainforest Alliance logo (Source: RA)

Industry's response

After much negative publicity from NGOs the industry had to react. Consumers started complaining on a large scale and complaints are bad for business. The industry responded in two ways:

1. Participation sustainability initiatives such as Common Code for the Coffee Community (hereafter referred to as 4C and Sustainable Agriculture Initiative (SAI)

2. Start up of coffee pilot projects in different coffee growing areas.

Figure 202: The Oxfam lady drinking her coffee (Source: Oxfam)

During this time the image of the roasting companies suffered and consumers became more and more critical of their behaviour. A famous picture that illustrates the feelings of consumers towards the roasting companies at that time came from Oxfam (Figure 202). The lady in the picture drinks coffee, but feels a bitter taste when she thinks about the heavy plight of producers

4C

4C is a multi-stakeholder approach towards improving sustainability of coffee. It was initiated by Deutsche Kaffee Verband (DKV) and GTZ (

Figure 203: Some roasting companies participating in 4C

Figure 204).

Figure 204: DKV logo

Multi-stakeholder means that numerous companies (Figure 203) and organisations are participating in the design and implementation of this code. Producing countries are represented by their coffee boards or associations (Figure 205). And also the NGOs who raised consumer awareness and forced the industry to act are participating (Figure 206). The initiative is expected to lead to a widely accepted understanding and acceptance of sustainable coffee.

Figure 205: Organisations of producing countries

Figure 206: NGOs

Furthermore, the initiative has some extraordinary members who are mainly there to contribute specific expertise. As a group they form the 4C. Most of the organisations present in 4C are also working in SAI.

Figure 207: 4C logo (Source 4c)

Figure 208: SAI logo (Source SAI)

Together these organisations try to determine what sustainable coffee is and what is not. This is important because as we saw before, the consumer is willing to pay a better price for a sustainable product.

Sustainability according to 4C & SAI

Although all coffee certificates talk about sustainability, interpretations of definitions and scopes differ greatly. On a farm level it makes sense to regard sustainability as: "the capacity of a coffee farming family to grow coffee without endangering future use of the garden and resulting in the financial profitability"

For this to become reality 4C aims to expand the definition of coffee quality to include sustainability of the production and processing method. Normally the price for a coffee is determined by amongst others the quality of the product in terms of taste and smell. With 4C coffee additional money should be paid to producers who adhere to the code and produce a sustainable product.

4C and SAI are very ambitious initiatives in that they aim at the mainstream coffee market. Mainstream roughly means all coffee that is presently not in any other certification scheme. This accounts for around 95% of all the coffee produced and involves 20-25 million (!) producers.

Future of 4C and SAI

At the time of writing 4C and SAI are still in the development phase. The initial designing of sustainability criteria (which say what is sustainable and not) are now being tested in the field in numerous pilot projects around the world (Figure 209 and Table 38). With the findings of the pilot projects the 4C Code will be fine-tuned and this should result in greater adaptability.

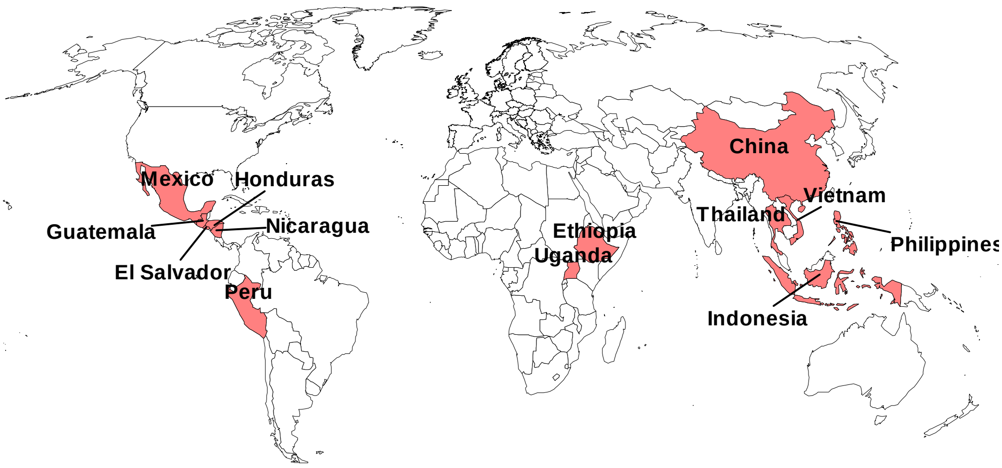
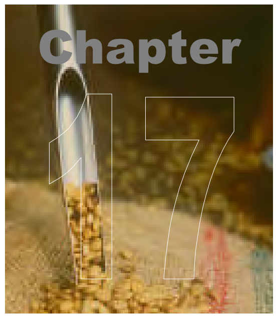


Figure 209: SAI Pilot projects worldwide

Table 38: SAI pilot project descriptions

Country/Region – Project name
China - Development of high quality Arabica green coffee in the Yunnan Province of China; Nestlé
El Salvador -Promotion of the sustainable production of Arabica green coffee in El Salvador; Neumann Kaffee Gruppe (NKG)
Ethiopia – Improving the sustainability of mainstream & forest Arabica green coffee production in the Oromia and Bonga region of Ethiopia; Kraft (soon to come)
Guatemala - twin projects: • Improving the social and environmental sustainability of already economically viable coffee production in 'Aldea Ojercaibal', Chimaltenango, Guatemala; Nestlé and VOLCAFE • Improving the economical, social and environmental sustainability of the coffee farmers from

Country/Region – Project name
Cooperativa 'Nuestro Futuro' in Huehuetenanago, Guatemala; Nestlé and VOLCAFE
Honduras - Improving the sustainability of Arabica green coffee production in San Juan, Honduras; Tchibo
Indonesia – Support to local production of quality Robusta green coffee in Indonesia; Nestlé
Latin America – Certification under Rainforest Alliance scheme and promotion of sustainable mainstream Arabica green coffee in Latin America; Kraft (soon to come)
Mexico - Support to Robusta green coffee farmers located in the Tezonapa region of Mexico; Nestlé
Nicaragua - Supply-chain collaboration for the implementation of SAI Platform principles and guidelines in the Bosawas Biosphere Reserve, Nicaragua; Nestlé and ECOM
Peru – Improvement of the sustainability of Arabica green coffee cultivation and processing in Ubiriki Valley, Peru; Sara Lee DE
Philippines - Development of high quality and high-yielding Robusta green coffee in the Philippines; Nestlé
Thailand - Development of high quality Robusta green coffee in the south of Thailand; Nestlé
Uganda - Increasing the income-generating capacity of shade-grown Robusta green coffee farmers in Luwero, Uganda; Sara Lee DE (soon to come)
Vietnam – Promotion of sustainable robusta production in Dak Lak; Nestle
Vietnam - Improvement of the sustainability of Arabica coffee cultivation and processing in Huong Hoa, Vietnam; Sara Lee DE and Kraft



After export

After all the effort that the farmer has invested the coffee bean still has a long way to go before it is being consumed. This chapter will highlight a typical roasting operations from the moment of export in the country of origin.

Nearly all coffee produced in Quang Tri, and Vietnam for that matter, is being exported. Most of the Vietnamese coffee goes to Europe and the United States. Germany is typically the largest buyer. Over the last 4 years Vietnam produced an average of 13 million bags of green coffee, with each bag weighing 60kg. Figure 210 shows to which countries this coffee was exported in 2002. The largest buyers were Germany, the USA, Spain and Italy.

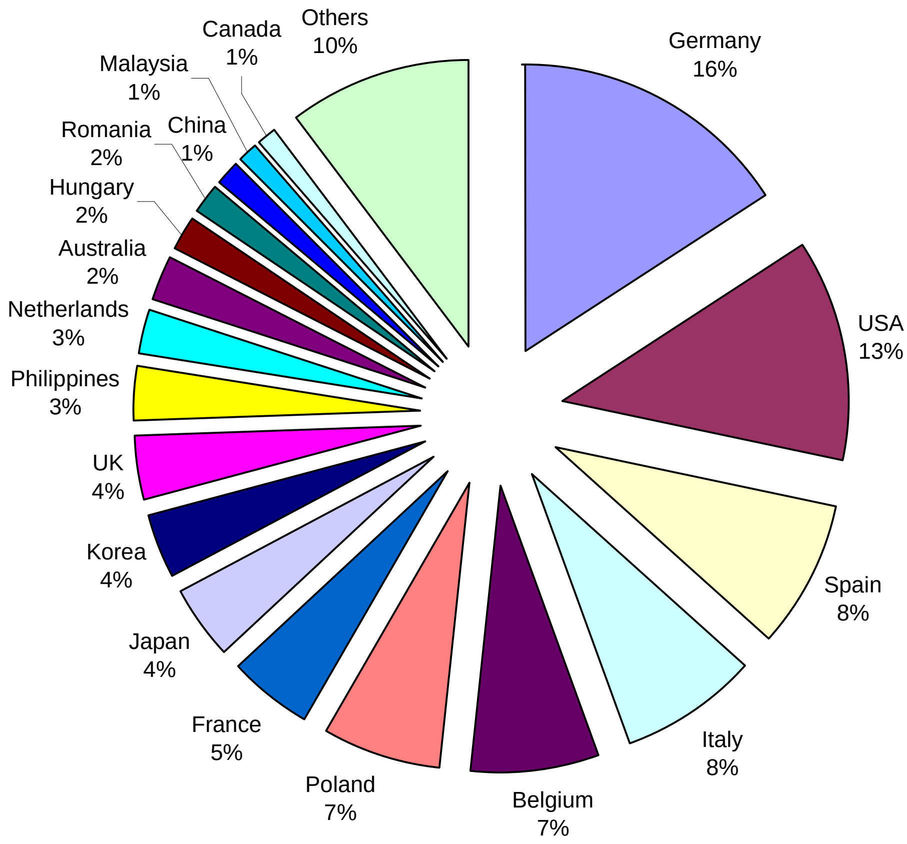


Figure 210: Vietnam exports 2002 by country

In companies like TaLaCo, which processes and exports, the standard procedure is that during the harvest the company contacts potential buyers, mainly in Europe. When TaLaCo contacts potential buyers they have a fairly good idea of how much green bean of what quality they will have at the end of the harvest.

If the buyer is interested negotiations over the price can start. The price is determined by the quantity and quality of the coffee, the present world market price and the relative demand for the type of coffee being offered. Because prices on the world market changes every day, the date at which the price for a particular shipment of coffee is set is quite important. Of course the exporter would like to set the price on a day when the world market price is high and the importer would like to set the price on a day when the price is low. Because nobody can exactly predict how the price will develop, this is always a bit a betting game.

When the price is set, an export contract is signed by both parties. The export contract details:

1. the amount of coffee being sold;

2. the grade of the coffee (the grade is an indication of the quality and lists a.o. the amount of defects allowed);

3. the maximum amount of foreign matter allowed (that means leaves, sticks and stones, usually 2-3%);

4. the maximum moisture content of the coffee, usually 11-12%; and

5. the expected date of shipment.

Although the coffee has been sold now, it is still in the country of origin and the buyer has never actually seen the coffee! Two ways are available to the buyer to prevent discrepancies between the quality of the shipped coffee and the quality described in the export contract:

1. the buyer can request an independent assessment of the quality by a specially certified organization. In Vietnam this is usually done by Cafecontrol from Ho Chi Minh City (they actually check 80% of all Vietnamese coffee every year!); and

2. the export contract has a clause that the buyer is allowed to refuse the coffee if the quality is different from what has been specified in the export contract. The coffee is then sent back to the country of origin and the exporter has to pay for the additional costs. This however, is a final measure that is hardly ever used.

Figure 211: Loading of containers

When the exporter has organized the local papers (e.g. taxes, customs declaration, etc) the coffee can be transport from the processing plant or warehouse to the port. Exporters from Quang Tri usually use the port of Da Nang. Here the coffee is loaded on a container ship to start its journey to the country of the buyer (Figure 211).

In the destination country, the coffee is transported by rail or road to the coffee roasting factory.

Figure 212: Train loaded with containers

At the harbor in the country of arrival the containers with coffee are unloaded. Transport from the harbor to the roasting plant can be either by train or by truck (Figure 212).

Whenever possible the roasters prefer transport by train.

Quality control

Upon arrival a quality check will be done. This check typically includes cupping. With cupping the taste and smell characteristics of the shipment are determined.

The cupping is a very important step. Apart from checking the quality of the shipment the cupping results are also used to decide how the coffee can be used (Figure 213).

Every roaster has a limited number of packaged coffee products (Figure 214). Usually, the coffee in these packages is a mix from several different origins.

Figure 213: Cupping

Figure 214: Some of SLDE's products

Consumers who buy these products naturally expect the coffee of a certain roaster to taste the same every time they drink it. However, suppose that we will have a very dry year in Huong Phung. The coffee will taste differently from Huong Phung coffee that was grown in a very wet year! Quality checking by cupping therefore does not only try to identify whether the quality meets the expectations based on previously sent samples, but also determines how much of which coffee can be used to create a certain blend.

Roasting

After cupping of a received shipment, and determining how the coffee can be used and in which blend, the coffee is stored in massive silos. Completely computerized systems then allow the operator to release a certain percentage of a certain coffee into a roasting machine. All these batches together make up the blend of a certain coffee product as we saw in the previous section.

Figure 215: Arrival of green coffee in the factory

Figure 216: Control of the roasting and blending process is computerized

Figure 217: Roasted coffee

Figure 218: Checking the darkness of the roast; remember, consumers want a stable taste and quality!

Figure 219: Packaging of roasted beans

Figure 220: Storage of packaged coffee

Figure 221: Coffee shop (Source: SLDE)

Quality perceptions of different countries

Of course taste patterns of people in countries are different. A good quality coffee for a Vietnamese consumer, with a nice buttery and slightly salty taste is a quality nightmare for say the Spanish consumer. Again, the taste of the Spanish, who like to drink Robusta coffee, is entirely different from what constitutes good quality in Northern Europe. Different quality perceptions are reflected by the types of coffee imported by countries (Figure 222) and the way different countries roast their coffee (Figure 223).

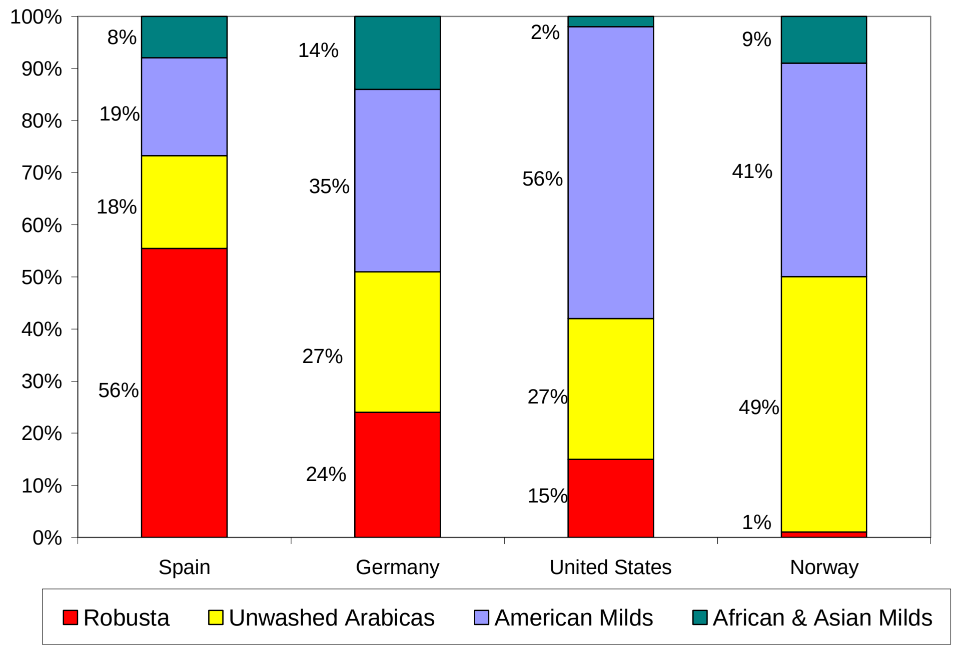


Figure 222: Coffee imports of Robusta and Arabicas by main consuming countries 2001

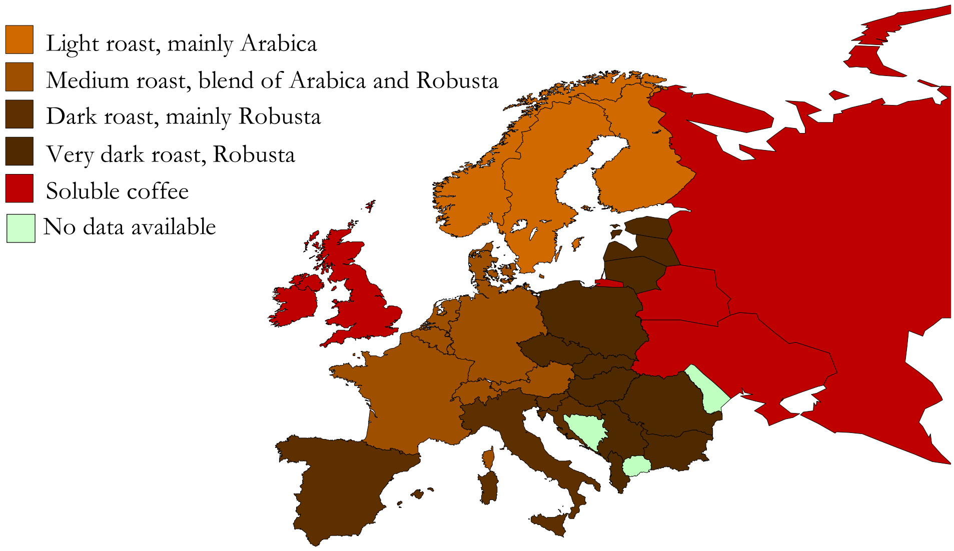


Figure 223: Roasting styles of European countries

Consumption

Traditionally, coffee is mostly consumed in the western world. These countries still account for the largest share of coffee imports. Growth of coffee consumption is fairly limited with at a rate of 1- 2% annually. Globally, most people drink roast and ground coffee. Around 23% of global consumption is soluble coffee, but in Vietnam, soluble coffee (like the Vincafe 3 in 1) accounts for 90% of the market (Jan von Enden, personal communication).

Over one and a half billion cups are drunk every day! Coffee comes in a wide variety of tastes (as we saw earlier) and methods of preparation (Table 39).

Table 39: Different styles of coffee preparation

Brazil	Vietnam	Northern Europe
		
Figure 224: Coffee filtering device from Brazil	Figure 225: Coffee filtering device from Vietnam	Figure 226: European style, the Senseo
Brazilian style coffee is prepared by heating water with added sugar over a medium fire. Just before boiling the fire is stopped and ground coffee stirred in. The coffee is now poured over a paper or cloth filter positioned on top of the contraption in Figure 224 with the coffee pot positioned underneath	For Vietnamese coffee, add around 20g of darkly roasted Robusta in the filtering cup and compress the coffee. Position the filering device over your cup and fill up the filter with hot water. Cover the filtering device and wait for the water to percolate. This coffee is typically consumed with condensed milk	In Europe many people are using the Senseo machine or Nespresso. Both Senseo, make one cup of coffee at a time and aim to deliver the taste you'll commonly find in restaurants and bars in Europe. The speed and convenience of both systems, cleaning is not necessary, contributed to the success.
Turkey		
		
Figure 227: Turkish coffee, step 1 adding sugar and water	Figure 228:Turkish coffee, step2, add ground coffee	Figure 229, step 3 heating the brew

Turkish coffee is very sweet. The logical fisrt step is to add two teaspoons of sugar. Now the *ibrik* is filled with water up to the start of the neck.

Add two large teaspoons of coffee, making sure not to stir the brew, the coffee should float on the water. Now the coffee is heated over fire, ina very slow manner, making sure it doesn't boil.

The coffee will start to foam, continue heating until the foam nearly overflows the *ibrik*. Stir it, the foam will disappear and repeat the heating and stirring 2 more times. Empty the *ibrik* in your cup and drink!

Coffee as an art

Figure 230: Barista at work! (Source: www.latteart.org)

Figure 231: idem

Figure 232: idem

The amount of satisfaction many people derive from their coffee has turned the brewing and decorating of coffee into an art in its own right. People who practice this art are called Barista (which means bartender in Italian). They typically take great pride in nice decorations (Figure 230, Figure 231 & Figure 232).

Annually, there are even Barista world championships!

ANNEX I ASSUMPTIONS ON FERTILISER APPLICATION FOR SUSTENANCE

Equation for calculating nutrients needed for sustenance fetilisation

Nutapplied = (NutCherries + NutSustenance – NutRecycled*EffNutRecycled - NutShadow) / EffApplication

Assumptions:

1. NutCherries: as described

2. NutSustenance : one can assume that in mature crops there is a linear relation between NutCherries and NutSustenance (for leaves and wood), therefore NutSustenance = alpha*NutCherries; assumptions: alpha = 0.5

3. NutRecycled: in mature crops and proper pruning, a large part of the existing vegetative material will be returned (because of pruning and leaf-fall); assuming a steady state in mature crops (i.e. no real growth of vegetative biomass), this means that NutRecycled = NutSustenance.

4. EffNutRecycled: The efficiency of recycling, i.e. the fraction of a recycled nutrient that becomes available for uptake by the crop, will depend on the nutrient. In the absence of erosion, for P it may be assumed that fraction recycling is near 100% (because of very limited leaching, and no transformation into gaseous forms) but for N it will be lower (leaching + gaseous), and for K it will be in between (only leaching). Assumptions: EffNRecycled = 0.8-0.9; EffPRecycled = 1 and EffKRecycled = 0.9

5. NutShadow: the effective (net) contribution of shadow trees, i.e. what they returned to the field minus the nutrients they took up; this implies that it is almost zero (or slightly negative) for P and K and potentially positive for N (in the case of shadow trees; let's assume 25 kg N per ha per year).

6. EffApplication: this is not the 'standard' agronomic efficiency, but the efficiency of incorporating the nutrient in the system; for P this could be near 1, for N it will depend on the number of applications (between 0.7-0.9 since coffee is a perennial crop with a better developed root system than annual crops that may have between 0.5-0.7efficiency for N) and for K it will be about 0.8-0.9

This leads to the resulting equation of

Nutapplied = (NutCherries * (1+alpha*(1-EffNutRecycled))-NutShadow) / EffApplication

Filling in the assumptions (in the absence of shadow trees):

NApplied = NCherries *(1+0.5*(1-0.87))/0.8 = 1.1/0.8 = 1.375 * NCherries

PApplied = PCherries * (1+0.5*(1-1))/1 = 1* PCherries

KApplied = KCherries * (1+0.5*(1-0.9))/0.85 = 1.235*KCherries

Year 2

Data in this table is based on farmers' and local coffee experts' estimates

Labour	**Unit**	**Amount**	**Cost/unit (VND)**	**Subtotal (VND)**	**Yield**	**Unit**	**Amount**	**Price/unit (VND)**	**Subtotal**	
Weeding	Days	150	20,000	3,000,000	Coffee cherry	kg	1,500	1,900	2,850,000	
Pruning	Days	20	20,000	400,000						
Pest and disease	Days	5	20,000	100,000						
Fertilising	Days	30	20,000	600,000						
Other	Days	20	20,000	400,000						
Harvesting	Days	50	20,000	1,000,000						
Subtotal				*5,500,000*						
Materials										
N (Urea)	Kg	240	5,000	1,200,000						
P (P2O5)	Kg	429	1,400	600,000						
K (K2O)	Kg	230	3,800	875,000						
Lime										
Manure										
Pesticides	estimate			100,000						
Subtotal				*2,775,000*						
Total				**8,275,000**					**2,850,000**	
Balance										**-5,425,000**

Year 3

Data in this table is based on farmers and local coffee experts' estimates

Labour	Unit	Amount	Cost/unit (VND)	Subtotal (VND)	Yield	Unit	Amount	Price/unit (VND)	Subtotal	
Weeding	Days	150	20,000	3,000,000	Coffee cherry	kg	5,000	1,900	9,500,000	
Pruning	Days	50	20,000	1,000,000						
Pest and disease	Days	5	20,000	100,000						
Fertilising	Days	40	20,000	800,000						
Others	Days	20	20,000	400,000						
Harvesting	Days	130	20,000	2,600,000						
Subtotal				*7,900,000*						
Materials										
N (Urea)	Kg	360	5,000	1,800,000						
P (P2O5)	Kg	600	1,400	840,000						
K (K2O)	Kg	329	3,800	1,250,000						
Lime	Kg									
Manure	Kg	25,000	100	2,500,000						
Pesticides				100,000						
Subtotal				*6,490,000*						
Total				**14,390,00**					**9,500,000**	
Balance										**-4,890,000**

Year 4

Data in this table is based on Fieldbook results from fields of a similar age. Fertiliser applications have been adjusted to recommendations from this manual.

Labour	**Unit**	**Amount**	**Cost/unit (VND)**	**Subtotal (VND)**	**Yield**	**Unit**	**Amount**	**Price/unit (VND)**	**Subtotal**	
Weeding	Days	128	20,000	2,551,364	Coffee cherry	kg	8,000	1,900	15,200,000	
Pruning	Days	53	20,000	1,060,163						
Pest and disease	Days	8	20,000	162,183						
Fertilising	Days	30	20,000	600,000						
Others	Days	20	20,000	400,000						
Harvesting	Days	161	20,000	3,213,917						
Subtotal		*399*		*7,987,627*						
Materials										
N (Urea)	Kg	174	5,000	869,565						
P (P2O5)	Kg	43	1,400	60,412						
K (K2O)	Kg	166	3,800	628,966						
Lime	Kg									
Manure	Kg									
Pesticides				150,000						
Subtotal				*1,708,943*						
Total				**9,696,56**					**15,200,000**	
Balance										**5,503,431**

Year 5

Data in this table is based on Fieldbook results from fields of a similar age. Fertiliser applications have been adjusted to recommendations from this manual.

Labour	**Unit**	**Amount**	**Cost/unit (VND)**	**Subtotal (VND)**	**Yield**	**Unit**	**Amount**	**Price/unit (VND)**	**Subtotal**	
Weeding	Days	89	20,000	1,770,095	Coffee cherry	kg	16,043	1,900	30,481,203	
Pruning	Days	28	20,000	562,624						
Pest and disease	Days	3	20,000	63,533						
Fertilising	Days	39	20,000	780,000						
Others	Days	20	20,000	400,000						
Harvesting	Days	333	20,000	6,663,461						
Subtotal		*512*		*10,239,71*						
Materials										
N (Urea)	Kg	349	5,000	1,743,776						
P (P2O5)	Kg	87	1,400	121,147						
K (K2O)	Kg	332	3,800	1,261,291						
Lime	Kg	5,000	50	250,000						
Manure	Kg	25,000	100	2,500,000						
Pesticides				100,000						
Subtotal				*5,976,214*						
Total				**16,215,92**					**30,481,203**	
Balance										**14,265,276**

Year 6

Data in this table is based on Fieldbook results from fields of a similar age. Fertiliser applications have been adjusted to recommendations from this manual.

Labour	**Unit**	**Amount**	**Cost/unit (VND)**	**Subtotal (VND)**	**Yield**	**Unit**	**Amount**	**Price/unit (VND)**	**Subtotal**	
Weeding	Days	78	20,000	1,554,555	Coffee cherry	kg	14,000	1,900	26,600,000	
Pruning	Days	64	20,000	1,272,727						
Pest and disease	Days	3	20,000	68,829						
Fertilising	Days	27	20,000	548,527						
Others	Days	20	20,000	400,000						
Harvesting	Days	213	20,000	4,260,198						
Subtotal		*405*		*8,104,836*						
Materials										
N (Urea)	Kg	304	5,000	1,521,739						
P (P2O5)	Kg	76	1,400	105,721						
K (K2O)	Kg	290	3,800	1,100,690						
Lime	Kg									
Manure	Kg									
Pesticides				100,000						
Subtotal				*2,828,150*						
Total				**10,932,986**					**26,600,000**	
Balance										**15,667,014**

Year 7

Data in this table is based on Fieldbook results from fields of a similar age. Fertiliser applications have been adjusted to recommendations from this manual.

Labour	**Unit**	**Amount**	**Cost/unit (VND)**	**Subtotal (VND)**	**Yield**	**Unit**	**Amount**	**Price/unit (VND)**	**Subtotal**	
Weeding	Days	72	20,000	1,447,732	Coffee cherry	kg	16,520	1,900	31,387,240	
Pruning	Days	140	20,000	2,796,499						
Pest and disease	Days	4	20,000	77,848						
Fertilising	Days	47	20,000	948,055						
Others	Days	20	20,000	400,000						
Harvesting	Days	322	20,000	6,446,730						
Subtotal		*606*		*12,116,865*						
Materials										
N (Urea)	Kg	359	5,000	1,795,609						
P (P2O5)	Kg	89	1,400	124,748						
K (K2O)	Kg	342	3,800	1,298,782						
Lime	Kg									
Manure	Kg	25,000	100	2,500,000						
Pesticides				100,000						
Subtotal				*5,819,139*						
Total				**17,936,004**					**31,387,240**	
Balance										**13,451,236**

Year 8

Data in this table is based on Fieldbook results from fields of a similar age. Fertiliser applications have been adjusted to recommendations from this manual.

Labour	**Unit**	**Amount**	**Cost/unit (VND)**	**Subtotal (VND)**	**Yield**	**Unit**	**Amount**	**Price/unit (VND)**	**Subtotal**	
Weeding	Days	44	20,000	880,801	Coffee cherry	kg	22,440	1,900	42,635,723	
Pruning	Days	91	20,000	1,827,123						
Pest and disease	Days	7	20,000	146,103						
Fertilising	Days	26	20,000	517,557						
Others	Days	20	20,000	400,000						
Harvesting	Days	446	20,000	8,924,792						
Subtotal		*635*		*12,696,375*						
Materials										
N (Urea)	Kg	488	5,000	2,439,115						
P (P2O5)	Kg	121	1,400	169,455						
K (K2O)	Kg	464	3,800	1,764,237						
Lime	Kg									
Manure	Kg	25,000	100	2,500,000						
Pesticides				100,000						
Subtotal				*6,972,806*						
Total				**19,669,181**					**42,635,723**	
Balance										**22,966,541**

Year 9

Data in this table is based on Fieldbook results from fields of a similar age. Fertiliser applications have been adjusted to recommendations from this manual.

Labour	Unit	Amount	Cost/unit (VND)	Subtotal (VND)	Yield	Unit	Amount	Price/unit (VND)	Subtotal	
Weeding	Days	51	20,000	1,018,136	Coffee cherry	kg	9,177	1,900	17,435,797	
Pruning	Days	116	20,000	2,325,362						
Pest and disease	Days	2	20,000	31,213						
Fertilising	Days	19	20,000	382,838						
Others	Days	20	20,000	400,000						
Harvesting	Days	223	20,000	4,450,736						
Subtotal		*430*		*8,608,285*						
Materials										
N (Urea)	Kg	199	5,000	997,471						
P (P2O5)	Kg	49	1,400	69,298						
K (K2O)	Kg	190	3,800	721,481						
Lime	Kg									
Manure	Kg	25,000	100	2,500,000						
Pesticides				100,000						
Subtotal				*4,388,251*						
Total				**12,996,536**					**17,435,797**	
Balance										**4,439,261**

Year 10

Data in this table is based on field observations in Huong Hoa and extrapolation of past Fieldbook results. Fertiliser applications have been adjusted to recommendations from this manual.

Labour	Unit	Amount	Cost/unit (VND)	Subtotal (VND)	Yield	Unit	Amount	Price/unit (VND)	Subtotal	
Weeding	Days	78	20,000	1,554,555	Coffee cherry	kg	18,000	1,900	34,200,000	
Pruning	Days	64	20,000	1,272,727						
Pest and disease	Days	3	20,000	68,829						
Fertilising	Days	37	20,000	740,000						
Others	Days	20	20,000	400,000						
Harvesting	Days	213	20,000	4,260,198						
Subtotal		*415*		*8,296,309*						
Materials										
N (Urea)	Kg	391	5,000	1,956,522						
P (P2O5)	Kg	97	1,400	135,927						
K (K2O)	Kg	372	3,800	1,415,172						
Lime	Kg									
Manure	Kg	25,000	100	2,500,000						
Pesticides				100,000						
Subtotal				*6,107,621*						
Total				**14,403,930**					**34,200,000**	
Balance										**19,796,070**

After 10 years, valuing all labour at 20,000VND/day, the net benefit amounts to 71,967,249VND.

Index

D

I

K

L

M

N

Q

R

S

Answers to questions

Q – page 11:

During which stage of cherry development do you think is the nutrition requirement of the tree greatest?

A - page 11:

During cherry filling the trees uses most nutrients, this influences timing of fertiliser applications

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Q - page 12:

Given the fact that Robusta can grow at lower altitudes than Arabica, what would be the difference in stomata density between the two?

A - page 12:

Robusta reportedly has fewer stomata, therefore loses less moisture and can grow in hotter climates

---

Q – page 13:

When you are planting, how can you prevent the development of crooked taproots in mature trees?

A - page 13:

By making sure the soil at the bottom of the plantin hole has been loosened. This helps the taproot to penetrate the soil and grow straight down.:

Q - page 14:

During which commonly found disease does blocking of stomata occur?

A - page 14:

The fungus Coffee Leaf Rust uses stomata to enter the leaf and feed on it

---

Q - page 15:

Why would the tree give preference to filling cherries rather than maintaining leaves when water or nutrients are in short supply?

A - page 15:

Cherries take preference over leaf maintenance when the tree is under stress, because cherries allow the tree to survive via a new generation.

Q - page 18:

How could you avoid the deviation from the genetic base of the mother plant when propagating?

A - page 18:

By not using sexual propagation, but vegetative propagation

Q - page18:

Do the leaves at the tip of the shoots also give you an indication of the trueness of the Catimor variety?

A - page 18:

Yes they do. Real catimor has brownish top leaves

Q - page 20:

Why is it recommended to use topsoil and not soil from deeper down?

A - page 20:

Because the topsoil contains more organic matter and is therefore more fertile.

Q - page 24:

How can you identify seedlings that have received too much nitrogen?

A - page 24:

Seedlings that have received too much nitrogen usually have elongated stems and heavy leaf growth

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Q - page 24:

Which nutrient related disease is often observed in nurseries?

A - page 24:

Brown eye spot can be observed in nurseries. This relates to mainly nitrigen deficiency, but can also be caused by a lack of shade

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Q -page 25:

Based on the conditions in Huong Hoa, which combination of species and varieties would be suitable for grafting?

A - page 25:

One could consider a Liberica rootstock with Catimor graft. The Liberica has a large and drought resistant rootsystem, while the Catimor is Coffee Leaf Rust resistant and gives large yields.

Q - page 26:

What is the advantage of grafting over propagation by seed from a disease resistancy point of view?

A - page 26:

The advantage is that vegetative propagation ensures an identical genetic make up of the new tree. Favourable chracteristics such as Coffee Leaf Rust resistance are genetically determined. Using seed on the other hand may result in deviations from the original genotype and result in reduced resistance against disease

---

Q - page 29:

Apart from fertilizer and compost application what other mechanisms contribute nutrients to the soil?

A page 29:

Other sources of nutrients are litterfall from coffee, shade and windbreak trees, natural deposition through rainfall (Nitrogen mostly), decomposition of organic matter in the topsoil, decomposition of old roots and run-off from higher areas

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Q - page 29:

Primary nutrients are used in large quanities, what does this imply for foliar fertilizer application?

A - page 29:

This means that spraying foliar fertiliser to remedy nitrogen shortage will most likely not be very effective. For micro nutrients folair fertiliser can be used.

Q - page 30:

Give the importance of pore size for tree development, which would be better: mechanical or manual land preparation?

A - page 30:

Mechanical land preparation uses often heavy machinery. Especially in wet conditions this may lead to compaction of the soil and smaller pores. This makes it more difficult for the young roots to penetrate the soil. Therefore manual land preparation should have preference.

Q - page 36:

Looking at the surrounding landscape what seems a likely origin of the basaltic parent material in Khe Sanh?

A - page 36:

The origin of the parent material is volcanic. When entering Khe Sanh, just before the customs station one can see old volcanic rocks on the right hand side of the road.

Q - page 397:

Which particle will bond more strongly with the clay particle Mg^{2+} or K^{+}? 38

A - apge 37:

Mg2+ will bond stronger with clay, because it's electrical charge is twice that of K+

Q - page 38:

Can you think of more reasons than the one mentioned why it's better to give several small fertilizer applications rather than one or two large ones?

A - page 38

Trees use fairly small amounts of nutrients, applying a large dose at one time does not mean the tree will use all that is available. Contrary, nutrients will be lost because the tree can only take up so much. Splitting fertiliser applications in smaller volumes reduces this problem

---

Q - page 39:

How much composted coffee pulp in dry matter would be needed to apply 150 kg of N (assuming a 5% N content)?

A - page 39:

150/5% = 3000 kg

Q - page 40:

Why does pH generally decrease with soil depth?

A - page 40:

This is because soil organic matter is fairly acid. Deeper down in the soil there is less organic matter available

---

Q - page 43:

How to determine the slope of a field?

A - page 43

By looking perpendicular along the slope keep your left hand level and let the fingers of this hand touch the lower palm of your right hand. Now raise the fingers of your right hand until they line up with the slope. Have somebody else measure the angle between your hands. This will give you a rough indication of the slope.

Q - page 45

Why is it important to use top soil in the planting mix?

A - page 45:

The topsoil contains more organic matter than the lower layers and is generally more fertile.

Q - page 46

Assuming a bulk density of 900 kg/m^3 for the soil in Figure 71 to what depth is the soil eroded if the total amount lost is 30Mt/ha?

A - page 46

30,000 Mt/ha / 10,000 m^2 = 3kg/m^2

3kg/m^2 / 900 kg/m^3 = 0.0033m

Q - page 48

Why is it important to loosen the soil in the planting hole sufficiently deep?

A - page 48

Loosening the soil allows the root to penetrate it more easily and leads to better establishment of the tree.

Q - page 49

How does covering the soil prevent excessive moisture loss?

A - page 49

By reducing the amount of sun shine that falls on the soil covering the soil reduces soil temperature and thereby evaporation.

Q - page 53

Why would one prefer deep rooting windbreak trees?

A - page 53

Deep rooting trees will utilise more of the soil depth than coffee trees. As coffee mostly depends on the first 0.5m of soil this will reduce competition for water and nutrients between windbreak and coffee.

Q - page 54

Apart from reducing evapotranspiration, what other effects can shade have on moisture?

A - page 54

Too much shade leads to higher humidity in the coffee field and this in turn may aggrevate Coffee Leaf Rust occurance.

Q - page 56

How can you in the design of your coffee field limit the potential amount of competition for water and nutrients between shade and coffee trees?

A - page 56

By selecting species that do not consume too much water and have deep roots. Deep rooting trees get water and nutrients from deeper down in the soil than coffee. This reduces competition.

Q - page 57

What is still needed in Figure 90 to optimize conditions for the newly planted coffee trees?

A - page 57

Despite the temporary shade the soil in Figure 90 recieves a lot of sun. A cover crop or mulch layer will reduce intercept light and reduce evaporation. This makes more moisture available for the coffee trees.

Q - page 60

If cover cropping is not an option in a newly established field, how could weed control be practiced without resorting to clean weeding?

A - page 60

Several options are available. One is to use mulching to suppress weeds. Another is to cut the grass and weed only around the base of the tree.

Q - page 67

Why do leafs discolour under N deficiency?

A - page 67

The leaves need nitrogen to make chlorophyll. Chlorophyll gives leaves the green color, hence a lack of nitrogen results in discolouration of leaves.

Q - page 68

During which stage of its live are phosphorus applications most important?

A - page 68

Phosphorus is used mostly for root development. Therefore it is important to have sufficient phosphorus during establishment of the field. Also after stumping more phophorus may be needed as the imbalance between canopy and root system that results from stumping means that a lot of roots die. This is because the little green matter that is left can not sustain the entire root system.

Q - page 70

How likely do you think Fe deficiencies are on the red soils in Khe Sanh?

A - page 70

The red color indicates high Fe content of the soil, deficiencies of Fe are therefore not very likely, although it depends on how easily the tree can uptake the Fe.

Q - page 71

How do energy prices influence the price of fertilizers?

A - page 71

Especially the production of nitrogen fertiliser requries a lot of energy. Hence higher energy prices result in higher prices for nitrogen fertiliser.

Q - page 74

Why is maintaining an adequate CEC level so important, and how can this be done?

A - page 74

The CEC refers to the capacity of the soil to deliver cations, what we call nutrients for the trees. Increasing CEC can be done by ensuring sufficient organic matter in the top soil.

Q - page 75

If you decide to use NPK in the first 2 years after planting, what would be a suitable composition?

A - page 75

During the first 2 years the rootsystem is being established. For this the tree needs phosphorus. A suitable NPK compund therefore should have a relatively high phosphorus content.

Q - page 76

How to select trees randomly?

A - page 76

Many ways are available. An easy one is to walk diagonally through the field and select say every fifth tree than you pass.

Q - page 83

What is the difference between compost and organic material?

A - page 83

Organic material refers to any material of organic origin, whereas compost is organic material that has been broken down by soil organisms. Nutrients in the latter are moer easily obtainable by the trees.

Q - page 84

What kind of damage could the organic acids from raw pulp do to the roots of the tree?

A - page 84

Organic acids in sufficient quantities can lower the soil pH. This in turn makes it harder for the tree to take up nutrients.

Q - page 90

When pruning, which type of branches would you favour over others?

A - page 90

Important is to maintain sufficient fruit-bearing wood.

Q - page 91

Why is it advisable to use pruing sissors?

A - page 91

Pruning sissors leave a very smooth and clean wound. The tree will heal the wound quicker compared to rough wounds that you get from ripping branches of by hand. Cleaner wounds thereby reduce the chance of disease infection.

Q - page 92

What is the best time of the year to prune?

A - page 92

After the harvest and the second time is one month after flowering.

Q - page 100

Why would one remove the branches on the eastern side of the tree and not on the western side?

A - page 100

By removing the branches on the eastern side of the tree first, maximum utilisation can be made of sunlight in the morning hours. This results in quick generation of suckers. Of course the decision depends to a large extent on individual field layout.

Q - page 104

How could the selection of taproots during propagation and planting influence future pest and disease problems?

A - page 104

A well developed root system is crucial for healthy trees and healthy strong are less easily affected by pest and disease.

Q - page 105

Why is it important to wash clothes that have been worn in a field infected with Coffee Leaf Rust before using them again?

A - page 105

These clothes may contain Coffee Leaf Rust spores. Wearing them without washing first may spread the spores to other fields.

Q - page 107

What does the leafrust infection in Huong Phung in 2002 tell you about propagation practices?

A - page 107

Original Catimor os Coffee Leaf Rust resistant, but unbriddled sexual propagation has resulted in a degeneration of the genotype. This means that present Catimor is not pure Catimor anymore. This is one of the reasons fields in Huong Phung were so heavily affected.

Q - page 109

How does drought affect die-back?

A - page 109

Drought makes it hard for the tree to take up nutrients. When drought and dieback occur at the same time the effects on the tree will be worse still.

Q - page 110

How can heavy crops such as pictured in Figure 146 be prevented?

A - page

A possible way is to selectively remove flowers by hand when the flowering is heavy. Alternatively, the use of shade can be practiced to reduce the occurance of heavy flowering.

Q -page 117

Why does application of pesticides have limited effect on stem borers?

A - page 117

The stemborer larvea are inside the tree and well-protected from pesticide applications. The best way to control them is to cut out infected parts and burn them immediately.

Q - page 122

How many people do you know that have had negative health effects from applying pesticides?

A - page 122

Of course this is personal and the answers will vary among people. A fact is that present birth defects in Vietnam resulting from agent orange are an extreme example of herbicide application affecting health.

Q - page 123

Which parts of the body take up pesticides most easily?

A - page 123

Firstly uptake is most easily throught the mouth and nose. Other important areas are those where the skin is relatively thin. The parts are the inside of elbows, crotch, thighs and the area between the shoulders.

Q - page 127

What has been the main consideration for promoting Catimor in Vietnam?

A - page

Important considerations were Coffee Leaf Rust resistance and high yields.

Q - page 136

What would be an optimal fertilizer application timing based on what you have just read?

A - page 136

Q - page 152

Why is replication so important to achieve reliable test results?

A - page 152

If you do only one single test without replications the outcomes can be influenced by a peculiarity of the field in which the test was done. By replicating the chance o such mistakes is reduced.

Q - page 153

Would you expect bias in an experiment on fertilisers, or plant spacing?

A- page 153

Although nitrogen and pottasium are mobile in the soil, this mobility is usually vertical or downhill. Bias may be possible because of this, but the effects are likely to be too small to notice. With a plant spacing experiment no bias will occur.

Q - page 159

Why did the share of the Asia-Pacific region increase so strong?

A - page 159

Reasons are two-fold. When Vietnam increased production in the 90-ties several African Robusta producers saw sharp decreases in production. This resulted in a larger global share for the Asia-Pacific region.

Q - page 164

Why is it interesting for farmers to sell to more than one exporter in the area?

A - page 164

Competition among exporters to buy cherries from farmers can drive up the price farmers receive. In Vietnam the share of export price earned by farmers is one of the highest in the world.

Q- page 166

Using 5USct/lb as premium for Arabica, how much would this be in VND per kg fresh cherry?

A - page 166

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1 lb = 0.45 kg

1 USD = 15,000 VND

1/0.45 = 2.22lb = 1 kg --> 2.22*0.05=0.10 USD/kg premium

0.10*1000=100 USD/Mt green bean

Conversion from green bean to fresh cherry is 6.5

Premium equals 100 USD per 1000*6.5=6,500 Mt fresh cherry.

Premium for 1 Mt fresh cherry 100/6.5 = 15.38 USD or 230,000VND

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1 www.ineedcoffee.com, accessed on 12-7-05

2 Rene Coste 1991, Coffee The plant and the product

3 Muschler, R.G. ; Shade improves coffee quality in a sub-optimal coffee-zone of Ccsta Rica

4 CAB International, Global Crop Protection Compendium

5 http://dev.ico.org/projects/pstem.htm, accessed 21-2-06

6 CAB International, Global Crop Compendium

7 H. Lempke, 2000, Extension Manual

8 Worldbank 2004