COFFEA ARABICA

PLATE XI.—*Coffea arabica* (Coffee). (From Jackson: *Experimental Pharmacology and Materia Medica.*)

A MONOGRAPH

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INTRODUCTION

Coffea arabica, native of Ethiopia, is known to be as one of the most important crops worldwide. One of its main products, brewed coffee, is believed to be the most consumed beverage after water. People tend to associate its tender aroma with energy and positivity due to its properties. It is not only used for a beverage but for plenty of other products such as candies, beauty products, and energetic beverages. In order to manufacture this products, the coffee bean has to go through a complex process, probably one of the most extensive process associated with any beverage. Each step of the process has to be completed with determination and passion, which determinates the quality of the coffee. Besides from this, this seed provides a great amount of antioxidants, and fiber; thus it helps to prevent plenty of illnesses. In eight Chapters, this monograph explores deep into the coffee seeds, including aspects and terms, such as, its origin and distribution, environmental factors that affect distribution, its biology and reproductive biology, then its propagation and management including vegetative propagation.

1. ORIGIN AND DISTRIBUTION

1.1 Origin

Coffea arabica is a species of the genus Coffea, originally indigenous to the forests of the southwestern highlands of Ethiopia and the Boma Plateau in South East Sudan. C.Arabica is believed to be the first coffee ever cultivated. The genus Coffea is native to tropical Africa, Madagascar, the Comoros, Mauritius and Réunion in the Indian Ocean.

1.2 Affinities and taxonomy

The plant was exported from Africa to countries around the world and coffee plants are now cultivated in over 70 countries, primarily in the equatorial regions of the Americas, Southeast Asia, India, and Africa. Coffea belongs to the class of Equisetopsida, to the subclass of Magnoliidae and to the family of Rubiaceae -all plants of coffee belongs to this family-. This plant has an extensive "family tree" in which are included the Carapichea lucida from the genus Carapichea, in which no uses are yet known to it. Also the Coffea ambongense, found in western Madagascar, is very similar to C. Arabica; C. Ambongense belongs to the genus of Coffea, to the class of Equisetopsida and the subclass of Magnoliidae. This specie is also used for commercial coffee production.

2. ENVIRONMENTAL FACTORS AFFECTING DISTRIBUTION

2.1 Biology.

Wild plants grow between 9 and 12 m tall. They have an open branching system; the leaves are opposite, simple elliptic-ovate to oblong, 6–12 cm long and 4–8 cm broad, glossy dark green. The seeds are contained in a kernel, also called "cherry", 10–15 mm in diameter, maturing red to purple and typically contains two seeds, which are the seeds used to produce coffee. In relation to the taxonomy, all coffee plants are from the family of Rubiaceae, which are evergreen trees that may grow 5 m tall.

Since Coffea arabica is self-pollinating, the seedlings are in most occasions uniform and vary little from their parents.

2.2 Cultivation.

There are many methods to plant coffee, some more efficient than others,but the traditional method o is to place 20 seeds in each hole at the beginning of the rainy season, as seen on figure 1.

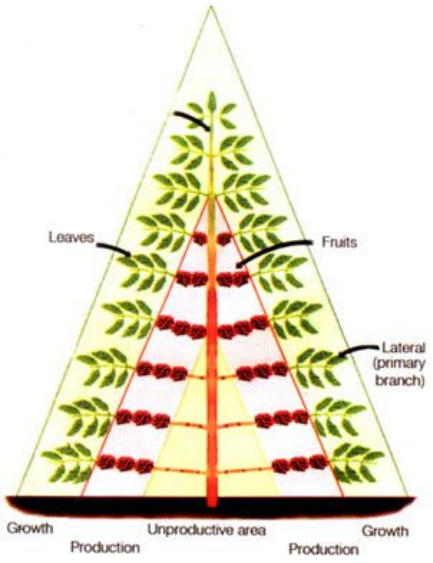


Figure 1

In contrast to this, since about half of the seed fail to sprout, the most effective technique consists in raising the seedlings in nurseries that are then planted outside at six to twelve months. The process of planting requires a lot of patience and knowledge; this specie takes approximately seven years to fully mature and if too much seeds are planted there can be a disadvantage in the production since C. Arabica produces too many berries. Thus leading to an inferior harvest and in some occasions damage in the yield. This issue can be prevented by trimming the tree when necessary.

2.2 Rainfall

C. arabica grows best with 1.0–1.5 meters of rain, evenly distributed throughout the year, followed by a dry season lasting 2-3 months, this dry season suits best depending on the specie. Lastly, in

order to have a successful cultivation, rainy and dry season must be well defined. Some countries that are characteristic for their well defined seasons are Kenya, Colombia and Ethiopia

2.3 Elevation

It is usually cultivated between 1,300 and 1,500 m altitude, but plantations grow it as low as sea level and as high as 2,800 m. As seen in Figure 2, elevation influences in the way coffee tastes, but its cultivation process will be very similar, almost facing no variations, depending on the altitude.

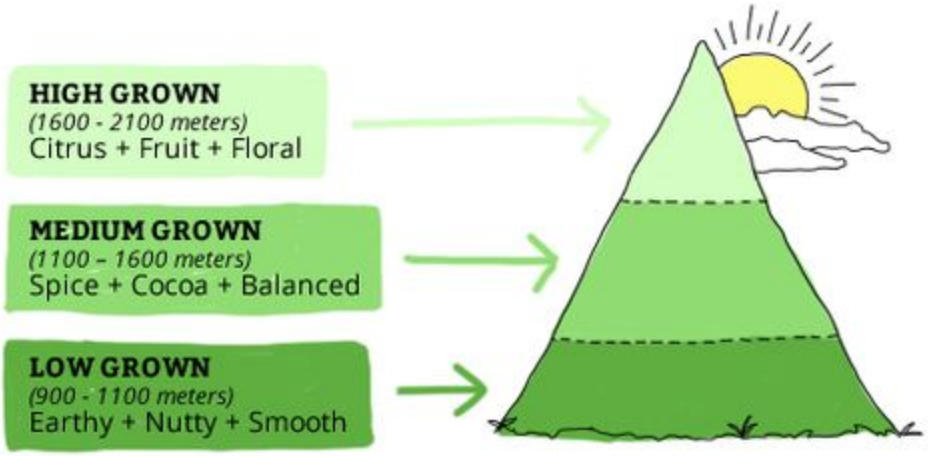


Figure 2

2.4 Climate

C. Arabica grows best with an average temperature of 15 and 24ºC. It can survive in low temperatures but not frost. Unlike other species, such as Robusta, Arabica grows better in light shade.

2.5 Pests and diseases

- Pests:
    - Black Twig Borer (Figure 3) is native to Asia. It attracts both Arabica and robusta strains. They bore into branches and leave a pinhole sized entry. It lives in humid conditions. It can be controlled by pruning and shade reduction.

Figure 3

- Cicadas (Figure 4): females lay eggs by cutting a hole in the branches and depositing the eggs. After hatching the eggs fall into the ground and start leaving off the roots of the tree

Figure 4

- Coffee borer beetle: it lays eggs in the seed endosperm. It can be controlled by proper plant pruning and ensuring that no coffee fruit is left in the fields

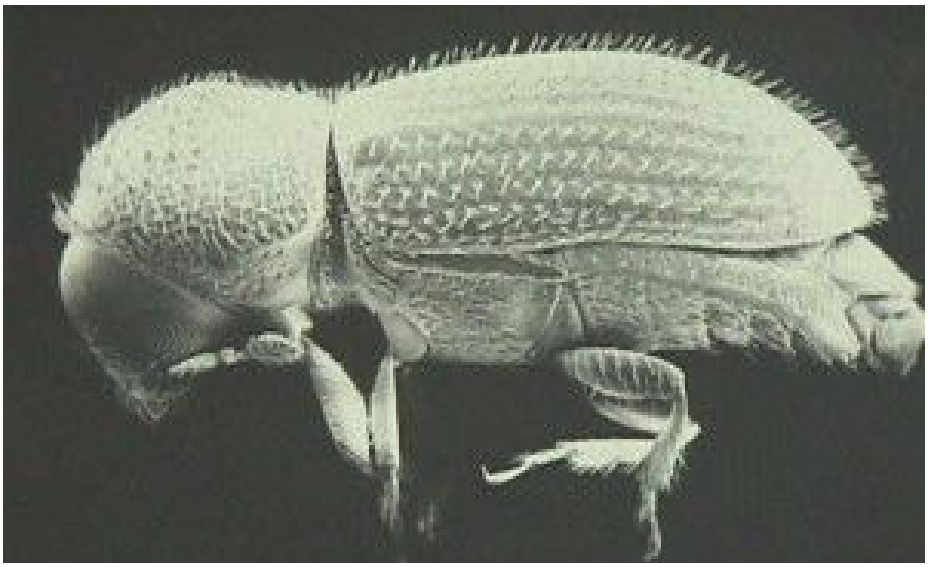


Figure 5

- Diseases:
  - Bacterial blight (Figure 6): it normally occurs in seedling nurseries and affects plant leaves and tissue

Figure 6

- Brown eyespot and berry blotch (Figure 7): it may attack both leaves and the coffee berry. It presents with tan spots with grey centers

Figure 7

- Phoma (Figure 8): is a soil fungus that can attack the coffee leaves and fruit. When infected the leaves will develop black spots while still unripe. This can be prevented through the use of wind-breaks.

Figure 8

3. BIOLOGY

3.1 Chromosome complement.

Coffea arabica is the only species, so far analyzed, in the genus family that is self-compatible and natural polyploid (cells and organisms that contain more than two paired homologous sets of chromosomes) with 2n=4x=44 chromosomes. This compatibility makes C. arabica outstanding since all other species of the genus family are self-compatible diploids (contains two complete sets of chromosomes) with 2n=2x=22 chromosomes. In relation to this, studies on the somatic metaphase chromosomes resulted in uniform karyotypes -picture of the plant's chromosomes by isolating them- that show almost no differences among species. This result is also influenced by the fact that chromosomes in

the somatic phase are very small (1 – 3 μm.) (Kim FJ, Chammas MF Jr, Gewehr EV, Campagna A, Moore EE, 2008)

3.2 Life cycle and phenology

3.2.1 Life cycle and longevity

Seedlings that are well taken care of and healthy take about two years to start developing coffee cherries, and 5 to 8 weeks to make their way to the surface of the soil. After that, from extracting the seeds, also known as beans, it takes nine months to develop to a coffee cherry, at this point the tree will be about a foot tall. Anywhere on the plant that a blossom was allowed to develop**,** a cherry will grow in its place on the stem. At this point farmers can starts harvesting but cannot start to sell it. As seen in Figure 1, the plant has to mature for another five years before the fruit has any commercial value. Before the plant starts to harvest cherries, the farmers have to take close care and protect from disease and infestation by feeding it with nitrogen-fixing fertilizers. The next step is processing, which means converting the raw coffee into consumable coffee; there are two methods for processing coffee, wet and dry. Once it reaches about five it becomes stronger though there is still a lot to care of. Coffee plants can live up to 100 years but they are most fertile between the ages of 7 and 20.

Life cycle of coffee through its first 5 years.

http://www.emerging-fashion.com/blogs/g/97972550-1-guide-to-coffee-an-introduction

3.2.2 Flowering and fruit seasonality

Harvest time varies depending on the geographic area, but mostly, south of the Equator harvest takes place between April and May, and North of the Equator it takes place between September and March. This seasonality shows how C. arabica grows best in medium temperatures, never too high and never too low. Finally, coffee is harvested during the dry season, when coffee cherries are at their best, bright red, smooth, and firm.

3.2.3 Flowering and fruiting frequency.

After the seedlings are planted it takes three to four years for sweetly smelling flowers to grow in the axils of the coffee leaves. In relation to this, about 6-8 weeks after each flower is fertilized, cell division takes place and the coffee fruit remains as small as a pin for a period dependent on the climate. Following that the ovaries will then develop into drupes in a quick growth period that takes about

15 weeks after flowering. Lastly fruit is produced only in the new tissue, so it can only be produced after the whole crop is harvested.

Coffee tree flower

http://www.constantinealexander.net/2012/week45/page/2/

3.3 Reproductive biology

3.3.1 Pollen

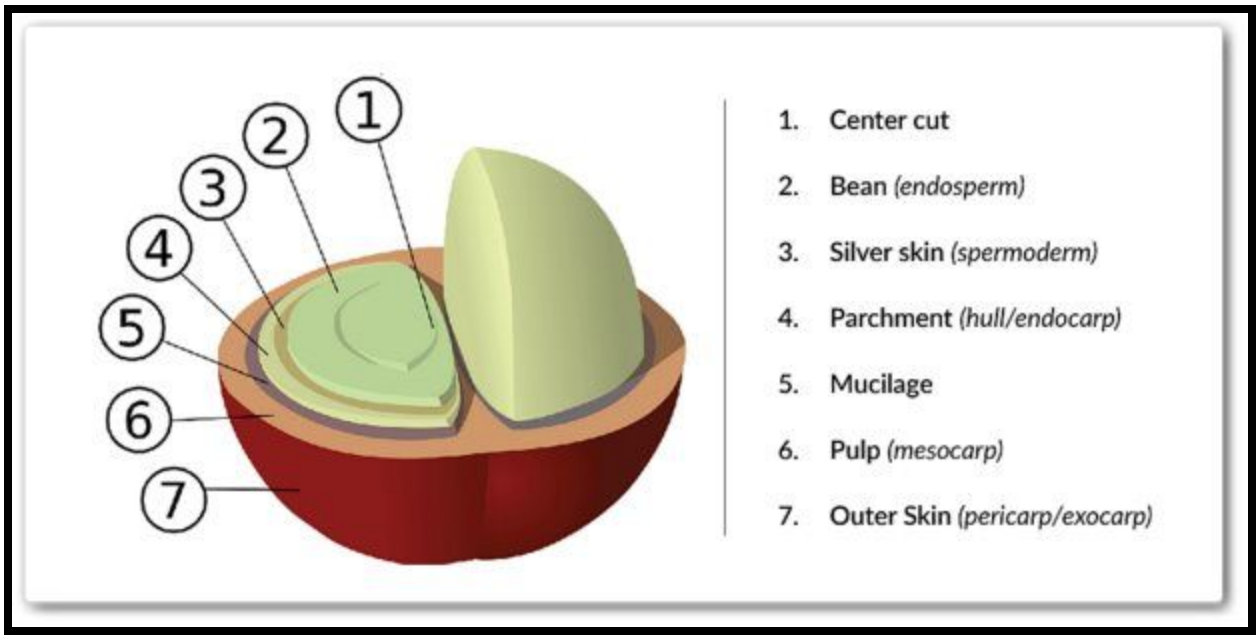
Coffea Arabica shows the highest degree of polymorphism (genetic variations) in its 13 species of pollen grains. The majority of the species are members of the Section Eucoffea (coffea) and two species belong to the Section Paracoffea (subgenus from the family Rubiaceae).

3.3.3 Pollination and potential pollinators

Since *Coffea arabica* is a self-pollinating plant, it has fewer mutations and variations throughout its life cycle as compared to robusta. Also even though it is self-fertile, bee pollination intensifies quantity and quality of the crops (Wojcik, Kevan, 2007).

3.3.4 Fruit development and seed potential

Until 12 weeks after flowering the bean (endosperm) remains small. After 12 weeks it will subdue, consume, and replace the integument (outer protective layer of the seed). The remain of the integument are what make up the silver skin (spermoderm). At this point, the endosperm will have thoroughly filled the space made by the integument nineteen weeks after flowing. Now, the endosperm is white and moist, but will acquire dry matter during the next few months. During this phase the endosperm attracts more than seventy percent of the total photosynthates (sugar produced by photosynthesis) produced by the tree. After this, the mesocarp (pulp) will enlarge to form the sugary pulp that surrounds the coffee bean. Finally about thirty-five weeks after flowing the coffee cherry will turn from green to red (Lover, C).



The anatomy of the coffee bean

http://highroadcoffee.com/the-anatomy-of-the-coffee-bean/

4. Propagation and Management

4.1 Natural regeneration

According to a study conducted to assess the diversity of naturally regenerated woody plants, soil fertility, performance of *Coffea arabica* and coffee cup quality under *Eucalyptus grandis*, showed how the plantation positively affected *C. Arabica*. Under the influence of *Eucalyptus grandis* plantation there were significant differences in the mean diameter and the total height of coffee plants in the plantation (Kitessa, H). In this case the plantation favores the coffee performance. It did not deplete soil nutrients and had no effect on the cup quality of coffee. Finally, to utilize *E. grandis* as a shade tree for coffee it is important to have in mind that the thinning of the shade tree has a negative impact on the coffee shrubs since it reduces the succession potential, which threatens the coffee production system (Kitessa, H) .

4.2 Nursery propagation

For the nursery propagation of *C. Arabica* ripe cherries are collected, pulped and the mucilage (viscous secretion) is taken out by fermentation. The newly picked seeds can either be planted or dried for later use. Coffee drying is done on wire mesh trays placed in the shade; and dried coffee seeds can last up for a year if correctly taken care of.

4.2.1 Propagation from seed

4.2.2 Pre- preparation and implications for germinations

The best time for soil preparation is from January to April (in between the two rainy periods) This weather ensures a good success rate for the new trees. Land preparation is prefered to be done manually because it will cause less damage to the structure of the soil, making it easier for the roots of the young trees to penetrate deeper soil layers (Mitchell, 1988)

4.2.3 Sowing and the germination process

There are two main methods for the germination of seeds. One of them consists on coffee seeds being pregerminated by spreading them on a sand bed and covering them with moist bag sacks or straw. In this method the seeds are watched constantly and closely and as soon as the plant emerge they are removed from the bed. The other alternative is to mix the seeds with humid vermiculite (is a mineral that when mixed with soil germinates seeds), or mix the seed expanded polystyrene and keep in the polythene bag (Mitchell, 1988)

4.2.4 Storage

If correctly stored, coffee beans can last up to a year or more (Mitchell, 1988; der Vossen, 1980). To accomplish this with green coffee beans it must be stored in dry and cool conditions. Exposure to the sun will quickly damage the coffee. It can be stored in pergamino or in burlap bassin as it allows air flow. In addition, when storing coffee seedlings the management is different. Coffee seeds live up for over two years if stored at 15°C at 41% moisture content in an airtight polythene bag (Mitchell, 1988; der Vossen, 1980). Roasted coffee storage differs too. It is the stage of coffee that maintains its freshness the longest. Nitrogen can be used to preserve the whole beans for an extended time (Mitchell, 1988; der Vossen, 1980).

5. Vegetative propagation

5.1 Grafting

The purpose of grafting is to combine a variety of traits of different trees into one, in order to achieve a better performance in the field. The best method for grafting is called top grafting. Grafting is very important and it largely depends on the weather. The best season to graft is from May to June, since it is cool and it has high humidity. The first step is to thoughtfully investigate which varieties and species are going to be used (Mitchell, 1988). When choosing, climate, soil, water supply and soil borne diseases are taken in account. Then, it is necessary to have pruning scissors, razor blades, plastic bags and thin string. Grafting can also be done in the nursery. For this method, specifically grown seedlings with the desired characteristics have to be grown. The receiving seedlings must be 4 to 6 months old and have 3 to 5 pairs of leaves. The part that is going to be grafted in the seedling is the tip of a sucker or top of another seedling (Mitchell, 1988)

5.2 Cuttings

Propagation by cutting is another technique. For this method similar cuts as in grafting can be used. After cutting, the plant should be put in water and transferred as soon as possible to a nursery bed. Weather influences as well, thus the best time to do this is in January and February. In this nursery bed 80% of the light should be allowed to enter. The cuttings should be covered with a plastic sheet. This cuttings should be aired by removing the plastic twice a day for 1 hour. During this hour, water can be applied, except when it is raining. 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 individual plastic bags. Then another 6 to 7 months that will result in 5 to 7 pairs, that can be finally moved to the field.

5.3 Planting

There are many methods to plant coffee, some more efficient than others,but the traditional method o is to place 20 seeds in each hole at the beginning of the rainy season, as seen on figure 1.

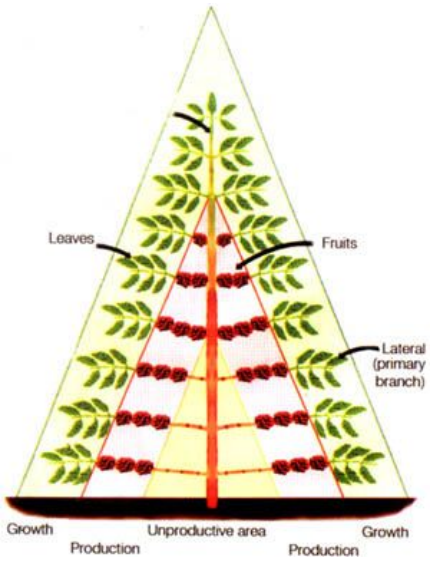


Figure 1 - Planting the seeds.

In contrast to this, since about half of the seed fail to sprout, the most effective technique consists in raising the seedlings in nurseries that are then planted outside at six to twelve months. The process of planting requires a lot of patience and knowledge; this specie takes approximately seven years to fully mature and if too much seeds are planted there can be a disadvantage in the production since *C. Arabica* produces too many berries. Thus leading to an inferior harvest and in some occasions damage in the yield. This issue can be prevented by trimming the tree when necessary.

6. Management

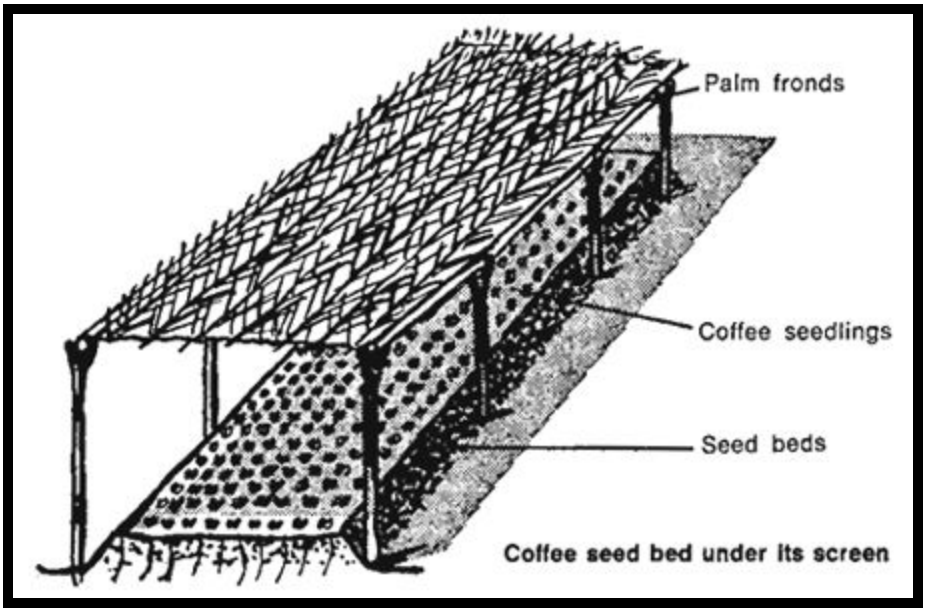
6.1 Flowering

Flowering takes place on lateral and secondary branches. Its full development takes about 2.5 months. Each flower has 2 loculi (small cavities or compartments)

6.2 Tending

In order to tend the seed plot it is important to have in mind that the coffee seedlings are small and delicate. Secondly, the seeds must be protected from the sun and put in shade, as seen in figure 2. A good strategy to protect the seed plot from the sun is to put up a screen (it can be made from palm fronds) above each bed from about 1.5 to 1.8 metres high. Also, the seeds need a great amount of water, thus it is necessary to water them often. On the other hand, it is important to tunnel the rows so that the weeds cannot grow and take space away from the younger seedlings. Finally in order to maintain a healthy seed plot, insects and diseases must be treated, and diseased seedlings must be pulled out.

Figure 2



Tending structure

Pest and disease control

Black twig borer: Black Twig Borer (Figure 3) is native to Asia. It attacks both Arabica and robusta strains. They bore into branches and leave a pinhole sized entry. It lives in humid conditions. It can be controlled by pruning and shade reduction. Ir can be controlled by pruning (specifically removing unwanted suckers) and shade reduction.

Figure 3 - Black Twig borer

Coffee borer beetle: It thrives in humid conditions and dense crop spacing. The finest way to stop infestations is through proper plant pruning and ensuring that all coffee is harvested and no coffee fruit is left in the fields between harvest.

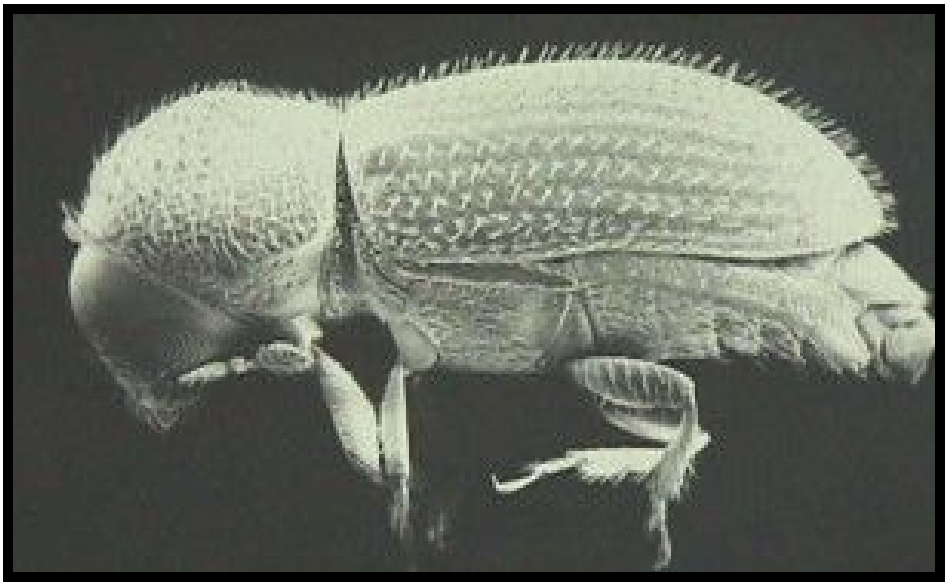


Figure 4 - Coffee Borer Beetle

Green scale: Control measures are similar to those for mealybugs

Figure 5- Green scale invading the plant.

Mealybugs: The mealybug strategy is to discharge a sticky honeydew that attracts ants, which leads to the development of a mold that covers the leaves and may affect the process of photosynthesis. Mealybugs can be controlled by maintaining shade at 30% for arabica and 20-25% for Rubusta (Wintgens, 2009)

Figure 6

Phoma: Phoma is a soil fungus that attacks the coffee leaves and fruit. The effects of the fungus are visible in the black or brown spots that the leave will develop. Effects can be mitigated through the use of wind-breaks in areas susceptible to phoma.

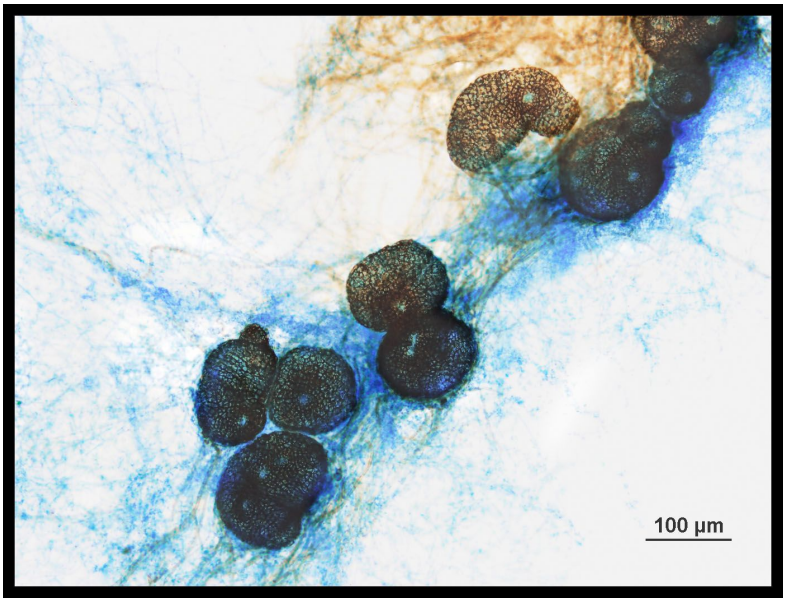


Figure 7

Coffee rust: coffee leaf rust is spread by wind and rain from spores from lesions on the underside of the plant (Mitchell, 84). This disease can be prevented by spraying copper based fungicides at 3-5 kg/ha at 4-6 week intervals during the rainy season

Figure 8

Coffee berry disease: is a fungus that lives in the bark of the coffee tree and forms spores that affect the coffee cherries. The best way to avoid the coffee berry disease is spraying Captafol and copper- based fungicides.

Figure 9

7. Emerging products, potential markets.

7.1. The overall picture

Coffea arabica seeds have been present since ancient times. In its native Ethiopia, it was used as a masticatory (chewing the seeds in order to feel the energizing effects) (Duke. 1983). Coffee beans are mostly used to produce coffee, one of the most important beverages in the world. Coffee is widely used as a flavoring, as in ice cream, candies, desserts and alcoholic beverages. Since caffeine is one of its main components, coffee is used as a stimulant, for the central nervous system, kidneys, heart and muscles (Healthline). On the other hand, coffelite, a

type of plastic, is made from coffee beans (Duke. 1983). Coffee with iodine is used as a deodorant (List and Horhammer, 1969-1979) . Finally, Caffeine is a widespread additive in over-the-counter diet pills, painkillers, and stimulants (Duke, 1984).

7.2 Potential markets

7.2.1 Coffee bean exports and produces.

The market is segmented into growers, roasters and retailers. South America was ranked as the major coffee-producing region, where Brazil produced about 43.2 million 60kg bags of coffee. In relation to this, according to the International Coffee Organization from October 2015 to October 2016 71.93 million bags of Coffea Arabica were exported. From which 9.13 bags were only from October 2016. The global coffee consumption is 151.3 million 60 kg bags consumed from Oct 2015 to Sept 2016 (International Coffee Organization, 2016). In 2015-2016 the coffee market ended in deficit for the second consecutive years, but the production and consumption in past years was so successful that it allowed the market to be well maintained (International Coffee Organization, 2016).

7.3 Food items based on coffee bean

7.3.1 Brewed coffee

Coffee statistics in 2016 show that coffee sales are increasing 20% per year. In relation to this, recent studies showed that Americans consumed on average 3.1 cups of coffee per day; mostly consumed at home, then at work. In relation to this, over 50% of Americans over 18 drink coffee everyday, which represents almost half of the population. On the other hand, independent coffee shops equal $12 billion in annual sales in the United States. In stores, the average espresso price is $3.45 dollars, and the average coffee price is $2.38. In contrast to this, the motivation to drink coffee varies in women and men. For women, drinking coffee is a way to

relax, and for men it is a way to wake up (E-Imports, 2017). As seen in Figure 1, the consumption is concentrated in Europe and off course Brazil, being one of the main coffee producers.

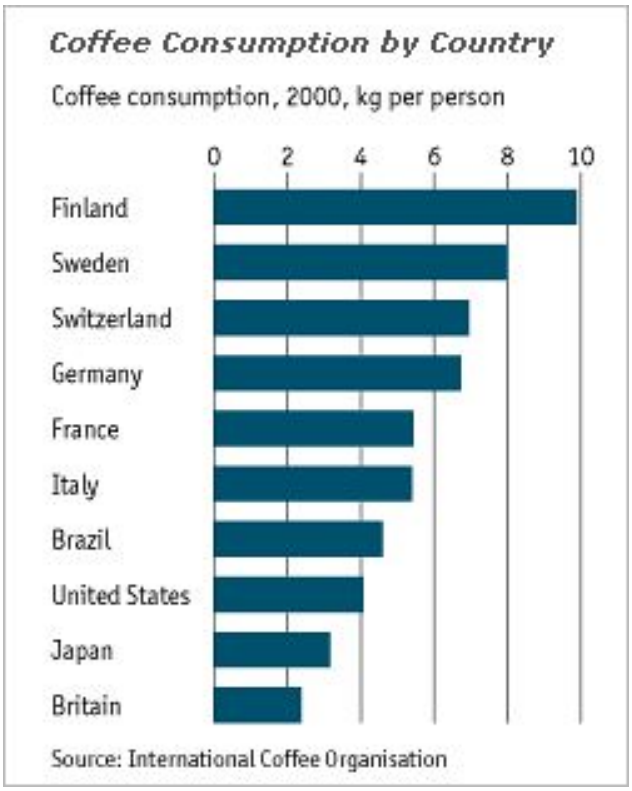


Figure 1, consumption by country

8. Medicinal and traditional uses

8.1 Medicinal uses and effectiveness

Brewed coffee is often used to increase mental alertness and to improve clear thinking. Caffeine can also improve alertness after sleep deprivation. Also, combined with glucose, it seems to improve mental alertness better that caffeine or glucose alone. In elder people coffee is possibly effective in preventing dizziness caused by blood pressure after eating a meal (postprandial hypotension) (Cannon, Cooke 2001).

Coffee can be possible effective in preventing some diseases. Some research suggests that it reduces the risk of colorectal cancer when drinking more that three cups per day (Prnewswire, 2000). Coffee also prevents or delays Parkinson's disease for people who often drink caffeinated beverages (Hensrud Donald, 2017). On the other hand, consuming coffee that has at least 400 g of caffeine per day seems to prevent gallstones. The greater the intake of coffee, the lower the risk. Finally coffee is also known for preventing type 2 diabetes (Arnlov J, Vessby B). The more people consume, the lesser the risk.

Of course, since coffee contains caffeine which is a stimulant it has its risks and warnings. Common side effects include headaches, restlessness and anxiety. Some more serious side effects that should be consulted with a doctor if presented are increase of cholesterol, increased heartbeat, and elevated blood glucose levels after a meal (Healthline Media).

8.2.1 Type 2 Diabetes

The health benefits of coffee for diabetes differs from case to case. Research from Harvard University showed that people who increased their coffee intake by over one cup per day had an 11% lower risk of developing type 2 diabetes. At the same time, people who reduced their coffee intake by one cup per day increased their risk of developing diabetes by 17% (Lane, James D. Feinglos, Mark, Surwit, Richard, 2008)

The effect of coffee is not clear yet, but research shows that caffeine may not be responsible for the influence on type 2 diabetes, since caffeine tends to increase glucose and insulin levels. That is why, for people who already suffer from diabetes the consumption of coffee is not recommended. In relation to this, according to a study from Duke University, people who suffer from type 2 diabetes blood sugar would ascend right after drinking coffee (Lane et al, n.d). Their blood sugar was higher on days that they drank coffee than on days they didn’t.

8.2.2 Parkinson's disease

Its effect varies in women and men. In men the effect depends on the amount of caffeine consumed. Men who drink he most caffeinated coffee, three to four cups per day, seem to have the greatest reduction in risk. Contrasting to this, in women, the amount of caffeine does not affect the influence of coffee. Three to four cups daily of moderate caffeinated coffee provides the most reduction in risk (Ascherio, Zhang, Hernan M, 2000).

8.2.3 Gallstones

There is plenty of research that suggests that coffee helps with the development of gallstones and the symptoms it brings. Coffee is beneficial in the early stages of gallbladder disease, and the effects can be seen after one cup a day. In relation to this, the effect of coffee in symptomatic gallstones (cause symptoms such as severe stomach pain) can be seen after 2 to 3 cups a day. But the effects appear to be different in men and women. It is important to highlight that that the effects of coffee are only beneficial when gallbladder disease has not fully developed, it only helps to prevent or delay the effects. It is believed that the effect of coffee is due to caffeine since decaffeinated coffee doesn't have the same effect (Leitzmann M.F, 1999-2002)

8.2.4 Colorectal cancer

Moderate consumption of coffee can reduce the chance of having colorectal cancer by 26%, the more coffee consumed the lower the risk (Gruber, Stephen, 2016) more than 2.5 coffee per day decreases the chance up to 50%, both caffeinated and decaffeinated coffee have the same effects. Caffeine and polyphenol act as antioxidants which contribute to the overall colorectal health (Rennert, Gad, 2016)

8.2.5 Health benefits

Besides from the influence coffee has in some diseases it also influences your daily life. According the Journal of Pain in 2007, two cups of coffee can decrease muscle pain up to 48%. Also one cup of coffee makes up almost 10% of the daily fiber intake (Journal of Agricultural and Food chemistry) On the other hand, according to a study, coffee influences your longevity. Women who drink coffee had lower risk of death from cancer, heart disease, and other aspects, thus affecting your longevity. Also, men who drink at least three cups a day have 24% less risk of dying early from a disease. In contrast to this, when consumed without additives (sugar or milk) coffee is good for your teeth since it kills the bacteria that causes cavities (Namboodiripad, Anila, 2009). Finally, a single coffee serving contains more antioxidants than grape juice, blueberries, raspberries and oranges.

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