HISTORY, BOTANY AND ECOLOGICAL REQUIREMENTS OF COFFEE

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INTRODUCTION

The purpose of this review is to present the summary of existing information on the origin, history, botany and environmental requirements of the coffee plant. Information has been drawn from the works of several authors and from my own four years of work experience in the Ministry of Coffee and Tea Development in Ethiopia and research results, especially of Arabica coffee.

ORIGIN AND PRESENT RANGE OF CULTIVATION

Ethiopia's gift to the world

Ethiopia is one of the 12 Vavilov centers of crop diversity in the World. Vavilov wrote: "On the whole terrestrial globe, the Abyssinian (Ethiopian) center is distinguished by its diversity of forms of hulled barley, violet-grained wheat, original races of peas, peculiar races of oats and by a series of cultivated endemic plants" (Harlan, 1969). Mooney (1979) also noted that Ethiopia has the most important pools in the world for the genes of durum wheat, barley, sorghum, linseed, finger millet, chick pea, cow pea, niger seed (*Guizotia abyssinica*) and Ethiopian rape (*Brassica carinata*). The country has served as source of propagules for many different crops which are being cultivated in different parts of the world. For instance, it has been reported that farmers in the U. S. A. alone benefit by about 150 million dollars per year from one barley variety resistant to yellow barley mosaic virus originally collected from Ethiopia (Tewolde Berhan G. E., 1989).

Among the above mentioned crops probably the most important gift of Ethiopia to the world which had and still has tremendous economic, social and spiritual impact on many people of different geographical locations, cultural background and psychological make up is coffee [*Coffea arabica* L. (Figure. 1]. It is one of the highly cherished international beverages used almost everyday, sometimes twice, or more times a day.

There had been confusion about the origin of *C. arabica* L. (Arabica coffee). The first belief that this plant was of Arabic origin was due to the fact that the first knowledge of the beverage and the tree was obtained from Arabia, hence the scientific name given, by Linnaeus. At present, however, most authorities agree that Arabica coffee originated in Ethiopia. According to Charrier and Berthaud (1985), all botanists who have explored the forests of the south-western highlands of Ethiopia agree that Ethiopia is the center of diversity of Coffea arabica.

Coffee Growing Regions in Ethiopia

In Ethiopia, coffee production is largely concentrated in 54 Woredas, principally in the western, southern and eastern parts of the country (ULG Consultant, 1993). The available information about the extent of total area covered with coffee, total coffee production, agro-ecological distribution and the systems of production is scanty and highly ambiguous/inconsistent. This can be attributed to the lack of recent and complete national survey. The only systematic national estimate available on the total coffee area and production, at Woreda level (Ministry of Coffee and Tea Development = MCTD, 1985) was based on the results of the Coffee Survey Project that was conducted in 32 major coffee growing Woredas during the 1982/83 and 1983/84 cropping seasons. The results from this survey are the only major sources that are being used for current estimation of coffee area and production in the different agro-ecological regions and coffee production systems.

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In general, the bulk of coffee production in Ethiopia comes from three major coffee growing agro-ecological regions: western-southwestern, southern and eastern coffee regions. Other minor coffee growing pocket areas are found in different parts of the Oromiya, Southern Nations, Nationalities and Peoples as well as Amhara Regions. The pocket coffee growing areas cover only about 1.7 % of the national coffee production area, and the production is exclusively used for local consumption.

Fig. 1 A Coffee plant (*Coffea arabica* L.) with mature fruits.

Western-southwestern coffee growing region

This region is dominated by coffee production, and accounts for about 58 % of the total land covered by coffee and 50 % of the total coffee production in the country. The region is believed to be the primary origin and center of diversity of Arabica coffee, and it houses most of the remnant forest coffee areas. It includes the administrative zones of Jimma, Metu, E. and W. Wellega, Assosa, Gambela, Bench-Shekicho, Keficho-Maji and S. Omo. The region has an average annual rainfall of about 1750 mm (range = 1200 - 2300 mm) evenly distributed over a period of 7-8 months between April and October (with a uni-modal pattern). It is predominated by a well-drained, deep friable, red lateric soils of volcanic origin with soil reaction ranging between 4.4 - 5.6 PH. The region is characterised by the dominance of semi-forest and forest coffee production systems, although some garden coffee production and almost all of the modern coffee estates are found there.

Southern coffee growing region

This region accounts for about 32 % of the total land covered by coffee and 35 % of the total coffee production in the country. The region covers the administrative zones of Sidama, Gedeo, Guraghe, Kembata, Tumbaro-Alaba, N. Omo, Borena, Arsi and Bale.

The first two are the most important coffee producing zones. The region receives annual rainfall ranging between 1200 and 1800 mm well distributed over the growing period of 8-9 months. The soils in the region are volcanic in origin, deep red brown, well drained and acidic. The major coffee production system in this region is garden coffee inter-cropped, usually with 'enset' [Enset ventricosum (Welw.) Sheesman]. However, forest coffee (in the Harrena forest of Bale) and some modern coffee plantations (in Arsi) are also found in the region.

Eastern coffee growing region

This region accounts for about 8 % of the total land covered by coffee and 8 % of the total coffee production in the country. It includes E. and W. Harerge and parts of Arsi. The region is characterised by low humidity and an annual rainfall ranging between less than 900 and 1200 mm, extending from March to October. The soils are derived from different origins and, hence, are highly variable. In the region, garden coffee is the only coffee production system. The region is reputed for its high quality coffee, fetching a high price in the world coffee market.

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Others

Minor coffee growing pocket areas in various parts of the country account for about 1.9 % of the total coffee land. About half of this pocket areas are located in Gojjam.

Coffee Production Systems in Ethiopia

The total land area used to produce coffee in Ethiopia is estimated at about 400,000 ha. Coffee production systems in Ethiopia are quite unique when compared with most of the coffee growing countries in the world. Besides being the only country in which coffee is harvested from naturally regenerating and unmanaged forest coffee populations, about 95 % of the coffee comes from subsistent farmers who have neither the capacity nor the access to use chemicals, such as fertilisers, herbicides, insecticides, fungicides or other pesticides. Even modern plantations, that cover 5 % of the total coffee land, do not apply chemicals, except low rate of fertilisation that is used occasionally.

The foregoing testimony makes Ethiopia, probably, the only country that produces and provides "organic coffee" to coffee industries and consumers around the world. However, the benefit that the country receives in return has not been satisfactory.

Ethiopia, being the primary origin of coffee, is endowed with large genetic diversity/wealth of the crop, which, apparently, has a great potential to perform well in the different agro-ecological regions of the country. The subsistent farmers have also developed efficient traditional coffee production systems, which are unique to each agro-ecological region, through continuous evaluation and promotion practices that have evolved over a long period of time. Although there are different opinions about the number and types of coffee production systems in Ethiopia, for the purpose of this paper, coffee production systems in Ethiopia are grouped into four broad categories as: forest coffee, semi-forest coffee, garden coffee and coffee plantations (MCTD, unpublished).

Forest Coffee

In this production system, coffee is harvested directly from wild populations of understorey coffee plants growing in Afromontane rain forests (referred to as "humid forest" by some authors) of west and south-western Ethiopia by subsistent farmers. Currently, forest coffee represents about 9 % of the total land covered by coffee, and contributes about 5-6 % of the total coffee production in the country. The management of forest coffee is limited to only a single slashing of the broad-leaved weedy plants around the end of the cropping season followed by harvesting. Harvesting of coffee is done by either picking or stripping off berries, and both the dry and wet methods of coffee processing are employed. The average yield of forest coffee has been estimated to be in the order of 200-250 kg/ha (Figure 2).

Semi-forest Coffee

Semi-forest coffee represents the production system in which forest coffee is manipulated through thinning of over-storey trees, removal of ground vegetation and enrichment of empty spaces in the forests by transplanting naturally regenerated or raised seedlings (Figure 3). In some instances, naturally regenerated or raised coffee seedlings are also planted under naturally growing or planted trees.

Currently, semi-forest coffee represents about 24 % of the total land covered by coffee, and contributes about 20 % of the total coffee production in the country. The management of semi-forest coffee is restricted to twice slashing of the annual weeds followed by harvesting. The harvesting and processing methods are similar to the production system cited above. The average yield of semi-forest coffee has been estimated to be in the order of 400-500 kg/ha.

Garden Coffee

For the purpose of this paper, all coffee farms (both non-intercropped and inter-cropped) established in the open, under medium or heavy shade, and having an area of less than 3 ha are categorised as garden coffee. The classical definition that described coffee farms having areas of 100-500 ha as garden coffee has become out-dated as a result of the villagization process of the 1980's. Similarly, common holding of coffee farms by peasants that were described as plantations have to be re-categorised as garden coffee, since the coffee plantations had been divided into small parcels and distributed among individual peasants.

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Figure 2. A natural coffee forest dominated by *Pouteria (Aningeria) adolfi-friederici* near Bonga town in south-western Ethiopia

Figure 3. One of the trees, *Polyscias fulva* (Hiern) Harms that is usually left as a shade tree for coffee and for hanging traditional beehives.

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On the basis of the above definition, garden coffee becomes the only system of production in Eastern and Southern agro-ecological regions, E. Wellega, parts of W. Wellega (excluding Anfillo and Gidamme) and other minor coffee growing pocket areas mentioned above. In general, garden coffee is estimated to represent 62 % of the total area covered by coffee and contributes 68-69 % of the coffee production in the country.

In the southern and eastern parts of the country, garden coffee farms usually contain less than 1000 - 2000 coffee trees/shrubs planted in the open or under medium shade with wide spacing that allows inter-cropping of annual or perennial crops. In the south, inter-cropping coffee plants with 'enset' is the common practice, while in Harerge coffee is grown under the shade of several trees (at least 16 species), usually inter-cropped with one or several (at least 15 species) important grain, fruit, vegetable, stimulant ('chat'), oilseed and spices crops (Demel & Assefa, 1991 a and b).

As a result of the above agro-forestry practices, the management in garden coffee production system is by far better and efficient compared with the above two systems. The coffee farms are regularly weeded and/or cultivated, occasionally manured, and in Harerge, where rainfall is comparatively low, the coffee farms are supplemented by irrigation. Harvesting is done by picking, usually, matured red berries; and the wet processing method of coffee is the common practice in Sidama, Gedeo and Hagere-Mariam areas. The average yield of garden coffee has been estimated to be in the order of 400-500 kg/ha.

Coffee Plantations

Coffee plantations represent about 5 % of the total area covered by coffee, and contribute about 6 % of the total coffee production in the country. The management of coffee plantations involves modern methods and improved technologies, with regard to choice of varieties, raising seedlings/nursery management, orchard establishment, etc., and post-planting operations, such as shade tree regulation, cultivation, fertilisation, control of weeds, diseases and pests as well as harvesting and processing using higher inputs. Both dry and wet methods of coffee processing are employed. The average yield of coffee plantations has been estimated to be in the order of 450-570 kg/ha.

Ethiopia is the only country, in the world, consuming 50 % of its coffee production, and Mesfin (1991) contends that Ethiopia is not only the native home of Arabica coffee but also the country that has shown the use of coffee to the world.

Now, the commercially important species of coffee, both of which originated in tropical Africa, are grown in some 80 countries in four continents (Africa, America, Asia and to a lesser extent Australia), of which some 50 export coffee (Wrigley, 1988). Judged by total value, coffee is one of the leading commodities in international trade, currently providing revenue of over 10 billion US Dollars annually to the producing countries, and work for an estimated 20 million people who grow, process and distribute the crop throughout the world. For many South and Central American countries, including Colombia and El Salvador, and many African nations, including Uganda, Burundi, Rwanda and Ethiopia, coffee is their major source of foreign exchange. Although the original home of Arabica coffee is Ethiopia, the major producers of the crop are countries found in Latin America. Brazil is the world's largest producer and a major determinant of world supply.

HISTORY

Early and current uses of coffee

The first use of coffee started a long time ago by the aborigines of Africa. Like many other plants, they used various parts of the coffee plant: leaves, fruits and seeds for food. As the ripe fruits of coffee are red with sweet pulp containing the stimulating caffeine, it is most likely that they have attracted the attention of the people as source of food. The short period of availability of fresh coffee pulp may have resulted in the switch to chewing the dry fruits. In the course of time, chewing the fruits gave way to the use of coffee in solid mixtures with other items. According to Wellman (1961), the use of coffee as solid was introduced from Africa to Arabia in pre-Islamic days, where it was eaten as a compressed product much as chocolate bars are consumed in the modern world. The Ethiopians are reported to have used such coffee bars as a sort of ration in the famous crusade of King Caleb (523-525 A.D.) when his forces went to punish the Himyaritic ruler Yusif Yarush in Yemen, who had been severely cruel in his persecution of early Christians. In Ethiopia, dried coffee berries have been

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used as a masticatory since ancient times (Purseglove, 1968). James Bruce, who travelled in Ethiopia to discover the source of the Nile between 1768 and 1773, described a concoction of ground, roasted coffee beans mixed into a ball with oil or fat, which was carried as food into the desert (Wrigley, 1988). The Oromos, one of the ethnic groups in Ethiopia, are reported to have had a special diet with a coffee base for use on long safaris. The roasted and finely ground coffee was mixed with butter or other edible oil. It was then formed into oblong lumps about the size and shape of almonds, and these were eaten as a source of concentrated energy. Camel drivers and others took coffee as pressed cakes on their caravan trips and ate it with dates. Similar uses of coffee in solid forms are reported from different African countries. Coffee was also used in early religious and marriage practices in Africa. In Ethiopia, coffee drinking is ceremonious. Its ceremonious drinking is a time to exchange news and well-wishing with friends and relatives, to express respect to guests and elders. Coffee was also used as currency in Cairo.

In addition to the customary cup use, coffee is consumed in various forms in Ethiopia. Huffnagel (1961) reported that the fruit is cooked in butter to make salted flat cakes rich in energy-yielding properties; the green cherries are roasted, ground, salted and mixed with butter for the same purpose; and the ground roasted seed is used in desserts. He also indicated that roasting is a very ancient custom. Each form of use has been also reported to have its own name (Mesfin, 1991). These forms are:

"Buna Kella" - ripe-red fruits boiled with fresh butter;
"Buna Besso" - fruits or beans roasted or boiled with butter forming part of other food items which are roasted and ground to be used by travellers, warriors, etc.;
"Buna Keshir" or "Hoja" - roasted pulps or mixture of pulps and beans drunk alone or with milk, butter, honey or salt;
"Kuti" - dried and pounded coffee leaves boiled with milk;
"Buna Areki" - liquor made from roasted coffee beans; and
"Chamo" - fresh leaves with pepper and other spices boiled with water and served with or without food.

Coffee is also consumed spiced with nutmeg, cardamom, ginger, cinnamon, fennel, cloves, black or ground hot red pepper.

Aside from its use as a beverage, coffee provides pulp and parchment which are used as manure, mulch, animal feed or fuel (Purseglove, 1968; Mesfin, 1991). Fresh coffee pulp is used for preparation of compost and tannin for tanning leather. Coffee was also used in early medicine in Arabia, Europe and America for many purposes (Wellman, 1961). It was used to comfort the brain, against pains in the head, lethargy and cough. It was and still is useful in sobering drunk people and in preventing sleepiness. It was also considered useful against rheumatism, gout, intermittent fevers, worms (for children) and it was considered a strong antihypnotic. It is still being used by many people to relieve headache in Ethiopia. The wood from the coffee trees can be used for fuel or construction purposes while nectar from the flowers is used by bees to make honey. The trees also have an indirect contribution to soil conservation as they provide shelter to the soil from the damaging heavy rain, hail and wind. Purseglove (1968) noted that coffee beans are also used to make coffelite, a type of plastic.

Early History

A good review of the different legendary stories of its discovery is given by Smith (1985) and Wrigley (1988), among which the most widely cited concerns a goatherd called Kaldi. He noticed that his goats, after chewing berries from some bushes started to prance about excitedly. He too tried the berries and enjoyed their stimulating effect. A monk who found Kaldi in this invigorated state, decided to try the berries. He took some of the berries back to the monastery, roasted and brewed them and tried out the beverage on his brethren. As a result they were kept alert during their long prayers at night.

Primitive man must have suffered from famine and hardship in each generation because of natural disasters, such as drought, floods, disease and pests, the depredation of wild animals, such as elephants, and prolonged tribal wars which destroyed his crops (Haarer, 1962). Because of these there must have been times when primitive man was forced to survive by feeding on the products of wild plants. To do so, birds and animals were watched to discover what they fed upon, and everything must have been tried and chewed to see if it was edible. The ripe fruits of some of the coffee species are sweet to the taste, and they are attractive to birds and animals. The chewing of wild coffee must have become a practice.

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Aborigines of Ethiopia used to carry ground roasted coffee mixed with oils or fats, made up into balls the size of a billiard ball to comfort and stimulate them during arduous journeys (Haarer, 1962). One such ball was said to give sufficient sustenance for 24 hours. Haarer (1962) suggested that Arab slave raiders may have noted these practices, or that captured slaves were found with dried coffee fruits in their possession. This might have led to the introduction and cultivation of coffee in Arabia.

Wellman (1961) gave two possible explanations about the introduction of Arabian coffee into Arabia. In his first explanation, he attributes the introduction to Persian invaders. He stated that during the latter part of the Sassanid Dynasty of Persia, there was an invasion of Yemen which was one of the invasions that occurred with the slow progress of the conquerors travelling overland from Persia and up the Nile Valley. The armies stayed for a long time in the territory they won, and from there made forays into Ethiopia. Early Arab invasions are significant part of Ethiopian history, and the existence of a Moslem area in Kaffa region today is worth noting in this respect (Meyer, 1965). During this time, the Persians took with them the things that interested them most. As they were great travellers and prodigious lovers of luxury, they searched in every corner for perfumes, spices, and stimulants to enrich their proud civilization. So, coffee may have been taken to Yemen in the course of these invasions. In his second explanation, he attributes the introduction to Ethiopians. He noted that Ethiopians had at one time travelled out of Africa, across the narrows of the Red Sea, to Arabia Felix (now Yemen). This was the better watered part of Arabia, with green gardens. Since ancient times, long before Mohammed, there had grown up a sanctuary in Arabia Felix, that later became known as Mecca. For very long period a separate kind of civilization flourished there, specializing in religion and in the arts of peace. Early in their prehistoric wanderings, it seems that Ethiopian adventurers and religionists visited, and settled in, the outskirts of this favoured place. It is believed that some of these travellers brought with them the first coffee seed from Ethiopia.

There are differences in opinion about the date of introduction of coffee into Arabia. Wellman (1961) considers the first introduction was about 575 (A.D.). Southard (1918) wrote that the Arabs took coffee from Ethiopia in about the eleventh century and planted it in Arabia. From there they took it back and planted it in Harar, south-eastern Ethiopia in the fifteenth century, when they occupied the country. But Haarer (1962) states that there is no reputable evidence of coffee in Arabia during the thirteenth century. More recently, Smith (1985) acknowledged that the wild Arabica coffee is indigenous to Ethiopia. He noted that it was discovered in 850 (A.D.), and was cultivated in Harar during its occupation by the Arabs. According to him coffee spread to Mecca and from there it was taken home by pilgrims to other parts of the Islamic world.

Although there is no general agreement as to when, how and by whom Arabica coffee was introduced, it is established now that the first country to which coffee was taken for cultivation from Ethiopia, is Yemen (old Arabia Felix). Later on, Yemen appears to be the secondary centre of distribution from which coffee was introduced to other countries, i.e. - India (1600), Sri Lanka (Ceylon) (1600-1696), Java (1690 and 1699) and Réunion (Bourbon) (1715-1718). These in turn were sources of planting material for yet other potential countries. Let us now see the interesting historical movement of the coffee plant to the places where it used to be and where it is now cultivated in the world.

The Spread of Coffee Drinking Habit

The exact date when coffee was first drunk is not known. However, it is well known that the drink was first discovered in Arabia about the middle of the fifteenth century. It was substituted for the infusion formerly made from the leaves of Catha edulis Forssk. In the beginning a concoction was made from the thin sweet pulp of the fruits of Arabica coffee, which the Arabs called 'kahwah', a name they used for wine. It appears that the original beverage made in Arabia from coffee was an intoxicating liquor, as it may well have become at times if it was allowed to ferment (Haarer, 1962; Wellman, 1961). That may be why it was known as 'wine of Araby' (Wellman, 1961) by the English-speaking world. The art of roasting and preparing a drink from the ground beans was discovered soon after the knowledge of the use of coffee had spread into countries bordering Arabia, and possibly first of all in Persia (Haarer, 1962). The habit of coffee drinking then spread all over the Moslem Middle East and reached Cairo in 1500/1510, Constantinople (now Istanbul) and Turkey in 1554 and Venice in 1560. It was the popularity of the coffee

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houses for all classes that promoted the drinking of coffee among the people of the Middle East (Wrigley, 1988). The coffee houses of the Middle East and Constantinople provided the town dweller with an inexpensive social activity which took him out of his house among other men whose company he found congenial. Europeans learned about coffee some 40 years before they had the opportunity to taste it (Wrigley, 1988). In 1615, a Venetian merchant brought coffee beans from Mocha to Europe (Smith, 1985). Wrigley (1988), quoting Heniger (1985), indicated that the first coffee from Mocha was brought to Holland by Pieter van den Broecke in 1616. Drinking of coffee was later introduced to other countries at different times: to Rome in 1625, France in 1644/1671, Oxford in 1650, London in 1652, Marseilles in 1659, The Hague and Amsterdam in 1663, Paris in 1675, Hamburg in 1679, Vienna in 1683, Leipzig in 1684/1694, New York in 1688, Russia in about 1700, Stuttgart in 1712, Berlin in 1721, Sweden and Denmark in 1756 (Wellman, 1961; Haarer, 1962; Wrigley, 1988). As Wrigley (1988) pointed out, the dates vary slightly according to the authority, which is understandable considering the paucity of records of this time and the small way in which coffee houses started. Although in vain, different religions and governments opposed and tried to stop the drinking of coffee for various reasons.

The Movement of Coffee Tree

Arabica Coffee (*Coffea arabica*)

During the latter half of the fifteenth century coffee beverage became a much desired luxury of royalty and nobles and the test for it spread among the wealthy and even the common people (Wellman, 1961). The spreading of coffee drinking to many countries created a lucrative trade for the Arabians, which they guarded jealously for many years (Smith, 1985). The raw beans were not allowed out of the country of cultivation without first being steeped in boiling water or heated to destroy their germinating power. Moreover, strangers were not allowed to visit the plantations. This firm control of the crop ensured them to be the only providers of coffee. However, the channels through which coffee was traded from Arabia and the Middle East to Europe were not easy in those early days and the product was costly to import. In the course of time, its monetary value increased tremendously. Because of its increasing importance both as a beverage and a prodigious source of income, several expeditions were sent by the Dutch, the French and the British to obtain seed or planting material from Arabia. Attempts were also made to establish coffee in Europe. For instance, coffee was planted at Dijon in France where it could not stand frost. Therefore, growing of coffee was and still is restricted to green-houses in the temperate regions. As a result, it was necessary for those countries that had colonies to consider the possibility of establishing coffee plantations overseas.

The first person who was successful in his attempt to steal coffee from Arabia, Mecca, was an Indian pilgrim called Baba Budan (Wellman, 1961; Haarer, 1962; Smith, 1985; Wrigley, 1988). He smuggled out the first seeds capable of germination from the highly protected plantations. He is said to have smuggled out seven coffee seeds, strapped to his belly, from Mecca and planted them at Chikmagalur in the mountains of Mysore (India) at about 1600 A. D. (Haarer included the year 1695 A.D. as an alternative). From there coffee spread to other parts of India, but it was not until the early nineteenth century that the British began to develop coffee estates (Wrigley, 1988).

The Arabs are believed to have introduced the coffee plant into Sri Lanka prior to the Portuguese invasion of that island in 1517. After heavy combat, the Dutch finally completed their conquest of Sri Lanka in 1658, but it was probably some time before they were able to turn their attention to coffee (Wrigley, 1988). The Dutch, who saw a future in coffee for the coffee-house trade of Europe, began expanding existing scattered coffee farms in Sri Lanka by about 1658 and the farms were doing well by 1690. Coffee started to be grown for profit by Europeans both in Sri Lanka and India. This began to break the dependence of Europe on coffee from Arabian ports and also started wider use of the beverage. After seeing its excellent production and development in Sri Lanka, and the wealth it brought, the Dutch continued their efforts of establishing coffee farms in the tropics. They obtained coffee plants from the Malabar Coast in India to be taken to Java (an island in Indonesia) in 1696. These were the first coffee plants introduced into the Dutch East Indies (now Indonesia). However, the coffee plants established in Java were lost by earthquake and flood in 1699. In that same year an expedition was sent to Malabar to obtain more planting material, which was successfully established and became the origin of all early coffee in the Dutch East Indies.

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In the first half of the eighteenth century Sri Lankan coffee was far more important than Java coffee. However, during the 1880's coffee growing in Ceylon rapidly became unprofitable, because of Coffee Leaf Rust (CLR), and was replaced by tea. By 1890, the coffee industry was virtually finished (Wrigley, 1988). The arabica coffee production in the Dutch East Indies developed until it was severely reduced by CLR in the 1880's and 1890's, when the industry turned to robusta and liberica coffees.

In 1706, a coffee plant was dispatched to the Amsterdam Botanical Gardens, where it afterwards produced seeds and seedlings which were distributed to the principal botanical gardens in Europe. In 1714, one coffee tree was sent to King Louis XIV of France who sent it to the Jardin des Plantes in Paris, where it was received by Antoine de Jussieu (professor of botany). Jussieu gave this coffee tree the name Jasminum arabicum laurifolio. This produced seeds and in due course seedlings.

The first attempt, by the French, to establish coffee in Réunion from seeds and small plants purchased from the port of Mocha (in Yemen) in 1708 failed and only two plants out of 60 survived the journey during a second introduction in 1715. The French continued their effort and became successful in 1717 or 1718 when they tried a third time. This time several plants, originally obtained from Ethiopia, were taken from Mocha. However, only one plant had survived in 1720; but it produced a good crop and several years later there were large plantations. The variety which did best of all in this island became known as 'Bourbon Coffee'. Hence, it was from this source that the 'Bourbon Coffee' was propagated. Similarly, the first two attempts to introduce coffee to Martinique, from Paris, by the French failed. However, they managed to introduce one coffee tree which was planted at Precheur (in Martinique) in 1723. This tree produced seeds which were used to expand coffee plantations, directly or indirectly, not only in Martinique but also in all the countries of the Americas, except Brazil, French Guiana and Surinam (Dutch Guiana) (Wrigley, 1988). Today, Martinique hardly produces sufficient coffee to satisfy its internal consumption.

As early as 1718, the Dutch had begun planting coffee, brought from Amsterdam, in Surinam. This was the first coffee planted on the continent of South and Central America. Then, it was introduced to Cayenne (in French Guiana) in 1722. Coffee was introduced to Brazil in 1727 (see Wrigley, 1988: 47-48 about doubts concerning the exact date of introduction) from French Guiana by Francisco de Melo Palheta (a Brazilian Army Officer) who was sent there to settle the boundary dispute that arose between the Dutch and French Guianas. Both of these countries had severe penalties for anyone trying to export viable coffee seeds or seedlings. However, wife of the Governor of French Guiana, who apparently had some love affair with Palheta, presented him with a bouquet which concealed among the flowers five coffee seedlings and a small bag of 30 coffee fruits (Wellman, 1961; Wrigley, 1988). On returning to Brazil, Palheta resigned from the army and started a coffee farm on the banks of the Ubituba River near Pára where they grew much better than in the Guianas. The bicentenary of the Brazilian coffee industry was celebrated in 1927.

'Bourbon Coffee' was taken by Catholic missionaries to Tanzania and Kenya at the end of the nineteenth century and it reached Uganda in 1900. French fathers are reported to have imported seeds from Aden into Kenya in 1895 giving rise to the variety as well as the name 'French Mission' which is distinct from bourbon.

Each introduction of Arabica coffee to different countries has its own interesting history. Readers interested in details of introduction of Arabica coffee to different countries are referred to the works of Wellman (1961), Haarer (1962), Smith (1985) and Wrigley (1988). Owing to limitation in space, the movement of coffee is summarized in the following chronological order based on the works of various authors. As some of the dates mentioned below vary with sources, alternative dates are provided.

-Yemen from Ethiopia by Persian invaders - ca 575 and ca 890
-Sri Lanka from Yemen by the Arabs - 1517; by Portuguese - before 1600; by the Dutch - between 1690-1696
-India from Yemen (only seven seeds) - 1600
-Java from India - 1690-1696; from Sri Lanka by the Dutch East India Co - 1699
-Amsterdam from Java - 1706
-Paris from Java - 1713/1714
-French Equatorial Africa from Paris by Royal bequest; also from Haiti - 1713/1714
-Sumatra from Java by the Dutch - 1714/1718/1719
-French Guiana from Paris by Royal bequest - 1715; Cayenne from Surinam - 1722

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-Réunion from Paris by Royal bequest - 1715 or 1717; from Yemen - 1717 - 1718
-Haiti (Terrier-Rouge) from Paris by Royal bequest - 1715/1720 or 1724
-Mauritius from Yemen - 1717-1718
-Mozambique from Ethiopia (early native introduction) - before 1717
-Madagascar from Mozambique (native introduction) - 1717
-Surinam from Amsterdam by the Dutch - 1718/1719
-Martinique from Paris by Royal bequest - 1723
-French Central Africa from Paris by Royal bequest - 1723
-Cuba from Haiti - 1724 ; from Dominican Republic (Santo Dominigo) by Spanish Missionaries - 1748 to 1750
-Guadeloupe from Haiti - 1726
-Brazil from French Guiana - 1727 (Pará in 1727; Manaos in 1770; Rio de Janeiro in 1774; S. Paulo in 1782; and 1880 and Bahia in 1787)
-Peru from Brazil - at unknown date
-Jamaica from Martinique - 1730 or 1732
-Tahiti from Réunion - 1740
-Mexico from Martinique by the Spanish - 1740; from West Indies - 1790
-Philippines by Spanish Missionaries - 1740; from Mexico - 1744
-Costa Rica from Cuba - 1748/1779; from Guatemala - 1796 and 1808
-Puerto Rico from Cuba - 1750
-Guatemala from Cuba - 1750-1760
-El Salvador from Puerto Rico - 1760; from Cuba - 1840
-Venezuela from Martinique by French priests - 1780 or 1782/1784
-Colombia from El Salvador - 1780-1790
-Bolivia, Equador and Panama from Colombia - 1784
-Hawaii from Brazil - 1825; from Guatemala - 1893
-British Central Africa from French Central Africa - 1878
-Malawi (Nyassaland) from Edinburgh Botanic Gardens/French Equatorial Africa 1878
-Zimbabwe from French Equatorial Africa - 1878;
-Natal from Zimbabwe/Malawi and from British Central Africa - unknown date
-Indo-China and Tonkin from Réunion by the French - 1887
-Tanzania (from 'Bourbon' seed) - 1890
-Kenya from Réunion by French Missionaries - 1895;
-Congo and Angola then to Mozambique from Kenya - (from the introduction in 1895)
-Australia - 1896
-Uganda from Malawi - 1900
-British East Africa (Kenya, Tanzania and Uganda) and Congo from Réunion by the French - 1901
-Rwanda from Guatemala - 1905
-Cameroon - 1905
-Uganda from Malawi - ca 1910

It is appropriate at this stage to make the following remark as pointed out by Wrigley (1988). The spread of Arabica coffee around the world was based on very limited number of trees: the seven berries taken by Baba Budan to India; the small shipment to Réunion; and the tree taken from Java to Amsterdam in 1706, together with its offspring in Paris which provided all the planting material for South and Central America. Consequently, the whole genetic base of the Arabian coffee industry is very narrow.

Robusta coffee (*Coffea canephora*)

Robust coffee occurs wild in the equatorial forest from West Africa to Lake Victoria, mainly between 10° north and south of the equator from sea level to 1500 m (Purseglove, 1968; Wrigley, 1988). It grows in West Africa, Zaire, Sudan, Uganda, north-western Tanzania and Angola although it is sometimes difficult to know whether a plant is truly indigenous or merely naturalized. It was planted on a small scale in Uganda and elsewhere in Equatorial Africa by the aborigines before the arrival of Europeans. However, its fruits were also collected from the wild trees.

Like Arabian coffee, berries of robusta coffee were chewed, especially during arduous campaigns or long journeys (Haarer, 1962). Their use as a masticatory lasted well into the twentieth century and no doubt still continues in Africa (Wrigley, 1988). Robusta coffee has been used as an offering to gods and the spirits. It has also been used in the ceremony of blood-brotherhood (Haarer, 1962; Wrigley, 1988). The similarity in shape and size of the two seeds which are found in a coffee fruit have been used by Africans to designate two brothers born from the same stem. When two Baganda wanted to become attached to each other within the meaning of blood-brotherhood, they separated the two seeds from the fruit. Each man took one, smeared it with his blood and gave it to the other to eat. These were chewed to consummate the union of eternal friendship.

The type specimen of *Coffea canephora* has been collected in the Gabon. However, planting material of

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robusta coffee was taken from Congo to Belgium (Purseglove, 1968; Wrigley, 1988). This was later distributed from the Brussels nursery firm known as L'Horticole Coloniale. The director of this firm sent 150 plants from Brussels to Java in 1900, with more importations made at later dates. In Java, it proved vigorous. It also became resistant to Coffee Leaf Rust, the disease which had decimated Arabica and later Liberica coffee. As a result, it was extensively planted. Robusta coffee had also been sent to botanic gardens in Europe earlier. It was introduced to Singapore and Trinidad from the Kew Botanic Gardens (England). Since 1900 robusta coffee has been widely distributed throughout the tropics, where it was successfully grown at lower elevations unsuited to Arabica coffee and where Coffee Leaf Rust is a serious problem. It is now the most important species in tropical Africa and Asia, but it is grown to a very limited extent in the New World, where Arabian coffee still dominates. Today, 90 per cent of what Indonesia produces is robusta coffee, making the country the largest producer of robusta in the world (Wrigley, 1988).

Robusta coffee was introduced into Uganda early in the twentieth century, in the belief that it was a different species. It was introduced into Ivory Coast in 1927 or 1929 (Wrigley, 1988). Today, Ivory Coast is the second largest producer of robusta coffee. Planting material of robusta coffee was first introduced into Cameroon from Java and Zaire although it has been introduced from many countries later.

Liberica coffee (*Coffea liberica*)

Liberica coffee was originally found near Monrovia in Liberia. It was spread by cultivation in West Africa from early times. Specimens of this species have been collected as early as 1792 in Sierra Leone. It was first grown at Kew Botanic Gardens (England) in 1872. But, it was not named until 1874. Liberica coffee was widely distributed throughout the tropics from Kew and other gardens. Planting material reached Sri Lanka and Java in 1873, Trinidad and Malaya in 1875. In Java, originally it was used to replace Arabica coffee which was being destroyed by Coffee Leaf Rust. However, it soon became susceptible and was replaced first by a hybrid of Arabica coffee and Liberica coffee which was first discovered in 1885 and later by robusta coffee which was introduced in 1900. Liberica coffee did not become important and contributes less than 1 per cent to the coffee market in the world.

Etymology of Coffee

In the country of origin coffee is known by the following local names: "boon", "bun", "bunna" (Amharic, Tigrinya), "buni", "buna", "buno" (Orominya), "narya" (Agewinya), "bun" (Aderinya), "buna" (Guraginya, Sidamonya, Afarinya, Kembatinya,), "gia", "jia" (Sahonya), "tukiya" (Welaytinya), "kawa" (Hadinya), "toke" (Gamonya) (Cufodontis, 1953-1972; Wolde Michael Kelecha, 1987). It is interesting to note that the Hadinya name of coffee 'kawa' is close to the Arabic name 'kahwah'.

Wellman (1961) listed names for the coffee drink in Arabia alone as 'kahwa', 'kaw-wat', 'cavet', 'cohvet', 'cofe', 'cohue', 'cophe', 'chaube', 'chahave', 'cahovah' and 'chohava', while the tree was called 'bon' and the fruit ' buna'. Coffee is known by the names 'buni' and 'mbuni' in Africa. It is also known as kahwah, kawa or gawah (Arabic, Kiswahili), café (French), Caffé (Italian), Kaffee (German), koffie (Dutch) and coffee (English). The Ethiopian word 'bun' is the source of the German word Bohn and the English bean (Smith, 1985). Coffee is also called Mocha, a name taken from the port of Mocha on the Red Sea coast from where it was shipped.

Different authors, including Ethiopians, claim that the name coffee is derived from the word 'kaffa' (also spelled as 'Kafa', 'Kefa' or 'Caffa'), name of the administrative region where Coffea arabica is found wild and the region now considered as its origin. It is perhaps important to note the similarity of the word 'Caffa' to the Arabic names 'caova' and cova' which are believed to be sources of the Latinized generic name, Coffea, coined by Linnaeus. Huffnagel (1961) suggested that whether the name coffee actually was derived from Kefa will always remain in doubt as the drink, the food and the fruit are all called 'bunna', and that it is highly unlikely that Ethiopians would have spread another name. He further pointed out that the Arabs who had long ago used the word 'qahwah' for coffee may be considered the first to bring the coffee beans outside the former and sequestered kingdom of Kafa and that it is possible for the name of the region of origin to be used then later transformed. It has also been reported that the name 'bunna' and 'coffee' are derived from "Buno Bedele" and "Kaffa" regions of Ethiopia respectively, known to contain wild Arabica coffee plants in Ethiopia.

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BOTANY

Coffee belongs to the genus Coffea in the plant family Rubiaceae, one of the largest flowering plant families containing some 500 genera and 6000 species. The number of species recognized by different authors as belonging to Coffea ranges from 25 to 100 (Wrigley, 1988), but Bridson (1982) considers that there are, in Africa, probably 25 good species with an additional 11 poorly known ones. However, the most important economic species of the genus are Coffea arabica L. producing about 80 per cent of the world's coffee, Coffea canephora Pierre ex Froehner supplying most of the remaining 20 per cent having grown in importance with the increase in sales of instant coffee since the Second World War and Coffea liberica Bull ex Hiérn contributing less than 1 per cent. No true members of Coffea are indigenous outside of Africa, Madagascar and the Mascarenes.

Botanical features of Coffea

All species of Coffea are woody, ranging from small shrubs to large, robust trees 10 m tall. Characters of the plants vary widely. Some lose their leaves at the beginning of the dry season, others keep them for three or more years; the three economic species are evergreen. The leaves range in colour from yellowish to dark green; the newly developed leaves of some varieties are bronzed, others purple-tinged; they vary in size from 1-40 cm in length, C. liberica having the largest. While the cultivated coffee species have dense clusters of white fragrant flowers, some species have flowers which are cream, even tinged with pink or purplish red and without fragrance. Some of the fruits have sweet pulp while others are unpalatable when ripe; they show a variety of colours, from green through red and purple to black, while others are such a clear yellow as to appear nearly white. Some are small as peas, others as large as plums.

All species of Coffea have opposite leaves and branches (although occasional abnormal individuals are found in which there are whorls of three). Coffee shoots have two distinct features: (a) the axil of each opposite and decussate leaf contains not one, but a series of buds, and (b) there are distinct vertical and horizontal shoots (Cannell, 1983). The vertical (orthotropic) shoots produce horizontal (plagiotropic) branches from the topmost buds in each leaf axil, while the lower buds can produce only new vertical shoots. But most of these lower buds usually remain dormant, and proliferate on the vertical stems and stumps of the trees, so that new vertical shoots (suckers) can be produced from them at any time by cutting off or bending the existing vertical stems (thereby removing 'apical dominance'). The horizontal (plagiotropic) branches can produce more horizontal branches from the topmost buds in each leaf axil, while the several lower buds each produce an inflorescence of 4-5 flowers. The horizontal branches cannot produce vertical stems. Once the leaf nodes on the horizontal branches have produced flowers and borne fruits, they cannot do so again. The growth in coffee trees is by a typical form of monopodial branching where the branches (primaries) remain subsidiary to the main stem, which continues to grow indefinitely by extension of the apical bud (Bridson in Wrigley, 1988). The largest horizontal branches are furthest from the apex of the main stem and their size decreases regularly towards the top of the plant. These horizontal primary branches tend to have the same pattern of branching along their length, giving rise to paired secondary and tertiary and even quaternary branches, which are collectively referred to as sub-laterals. The result is a pyramidal development, where the shape of the crown is a series of discs one over the other, which provides a complete ground cover within the radius of the tree.

In most species the flowers are borne with leaves, but in some the flowers are borne on leafless branches. The flowers are axillary but may rarely be terminal. In the majority of species the flowers are individually borne, 1-3 being present at an axil, while in the commercial species one or more fascicles of flowers with a common stalk (peduncle) occur. Fascicles and single-flowered inflorescences may occur in the same axil. The corolla is white or rarely pink. The majority of species have (4-)5-lobed corollas, while some have 6-9(-12)-lobed corollas. The corolla tube is typically cylindrical, widening just below the throat. However, in some species it is much shorter than the lobes while in others it is slightly shorter than or almost equal to the length of the lobes. The stamens equal the corolla-lobes in number, they are attached at the mouth of the corolla-tube and are erect and exerted; the filaments are dorsally attached to the linear anthers. The ovary is two-locular and ovules are solitary. The style is slender and exceeds the corolla-tube. The stigma is always bilobed and exerted.

The fruit is a drupe, usually fleshy, containing 2, sometimes 1, more or less coriaceous, one-seeded

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pyrenes. It varies in size but very little in shape. Its colour varies from yellow to black, though is mostly orange to red. The disc of C. liberica is prominent on the fruit, while in a few other species the apex of the fruit is constricted into a beak or bottle-neck-shaped. Ribbed fruits are also known in the genus. The skin of the fruit contains the pulp, or mesocarp, which is juicy (although this is not the case in all species) and this envelops the endocarp or parchment shell. Inside the parchment is found the seed. In C. arabica, the seed-coat known as the 'silver skin', but it is not silvery in colour in some other species. Seeds ('beans') commonly taper little to one end and have a crease down the middle of their flattened sides at the place where the two seeds come together in fruit. The embryo is erect, somewhat curved and is surrounded by the pale endosperm which becomes horny when mature and dry. The above description is based on the works of Wellman (1961) and Bridson (1982, 1988).

Taxonomy

The first botanical description of coffee was made by Antoine de Jussieu based on a single plant cultivated in Paris obtained from the botanical garden of Amsterdam in 1714. He coined the name Jasminum arabicum laurifolia (Oleaceae). However, Linnaeus classified it as a separate genus, Coffea, in the Rubiaceae in his Genera Plantarum (1737). Coffea arabica was described in his Species Plantarum (1753) and this name is still in use today. The works of both Jussieu and Linnaeus were based on specimens of direct or indirect Arabic origin. Quoting the works of various authors, Sylvian (1955) discussed descriptions of Arabica coffee from Ethiopian material. The names used in these descriptions include Coffea arabica var. abyssinica Chev., Coffea abyssinica Hort. and Coffea kaffensis Bieber. The latter name was used by Bieber who had widely travelled in the Kefa district (Ethiopia).

The taxonomy of the genus Coffea is difficult, as the morphological characters traditionally used to separate species are weak and often present a degree of overlap. Undoubtedly, some groups of species are more closely interrelated than others but, as yet, such species clusters have not been clearly defined by sound taxonomic characters, morphological or others (Bridson in Wrigley, 1988).

For the historical outline of classification of coffee, readers are referred to the works of Charrier and Berthaud (1985) and Bridson (in Wrigley, 1988). In the following text current taxonomic position of Coffea will be discussed. The genus Coffea is divided into three subgenera, Coffea, Baracoffea and Psilanthopsis by Leroy (1980). These have the following diagnostic features as presented by Bridson (in Wrigley, 1988).

General for genus Coffea: anthers and styles always exerted; corolla-tube usually about the same length as the lobes (but longer in a few Madagascan species.); flowers borne on axillary inflorescences (monopodial development) or less often terminal on reduced shoots (sympodial development).

Subgenus Coffea: calyx-limb reduced to a rim; fruit not ribbed, or only slightly ribbed; flowers, one or several in axillary clusters; corolla tube about the same length as the lobes; species of forests and woodlands.

Subgenus Baracoffea: calyx-limb reduced to a rim; fruit not ribbed, or only slightly ribbed; flowers solitary, terminal on reduced shoots; corolla-tube about the same length as the lobes (African species) or longer than the lobes (Madagascan species); species of arid areas. Subgenus Psilanthopsis: calyx-limb well developed and dentate; fruits distinctly ribbed.

Subgenus Coffea contains by far most of the species and includes all those commercially important. New species are still being described. For instance, Bridson described 5 new species in 1982 and 1986 from East Africa, and Leroy has described several species from Madagascar and Mascarenes in the past two decades. There is also a possibility of other new species to be described in the future.

Subgenus Baracoffea was originally based only on one species from Madagascar, but now contains additional two Madagascan and one East African species. It is reported to be interesting from an evolutionary point of view since it seems to form a link between the two genera: Coffea and Psilanthus (a genus closely affiliated to Coffea).

Subgenus Psilanthopsis comprises only one Angolan species and it is considered to be related to some of the poorly known East African species.

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Bridson (1988 and in Wrigley, 1988) gives some diagnostic features of the three most important economic species to facilitate their identification. These features are the following:

Common for C. arabica and C. canephora: stipules apiculate or aristate or occasionally acute; apices of leaves distinctly acuminate; domatia (small cavities) absent or situated in the nerve axils.

C. arabica: bracteoles bearing small subfoliaceous lobes (not exceeding 0.5 cm long); pedicels 1-2(-3) mm long, so that the calyces exceed the bracteoles at anthesis; leaves 7-18 cm long; lateral nerves in 7-10 main pairs; domatia glabrous or rarely ciliate, sometimes absent; flowers (4-)5(-6)-merous.

C. canephora: bracteoles bearing large subfoliaceous lobes (up to 2.2 cm long); pedicels usually very short, so that the calyces do not exceed the bracteoles at anthesis; leaves 12-35(-40) cm long; lateral nerves in (8-)11-15(-17) main pairs; domatia absent or pubescent; flowers 5-6(-7)-merous.

C. liberica: stipules obtuse or occasionally acute, rarely apiculate; apex of leaves obtuse, rounded and shortly acuminate or rarely acute; domatia usually situated across the base of the lateral nerves or occasionally in the nerve axils; leaves mostly 14-37 cm long; lateral nerves in (7-)8-13 main pairs.

Between 40 and 50 infraspecific taxa of C. arabica have been mentioned in the literature. Taxonomically, they are better referred to as cultivars (Bridson, in Wrigley, 1988). Many authors recognize two varieties of C. arabica, namely: var. arabica and var. bourbon. Var. arabica is now considered to have originated from the native Ethiopian C. arabica, which was subsequently distributed into cultivation from the Yemen. Var. bourbon arose as a spontaneous mutant from Ethiopia cultivated by the French on Réunion. The two varieties differ from each other in that var. arabica has bronze-tipped young leaves and pendulous fruit-bearing branches while var. bourbon has green-tipped young leaves and fruit-bearing branches which bend down only at the tips. Coffee plants corresponding to both varieties, having considerable variations, can be found in coffee growing regions in Ethiopia. All other infraspecific taxa are assumed to have been derived from these two varieties.

It is beyond the scope of the present paper to present a detailed account of the taxonomy of coffee. Interested readers are referred to the works of Chevalier (1947), Wellman (1961), Haarer (1962), Leroy (1980), Bridson (1982) and Charrier and Berthaud (1985). However, in the following text, an effort will be made to discuss the overlooked or probably the forgotten part of Coffea arabica, i.e. the infraspecific classification (varieties, cultivars and land races or types as they are referred to by some), which are the potential sources of genetic diversity found in Ethiopia.

Infraspecific categories of *Coffea arabica*

All botanists who have visited the coffee growing areas have reported that there is only one species of Coffea in Ethiopia, i. e.,*C. arabica*. The presence of numerous land races (types) of coffee has been recognized for a number of years, although a thorough modern taxonomic survey is lacking (Sylvian, 1958; Wellman, 1961; Meyer, 1965; FAO, 1968; Melaku, 1982a, b; Watkins, 1985, 1987; Tewolde, 1990; Demel & Assefa, 1994; Meseret, 1996). Traditionally, problems in coffee research have largely been confined to the cultivation, disease and pests as well as economic aspects associated with marketing of the crop. However, the great variability of the species, especially of Arabica coffee, in Ethiopia deserves taxonomic studies to identify and establish the different varieties/cultivars/land races (types) which will help to conserve its genetic diversity. The number of traditionally recognized land races of Arabica coffee in Ethiopia is very large. No scientist has as yet fully and systematically described and documented them (Tewolde, 1990). Since cultivated and wild coffee are often in the same general vicinity, it is hardly surprising that a large genetic variability exists in cultivated Ethiopian coffee. According to Sylvian (1958), one of the most detailed classifications of Ethiopian land races (types) among the earlier works was that of Spaletta. He based his classification almost uniquely upon the beans and recognized four main varieties. Sylvian (1955, 1958) cited 12 land races (types) in his tentative classification of coffee in Ethiopia. He considered habit of trees, size and colour of leaves, calyx characteristics, size and shape of fruits and seeds as well as yielding ability in his classification. In 1988 we studied coffee (also known as Harar/Mocha coffee) grown in the Harerge region, located in south-eastern Ethiopia (Demel and Assefa, 1994) and found about 22 different locally identified land races of coffee. The names of these land races are given by the farmers. They based on the name of the

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Figure 4. A new land race coffee type that we discovered at Dawo Tobi, near Mugi town in Western Ethiopia. Characteristically the stems are whitish.

place from where the land race was first obtained; the habit and mode of branching of the trees; the way the fruits are produced on the trees; the size of leaves; names of individuals and unknown reasons. Farmers have gathered such experience, through time, that they can easily demonstrate the differences among the various land races in their neighbourhood. We divided the 22 land races into two of the varieties, var. arabica and var. bourbon, based on the colour of the pair of leaves at the tip of leaf-bearing branches. Out of the 22 land races, 19 were categorized as var. arabica since they possess bronze-tipped leaf pair, usually smaller than the other leaves, and the remaining 3 as var. bourbon since they have green-tipped leaf pair. At times, as many as 5 different land races were encountered in a single area of coffee farm.

Most of the coffee farms in the region are relatively small as a result of which cultivation of the crop is very intensive, sometimes involving coffee and several other crops, such as sorghum and maize on the same piece of land. Because of the intercropping practice, the farms are regularly tended. During harvesting only the ripe fruits are picked and dried carefully. The care provided by the farmers coupled with the favourable environment has helped the coffee produced in the region to become the best Ethiopian Arabica Coffee. As Premium Blending Coffee, it attains highest price in the coffee marketing world.

Recently, the Ministry of Coffee and Tea Development prepared a document in which the different locally identified land races of coffee from the various coffee growing regions are presented (Admasu et al., 1989). According to the document, there are more than 130 different locally known land races of coffee in coffee growing regions of Ethiopia. This figure may increase if thorough investigations are made (Figure 4).

Further taxonomic investigations may lead to lumping of several locally known land races into one since one land race may have different names used by the farmers living in different areas. One other factor to be considered in this connection, given the growth of different land races under widely different ecological conditions, is the difficulty of distinguishing between the effect of environment and those of genetic constitution. However, the collection of seeds and establishment of these land races at one place may help to determine how far environmental differences alter the expression of genetic constitution.

Although Arabica coffee is extensively cultivated throughout the tropics, Ethiopia is still the major centre of genetic diversity. It is also indicated that the coffee cultivated all over the world is propagated from very few trees originating from Yemen suggesting that its genetic base is narrow. This can be easily demonstrated by citing some events from the history of coffee cultivation in the world. Coffee production was totally abandoned in Sri Lanka as a result of the introduction of Coffee Leaf Rust in 1869. Similar phenomena were encountered in Java and Sumatra in 1876. The picture would have been different had there

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been genetic variability within the cultivated coffee in these countries. On the other hand, economic coffee production is still possible despite the fact that leaf rust is endemic to Ethiopia and even in the out-break of a new disease known as Coffee Berry Disease (CBD) in 1971 (Tewolde, 1990). This is attributed to the availability of genetic variation large enough to withstand diseases and pests. Moreover, using this resource, Ethiopian scientists were able to identify CBD resistant cultivars, which are now being distributed to coffee growers. Germ plasm collected from Arabica coffee in Ethiopia at different times is being used in breeding programmes to develop high yielding and at the same time resistant cultivars. These examples show the importance of the genetic diversity of Arabica coffee existing in Ethiopia for future development of the crop.

Although Ethiopia has the genetic wealth of Arabica coffee (also of several other crops), given its extremely poor economic capability, it cannot possibly conserve this world resource of great importance on its own (Tewolde Berhan G. E., 1990). The world should realize, therefore, that left to the capability of Ethiopia alone, there is the greatest of risks that man will lose much of the genetic base of one of his most important cash crops. This should be enough for a world-wide co-ordinated effort to help Ethiopia save the gene-pool of C. arabica on behalf, and for all, of mankind.

Conservation of the Arabica gene-pool should, therefore, be of world importance as it provides opportunities both for the development of disease and pest resistant cultivars and for improving coffee yield. This calls for a world-wide combined effort in the investigation, germ plasm collection and conservation (both in situ and ex situ) of the crop especially at a time when the forests housing this genetic diversity are disappearing at a shocking rate as a result of deforestation, climatic change, overgrazing, war (especially ethnic clashes), etc.(Figure 5). This is even exacerbated by the fact that coffee production in the country is in severe competition with other lucrative agricultural crops, for example with 'chat' (Catha edulis (Vahl) Forssk.) in the south-eastern part. Here, coffee plantations are being replaced by 'chat' plantations, a stimulant plant getting popularity and markets both within and outside the country. This and other similar competitions definitely lead to genetic erosion of coffee.

Harlan (1969) pointed out that Ethiopia has a survival of an entire agricultural system little changed from prehistoric times in that ancient methods of tillage, sowing, reaping, threshing, winnowing, dehulling and processing for consumption have been preserved, as have the uses and attitudes of the people towards their ancient crops. Here, one can still study things that history failed to record about the evolution of the agricultural system that provided the base for Western civilization. He further noted that there is no other place left where this can be done since other centers have been destroyed by the replacement of ancient varieties by new products of plant breeding. Other centers have disappeared under the impact of modern technology. After twenty four years, very little has changed in Ethiopia to contest Harlan's statement. However, coffee farms have rapidly been either newly established or replaced/enriched by resistant varieties of CBD, a result of modern technology. Although this has a positive contribution in increasing yield, it may lead to genetic erosion if those coffee farms being replaced are not represented by germ plasm collections which will be established for conservation elsewhere.

Fig. 5 The disappearing natural coffee forest ecosystems.

The above being the case, little effort, as compared to the available large genetic base, is being made to materialize investigation and conservation of the gene-pool of Arabica coffee. As far back as 1955, Sylvian wrote "it is somewhat surprising that after more than two

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centuries of cultivation in the western world, practically no study of C. arabica L. has been made in Ethiopia which appears to be the native home of this species of such economic importance". Tewolde Berhan G. E. (1990) summed up the problem of coffee in Ethiopia by saying "Arabica coffee has the bizarre distinction of being commercially one of the most important and, at the same time, in terms of genetic conservation, one of the most neglected crops in the world".

If the genetic variability of wild and cultivated coffee populations is to be saved from erosion and extinction, there is an urgent need to conserve the natural forest habitats which are being destroyed very rapidly and to make botanical studies which ultimately will also help to collect germ plasm which will be used in establishing living collection. This needs dedication from bodies concerned both within and outside the countries of origin and genetic diversity of coffee species and financial support from donor organizations.

ECOLOGICAL REQUIREMENTS

The productivity and longevity of a coffee plantation depends upon the environmental conditions and management. Ideal conditions are those which permit good crops to be harvested annually without exhaustion and die-back and without the numerous pests and diseases. Therefore, a brief discussion of the various ecological requirements is appropriate.

Rainfall

Arabica coffee can be grown with an annual rainfall of under 762 mm to well over 2540 mm, although the best conditions are provided by annual rainfall of 1524-2286 mm (Purseglove, 1968). In most of the best coffee growing regions of Africa, Latin America and South-east Asia, the rainfall is significantly above 1,800 mm annually and is well distributed throughout the year with drier period of two to three months when growth slows, young wood hardens and flower buds develop (Van Hilten, et al., 1992). In India and Indonesia and in certain parts of coffee-growing areas of Africa, rainfall exceeds 2,500 mm a year. In Brazil and in certain parts of Central America, coffee is produced in areas with rainfall of below 1,500 mm. The rainy season in these sites lasts about six months and is followed by several months of dry weather during which the harvest takes place. In some areas where rainfall is low, coffee is irrigated as, for instance, in the coffee producing valleys of Harerge, south-eastern Ethiopia and Yemen. In some areas of limited rainfall, for example in Kenya (east of the Rift Valley), coffee is highly sensitive to competition by weeds and shade trees which necessitates mulching to conserve soil moisture. Coffee producers in some countries, for example in Brazil, grow coffee in full sun as there is insufficient soil moisture both for the coffee and shade trees (Willson, 1985). Since coffee is evergreen, it requires sub-soil water at all times, but the surface feeding roots require a drier period for part of the year to slow up growth, ripen the wood and initiate flower buds. However, a higher water table or heavy clay soil limits root penetration.

Robusta coffee is grown with rainfall ranging from 1016-2540 mm, the optimum being 1778 mm (Purseglove, 1968). Liberica coffee, on the other hand, requires a heavy rainfall.

Temperature

C. arabica prefers a climate tempered by altitude with temperatures of 18-24°C and with contrasting seasons while C. canephora grows best under warm equatorial conditions with annual temperatures averaging 24-26°C and less contrasting dry and rainy seasons (Van Hilten, et al., 1992). C. liberica has been reported to require high temperatures as it is adapted to hot and wet lowland forests (Purseglove, 1968). At temperatures above the optimum, forced rapid growth occurs associated with too early bearing, overbearing, early exhaustion, die-back and disease attack. Higher temperatures can also cause flower shedding and reduce fruit formation. On the other hand, coffee trees will show slow, stunted and uneconomic growth, high production of secondary and tertiary branches and the so-called "hot-and-cold" disease in cold temperatures. Neither Arabica nor robusta can withstand frost, although Arabica is more resistant to cold. The problems of high and low temperatures can be mitigated to some extent by using shade trees and mulching.

Soils

Coffee grows well under certain physical and chemical properties of the soil (Willson, 1985). Among the physical properties, soil structure which allows good drainage is the most important

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requirement since water logging reduces yield considerably and even results in the death of coffee trees themselves if they stay long enough under waterlogged condition. In general, heavy clay soils are not suitable for coffee cultivation as they have poor soil drainage, as a result of which root penetration and growth is either difficult or impossible. Water capacity and depth are other two properties that should be considered when planning for coffee cultivation. High water capacity helps to maintain evapotranspiration during the dry season since it provides sufficient available water while deep soil allows root proliferation by offering a larger volume of soil which contains more water and nutrients around the coffee trees. Especially, in places where there is a long dry season coupled with lower rainfall, deep soils are necessary. It has been suggested that 3 meters depth of soil is ideal. At the other extreme coffee is grown successfully where rainfall is high, the dry season short and cloud cover frequent in clay soils only 15 to 20 cm deep over heavy clay which is not penetrated by coffee roots, for example in Papua New Guinea (Willson, 1985). In such conditions, crop yields can be markedly reduced in years with excessive rainfall or an unusually long dry season. The most important properties of soils for the growth and yield of coffee are pH (acidity/alkalinity) and the quantity of nutrients available to the plants. Various reports indicate that coffee is grown on soils varying from extremely acid (pH below 4.0) to slightly alkaline (pH up to 8.0). However, neither of this extremes is suitable for economic high output production. A slightly acid soil is preferred.

Arabica coffee can adapt to soils derived from various parent material and is reported to grow well on deep, slightly acid, well drained, fertile loams of lateric or volcanic origin with reasonable humus content (Purseglove, 1968). As might be expected from the wide distribution of wild plants at varying altitudes and different environments, robusta coffee is not so specific in its requirements as Arabica coffee and shows a wider range of adaptability. Robusta coffee is grown on red sandy, clay or gravely loams in Uganda (Wrigley, 1988). Liberica coffee can also be grown on a variety of soils, from peat to clay and on poorer soils. It can withstand more neglect than the two other species

Altitude

Altitude is important for its direct influence on climatic conditions. It appreciably affects temperature in that there is a fall of about 6°C for every rise of 1000 m in altitude. Arabica coffee is an upland species growing naturally as an understorey tree in forests of southwest Ethiopia between about 1370 and 1830 m above sea level (Purseglove, 1968). Favourable conditions for the growth of Arabica coffee are found on the equator at approximately 1525-1830 m above sea level. However, the optimum altitude for the growth of coffee differ from country to country. For instance, the optimum altitude on mount Kilimanjaro in Tanzania is 1370 to 1680 m while it is 1590-1770 m and 920 m in Kenya and Mexico, respectively. In equatorial areas Arabica coffee is a highland crop growing between 1,000 and 2, 000 m above sea level (Willson, 1985). As the distance from the equator increases, Arabica coffee continues to be a valuable crop at lower altitudes until restricted by frequent or lengthy frosts. Wellman (1961) discussed the wide range of altitude and topography in which coffee is grown. It is grown in areas with fairly high elevation (e.g. Ethiopia), on steep slopes/hillsides (e.g. Puerto Rico), on flat or slightly rolling land (e.g. Brazil), on flat and moderately undulating topography (e.g. Kenya), on high and rugged as well as in flat lowlands (e.g. Panama), at about 610 m and less (e.g. Costa Rica) and on flat lands almost at sea level (e.g. Ecuador).

Robusta coffee grows from sea level up to 1500 m (Purseglove, 1968; Wrigley, 1988), with an optimum altitudinal range of 300-760 m in Java. It grows very well at 1220 m near Lake Victoria in Bukoba and Buganda.

Humidity and cloud

Humidity plays a role in governing the loss of water or moisture by evapotransipiration. When it is high, loss of water is reduced and vice versa. It is especially important during the dry season as high humidity decreases the stress on the coffee trees thereby extending the rainless period through which the plants will survive without damage.

Cloud is important in that it intercepts sunlight thereby reducing its intensity. This leads to an increase in humidity and lowering of temperature both of which are favourable during long dry seasons. Cloud may also contribute to soil moisture when it appears near the ground in the form of mist.

Wind

Wind may have different effects on the growth and yield of coffee. Strong wind is detrimental as it may

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break branches of coffee trees. It also increases evapotranspiration as a result of which it creates water stress in the trees. Cold wind increases the effect of low temperature leading to an increased effect of the so called 'hot-and-cold' diseases. Hot wind may cause wilting or even death of leaves of coffee trees. Both cold and hot wind can reduce growth and yield of coffee. However, these problems can be counteracted by providing wind-breaks for the coffee trees.

Topography and aspect of the coffee growing areas are also important ecological factors. Steep slopes with problems of erosion and access, valley bottoms, with risks of frost, and sites close to seas, with risk of salt spray, and areas liable to flooding should be avoided.
In Ethiopia, coffee growing areas are located in the altitudinal range of 550 and 2550 m, the highly suitable range being 1500-1800. The range of temperature which is highly suitable for coffee growing is 22-25°C, with little variation between the seasons but with great monthly and daily fluctuations. Annual rainfall above 1300 mm is highly suitable for growing coffee although coffee can be grown within the range of 900-1300 mm of rain per year. Cloudiness is relatively high especially during the rainy season. The mean relative humidity of wet months for the highly suitable areas to grow coffee ranges between 50 and 70 per cent, although coffee can also be grown in areas with mean relative humidity ranging between 70 and 90 per cent. The mean relative humidity of dry months in coffee growing regions ranges between 20 and 50 per cent, the highly suitable range being between 40 and 50 per cent (Admasu et al., 1989). The Ethiopian forest soils are deep, red to brown-red, lateric loams or clay loams of volcanic origin, having a pH range of 4.5 to 6. This indicates that Arabica coffee growing in Ethiopia favours acid soil (Sylvian, 1955).

Measures used to modify coffee growing environment

Shade

The use of shade is controversial. In many coffee growing countries coffee is grown satisfactorily without shade. When coffee is grown under optimum conditions of soil and climate, with a high standard of cultural practices and adequate inputs, higher yields are obtained without shade (Purseglove, 1968). Where soil conditions are not so favourable, rainfall is excessive, temperatures are too high or too low and possibly where there is a prolonged season of many hours of bright sunlight as well as low standard of cultivation, it is advisable to use shade to sustain regular yields and prevent over-bearing. Coffee trees established without shade give higher early yields than shaded coffee. Nevertheless, they have tendency to over-bearing, die-back, biennial bearing, erosion, disease and short productive life. However, in its country of origin, C. arabica grows naturally as an understorey tree under the shade of several trees. Sylvian (1955) made the following observation about shade trees in coffee forests in Ethiopia. In places where the upper stories of the coffee forest have been removed the yield usually rises but the coffee trees, because of this increased production/direct exposure to rapid fluctuations in temperature, become weakened and are more susceptible to some diseases. After a few years, they lose all vigour and sometimes die. In some forests where the lower shrubs and trees competing with coffee have been removed but most of the upper storey left intact, the yields have been increased and the plants seem to maintain their good health. In coffee producing areas of south-eastern Ethiopia, a total of seventeen permanent and temporary shade plants have been found being used in coffee farms (Demel and Assefa, 1991a). The general benefits obtained from planting coffee trees under shade are discussed by Purseglove (1968).

Mulch

As pointed out earlier, in areas where moisture is limiting, coffee is highly sensitive to competition by weeds and shade trees. This problem can be solved by using mulching, i. e. covering the topsoil with non-living crop residues for the purpose of protecting the soil and increasing coffee production. The benefits of mulching are discussed in detail by Wrigley (1988). Mulching reduces soil temperature, protects the soil, conserves rainfall (moisture), has a beneficial effect on soil nitrate, increases the nutrients available to the coffee plant and replaces those removed with the crop, increases the organic content of the soil, promotes good root growth, reduces the growth of weeds and soil acidity. As a result mulch increases yield. However, it has economic disadvantages. A large area of land is required to produce mulching material, land which is generally suitable for growing coffee or food crops. Moreover, cutting, carrying and spreading the mulch takes a lot of labour, time and money. Besides, the heavy work is not liked. On the other hand, dry grass or any other mulch can be a fire hazard,

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particularly in a severe dry season while in a wet season material used for mulch might take root and become competitive.

Cover crops

Where rainfall or moisture is adequate, it may be beneficial to plant cover crops with coffee (Wrigley, 1988). The cover crops help to protect the soil from erosion, reduce soil temperature, build up the soil organic matter and fix atmospheric nitrogen if they are leguminous. Moreover, the coffee trees will benefit from the regular tending activities of farmers because of these crops. It has been reported from several African countries that coffee is grown as part of traditional tree crop based agroforestry practices. For instance, in south-eastern Ethiopia, the wide spacing (3.5 x 3 m) used by farmers between coffee trees allows them to plant other cover crops and shade trees. A total of 15 important grain, fruit, vegetable, stimulant, oilseed and spice crops as well as 17 shade plants were recorded (Demel and Assefa, 1991b).

In this region, coffee was also observed to be planted in gardens dug down to about 50-70 cm in a rectangular shape (Demel and Assefa, 1991b) to provide the seedlings with favourable 'micro-environment'. The basin catches ample water during the rainy period and protects the seedlings from damage by animals, heavy wind or storm. One other remarkable practice associated with this is the planting of tomato as a nursing plant. The tomato plants are supported by sticks during their prolific growth in such a way that they provide temporary shade to the coffee seedlings. On maturation, the tomato plants provide both edible fruits for human consumption and organic matter, which improves soil fertility for the coffee seedlings.

Pruning

Pruning opens up the coffee tree to allow more light and wind movement into the tree (Wrigley, 1988). The increased light is important in inducing more flower buds. Photosynthesis is increased by leaves which were previously heavily shaded. Creating greater freedom for air to pass through the coffee plot and individual trees, dries out the leaves more quickly after rain or heavy dew, making conditions less favourable for the spread of certain diseases.

FACTORS GOVERNING THE QUALITY OF COFFEE

The quality of coffee is governed by two main factors: the inherent properties of the mature beans resulting from environment and genetic constitution, and the manner in which the beans are treated from harvesting to delivery on the market (Sylvian, 1958). The quality of coffee includes a series of characteristics of a physical as well as a chemical nature. The physical nature refers to the general aspect of the product as determined by size, shape, uniformity, freedom from visible defects and other external traits. Chemical characteristics include factors affecting aroma, flavour, body, and acidity, which vary according to chemical constituents within the bean. When the fruits mature they should be carefully picked as this greatly influences the aroma, taste and other qualities of the marketable product. Fruits should be harvested when they are fully ripe as both unripe and over-ripe fruits provide a poorer grade coffee (Figure 6). Stripping of coffee should be avoided during harvesting. This leads to mixing of unripe, ripe and over-ripe fruits as well as the stripping of leaves and buds from the branches. Mixing green, pink and black fruits and even those collected from the ground with the ripe ones will produce coffee without aroma and often with an unpleasant taste. Therefore, this practice must be avoided. Stripping of leaves and removal of buds will affect

Fig. 6 Fully ripe coffee fruits.

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the future production of coffee from the trees or it may even lead to their death. Methods of drying coffee also affect the quality. Drying coffee on the ground, as it is practised by some coffee growers in Ethiopia and probably other countries too, produces an earthy or muddy taste. Leaving the fruits for several hours or overnight in heaps or in bags/baskets may favour moulding and causes a preliminary fermentation giving the coffee a disagreeable taste and odour (Huffnagel, 1961). This condition may be aggravated in the presence of dew or rainfall. Adulteration of coffee seeds with seeds of other species and their contamination with materials such as oil or fuel reduces the quality of coffee. The quality of coffee can be greatly improved by using the wet method of processing (which gives what is known as "washed coffee", Figure 7). Great care is also required during the transportation of coffee fruits/beans from place to place until they reach coffee processing industries or consumers to avoid any event that may result in the reduction of its quality

During my four years of work experience (1977-80), first as a quality inspector at Jimma and later as an extension agent at Agaro in the Ministry of Coffee and Tea Development, I have observed farmers harvesting immature green coffee, sometimes with the leaves, by stripping them off the branches (Figure 8). This has a direct bearing on the quality of the coffee and on the well being of the coffee plant since the loss of leaves means a decrease in the photosynthetic ability of the plant. Moreover, I also observed the fresh fruits stored in sacs and other containers without appropriate ventilation. This encourages moulding and blackening of coffee. Other activities which reduce the quality of coffee cultivated in Ethiopia are: drying coffee on the ground; pounding coffee fruits using traditional mortar and pestle to separate the beans from the hulls; adulteration of beans with other seeds, notably seeds of Cordia africana (one of the principal coffee shade trees) which are similar in appearance to those of coffee and contamination of the beans with other materials. However, coffee is carefully inspected, several times, graded and cup-tested before export to ensure that it contains high quality, rich in body, aroma and with the unique natural highland flavour. Ethiopia is known to produce some of the world's finest varieties such as 'Yirgachefe', 'Limu' and 'Harar' (also known as 'Harrar' or 'Harari') (Van Hilten et al., 1992). Harar coffee has a niche in the Middle East where it realizes substantial premium even over top-quality washed Arabicas. Several authors claim that due to the use of traditional cultural methods and negligible use of inputs like chemical fertilizers, pesticides or herbicides, Ethiopian coffee is relatively pure and is appreciably free from chemical residues that are now known to be harmful.

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Fig. 7 Washed coffee being dried on tables.

Fig. 8 Ladies stripping branches of the coffee plant during harvesting . Note the twigs, leaves and buds mixed with the coffee fruits.

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