Climatic Variables and Impact of Coffee Berry Diseases (Colletotrichum Kahawae) in Ethiopian Coffee Production

Kifle Belachew* Demelash Teferi
Ethiopian Institute of Agricultural Research, Jimma National Coffee Research Centre. P.O. Box 192 Jimma, Ethiopia. Livelihood

Abstract
Coffee is a vital crop in social, cultural and national economy of Ethiopia. Despite coffee plays dominant role in social, cultural and national economy, the country's coffee industry is challenged due to major coffee diseases like coffee berry diseases while coffee growers did not use resistant coffee varieties. Understanding the potential impact of coffee berry diseases in relation to climatic variables is critical. More over climate change impact negatively on suitability of coffee production areas with change in diseases and insect pest patterns. Areas that are currently still suitable for Arabica coffee require adaptation and mitigation strategies in order to sustain the livelihood of farmers depending on Arabica coffee production. Coffee trees around Western part of the country (Gimbi area) don't producing for three consecutive years (shift from bi-annual to tri-annual coffee bearing) which is associated with climate change. Research is needed to carry out impacts and implication of climate change (soil erosion, loss of cash crop, disease and pest) adaptation strategies (managing water source and improvement, ways of soil conservation activities, use of shade trees and integrated pest management) should be identified & studied. Moreover, there is a need to investigate further information and researches on change in biology of CBD pathogen, resistant durability of previously released CBD commercial cultivars, coffee farming systems and their influences on coffee berry disease prevalence, awareness of farmers about climate change and other related issues. Thus, the frequency and severity of climatic extremes are increasing and making adaptation an absolute necessity through using current information on climate variability to develop long term plans for managing coffee berry disease via reducing the vulnerability of Ethiopian coffee growers.
Keywords: Climate variables, Coffee production system, Coffee Berry diseases, *Colletotrichum kahawae,*

1. Introduction

The issue of climate variability has become more threatening not only to food security and sustainable development of any nation, but also to the totality of human existence. About 66% of the total areas of Ethiopia fall within arid and semi arid climatic zone of the country (MoARD (Ministry of Agriculture and Rural Development), 1998). Nevertheless, agriculture, which is highly sensitive to climate variability, is the driver of the country's economy as it accounts for half of Gross Demostic Product (GDP) and 80% of employment (MoA (Minsitry of Agriculture), 2007). Thus, the dependence of Ethiopia on agriculture makes its economy extremely vulnerable to the risks associated with climate variability. Moreover, the projected higher temperature and variable precipitation levels will unequivocally depress crop yields through direct effects as well as indirect impact by triggering insect pests, diseases and weeds (Gadgil *et al.*, 1998). Therefore, climate variability is and will form a serious concern for both researchers and development planners in Ethiopia.

The seasonal climate variability of Ethiopia, particularly rainfall, is influenced by weather systems of various scales; from meso-scales, to the large scale, mainly El Nino-Southern Oscillation (ENSO) related phenomena (NMSA (National Meteorology Service Agency), 1996). The climate of arid and semi arid region of Ethiopia is characterized by high rainfall variability and unpredictability, strong winds, high temperature and high evapo-transpiration (Mamo, 2005). It is, therefore, essential to assess the effect of climate change on crop diseases and insect pest dynamics over an area so as to quantify its effects especially on diseases out break and damage that could be translated into the best adaptation and mitigation options according to the development potential and specific challenges under a specific crops and economically important diseases and insect pests.

Coffee is a non-alcoholic and stimulant beverage crop, and belongs to the family Rubiaceae and the genus *Coffea*. Coffee is not only one of the highly preferred international beverages, but also one of the most important trade commodities in the world next to petroleum (Tefestewold Biratu, 1995). Arabica coffee which 80% commercial species is grown in more than fifty tropical and sub-tropical countries. Majority of these countries supply the product to world market (Getachew, 1990). Ethiopia is among these countries which heavily depend on coffee to earn its foreign exchange earnings. About 35 % of its export is covered from coffee (Alemayew *et al.*, 2008; Nigussie *et al.,* 2008). Ethiopia is believed to be the country of origin of arabica coffee that makes over 80% of the world's production (Paulos Dubale and Demel Teketay, 2000). Current contributions of coffee is more than 25 % of the country's foreign exchange earnings, over 5% of the GDP, 12 % of the agricultural output, and 10% of the government revenues (CSA, 2010). Coffee production systems in Ethiopia are grouped into four broad categories namely, forest coffee, semi-forest coffee, garden coffee and coffee plantations (MCTD, 1992). They account 10, 35, 35 and 20 % of the total production, respectively. The most important cultivation areas of coffee are southwestern and southern Ethiopia.

Ethiopia is the only country in the world where coffee grows wild as an understorey shrub or small tree in the Afro-montane rainforests (Paulos Dubale and Demel Teketay, 2000; Bayetta, 2001). It is believed that forests harbor a large genetic pool of arabica coffee that represents a potential source to develop the crop for the benefit of present and future human generations in the world (Sylvian, 1958; Tefestewold Biratu, 1995). Many abiotic and biotic factors are the major constraints of coffee production in the country the most important of which are diseases caused by many etioletic agents, mainly the fungi. The crop is prone to a number of diseases that attack fruits, leaves, stems and roots, and reduce the yield and marketability (Eshetu Derso, 1997; Eshetu *et al.,* 2008). The major coffee diseases in Ethiopia are coffee berry disease (CBD), coffee wilt disease (CWD) and coffee leaf rust (CLR).

The climate change as rise in temperatures and erratic rain fall on wide spread infection of coffee berry disease may already be affecting coffee production in Ethiopian. Rising temperatures and erratic rain fall are threatening sustainable coffee production by enabling outbreak of diseases and infestations of insect pests that decrease the quality and yield of coffee berries (Technoserve, 2011). Recent scientific evidence suggests that the frequency and severity of climatic extremes is increasing, making adaptation an absolute necessity. Adaptations such as shade tree planting for coffee and using recent information on climate variability to develop long term plans for managing them may help reduce the vulnerability of Ethiopian coffee growers to continued changes in temperature and rainfall (Amsalu, A. and Ludi, E. 2010). Therefore, this paper is prepared to review the potential effect of climate change on dynamics of coffee berry diseases and to generate information for researchers concerned on it.

2. Coffee and its production systems in Ethiopia

Ethiopia is the primary center of origin and genetic diversity of Coffee (*C. Arabica* L.). Arabica Coffee grows under very diverse environments including altitude (550 - 2600 m) and annual rainfall (1000 - 2000 mm). *Coffea Arabica* L. is indigenous to Ethiopia and the principal source of foreign currency. It is mainly produced in the Southern, South Western and Eastern parts of the country. Forests in Southwestern part of Ethiopia are the primary center of origin and center of genetic diversity of *Coffea arabica* (Sylvian, 1958; Meyer, 1965; Melaku Werede, 1984). Ethiopia is the only country in the world where coffee grows wild as an understorey shrub or small tree in the Afro-montane rainforests (Paulos Dubale and Demel Teketay, 2000; Workafes Woldetsadik and Kassu Kebede, 2000) viz. Kaffa, Sheka, Yayu Birehane kontire and Anfillo. It is a wild type of coffee grown spontaneously in the humid hot forests of southwestern parts of the country in the administrative zones of Kaffa, Sheka, WestWellega, Illubabor, and Bench-Maji of SNNPR and Oromia regions.

There are four types of coffee production systems in Ethiopia: forest coffee, semi-forest coffee, garden coffee and plantation coffee. These four production system mainly due to varying level of plants associated with coffee, nature of coffee tree regeneration and human intervention in coffee production system (Woldemariam *et al* ., 2008).

Forest with wild Arabica Coffee populations occur in the southeastern and southwestern highlands of Ethiopia mainly at altitudes between 1000 and 2000 m.a.s.l. (Wolde-Tsadike and Kebede, 2000; Senbeta, 2008). Forest coffee accounts for about 10% of the total coffee production in Ethiopia. According to Paulos Dubale and Demil Teketay (2000) Wild animals and birds disseminating seeds within the forest community assist spontaneous regeneration. The forest is also covered by heterogeneous species of overhead shade trees. The occurrence of wild coffee types with distinct phenotypic differences in the forests around Sheko, Tepi and Bebeka; Gewata and Geisha in Keffa, Obacherko in Gera, Geba-Doggi valley near Yayu in Illubabor and Eba forest in Anfillo, all in Southwest Ethiopia, and the average yield of forest coffee has been estimated to be in the order of 200-250 kg/ha (Paulos Dubale and Demel Teketay, 2000). The management of forest coffee is limited to only a single slashing of the broad-leaved weeds at the beginning of the cropping season followed by harvesting.

Semi-forest coffee production system is commonly found in Illubabor, Jimma, Keffa, Sheka, Benchi-Maji and west Wellega zones. Forest coffee lands of considerable sizes that are located near the main roads, rural towns or peasant villages are covered with coffee trees standing in scattered manner and are managed with little cultural practices such as weeding and shade regulation (Workafes Woldetsadik and Kassu Kebede, 2000; Senbeta, 2008). These types of plantations are known traditionally as semi-forest type and are believed to have evolved from forest coffee production system. The farmers slash the weeds and shrubs in the relatively light forests and fill in the open spaces with local seedlings. According to MoARD (1992), it was estimated that semi-forest coffee occupies nearly 136,000 hectares (34%) of the total area of coffee land in the country. Currently, semi-forest coffee represents about 24 % of the total land covered by coffee, contributes about 20% of the total coffee production in the country and its average yield has been estimated to be in the order of 400-500 kg/ha (Paulos Dubale and Demil Teketay, 2000).

Garden coffee is found in the vicinity of farmers' residences. It is found mainly in the Southern and Eastern part of the country (Sidamo, Gedeo, North Omo, Gurage Zones, Hararghe, and Arsi Bale). It accounts for about 50% of the total production. This production system is on the increase as it is currently being introduced in South West Ethiopia (Wolde-Tsadik and Kebede, 2000). This production system is common in coffee improvement Weredas of Sidamo, Gedeo, West Harerge and West Wellega, and with an area of less than 0.5 hectares (Workafes Woldetsadik and Kassu Kebede, 2000). Improved management of row planted coffee in Harerge, in South and Southwestern part of the country has been used as intensive coffee production system. Spacing, planting pattern and tree density depends on the type of selections planted.

Plantation coffee is grown on plantations owned by the state (currently put up for privatization) and on some well managed small to medium holder coffee farms. In this production system, recommended agronomic practices like improved seedlings, spacing, proper mulching, using mineral fertilizer and manure, weeding, shade regulation and pruning are practiced. Percent share of Commercial Farms from total Production was 20.2, 11.4 and 16.9 for year 2011 – 2013 respectively. The production volume of commercial farms reached 531,038 tons in 2013. Currently 135 private investors were involved in small to large scale coffee farms with total area coverage of 114,525 ha.

3. Coffee diseases in Ethiopia

Coffee Berry Diseases (C*olletotrichum kahawae),* Coffee leaf rust (*Hemileia vastatrix*), Coffee Wilt Diseases (*Gibberella xylarioides*), bean discoloration (*Pseudomonas syringae*), leaf blight (*Ascochyta tarda*), root-rot (*Armillaria mellea*), brown-eyespot *(Cercospora coffeicola*) and damping off diseases of seedlings (*Rhizoctonia* spp., and *Pythium* spp.), Fruit-rot (*Fusarium* spp.), and thread-blight (*Corticium kolleorega*) were recorded associated with coffee in Ethiopia (Merdassa Ejetta, 1985; Eshetu Derso *et al*., 2000)

There are however, many research findings documented that coffee diseases and insect pests situation in coffee production pose great treat. Among three major coffee diseases namely coffee berry diseases (C*olletotrichum kahawae*), coffee wilt disease (*Gibberella xylarioides*) and coffee leaf rust (*Hemileia vastatrix*); coffee wilt disease is the second distractive disease dramatically limiting coffee production in Ethiopia (Eshetu *et al*., 2000; CABI, 2003; Flood, 2009). The disease has been a serious problem to the production of coffee in central and eastern Africa like DR Congo, Uganda, Tanzania and Ethiopia since the 1990s killing hundreds of trees and the disease attack**s** all commercial coffee species including *Coffee arabica* and *Coffee canifora* at any growth stage (Rutherford, 2006; Flood, 2009; Girma *et al*., 2009). Coffee berry disease (CBD) is the top major disease of coffee in Ethiopia, which attack mainly the green berries of coffee. CBD was first observed in Ethiopia in 1971 (Mulinge, 1973). Since then it spreads and found in all coffee producing areas in which it has been favored by favorable environmental conditions.

Following the advent of CBD and modernization of the crop production system leads to the replanting of limited number of CBD resistant cultivars, which brought deforestation and rehabilitation of diverse coffee population. Side by side modern cultural practices are widely employed (Van der Graaff, 1981; Eshetu, 2000; Eshetu *et al.*, 2008). These practices comprise more weeding and digging to remove noxious grasses. This results in more wounding of the trees and better chances for transmission of the pathogen of coffee vascular wilt disease (*Gibberella xylarioides*) (Vander Graaff, 1981; Pieters and Van der Graaff, 1980; Van der Graaff, 1983; Girma *et al.,* 2004). Damage caused by *Gibberella stilboides* in Ethiopia seems to be confined to a collar rot of young seedlings, some susceptible collections were observed at Jimma research station, and root rot damage was rare and might be caused by basidiomycetes (Van der Graaff, 1981).

Different studies indicate that the prevalence of coffee wilt diseases at different coffee growing regions and production systems of Ethiopia was very high. Coffee Wilt Disease (tracheomycosis) is a systemic vascular disease caused by the fungal pathogen, *Gybbrella xylarioides* Heim and Saccus (Fussarium *xylarioides* Steyaert) that totally kills coffee plant at any growth stage in all production system and agro ecology. Coffee wilt diseases is more prevalent in plantation and garden coffee than forest and semi-forest coffee (Girma *et al.*, 2001; Girma *et al.*, 2009; Sihen *et al.*, 2012). CWD was more prevalent in fields of garden production system like Harar and Bale area with severity range of between 27.2% and 43.5% which is high compared to that of the semi-forest coffee production system (Girma, 2004). The incidence of CWD was above 35% in garden coffee of West Gojam zone of Amhara regional state. The CABI (2003) technical report indicated that the national incidence and severity of CWD in Ethiopia were 27.9% and 3%, in monitory terms it causes an estimate loss of more than 3.7 million US dollar annually, respectively. However, the incidence and severity varied from place to place in a range of 0-100% and 0-25%, respectively.

Leaf rust (*Hemileia vastatrix*) was reported by Sylvian (1958). Coffee leaf rust was considered as the most sever foliar coffee disease so far known which may be because it led to the abandoning of coffee growing in Sir Lanka only six years after the disease was first identified (Muller *et al.*, 2004). They inferred that coffee cultivation was replaced by tea plantations and it principally contributed to the wide spread consumption of tea in the United Kingdom. Similarly, Arabica coffee farms in South Asia were converted to Robusta coffee, tea or rubber plantations (Mayne, 1932; Wellman, 1961). This spread and scale of epidemics was suggested to be due to the use of a limited number of varieties and the predominant self-fertility of *C. arabica* (Rodrigues *et al.,* 1975) and uniform cultural practices over a long period (Wellman, 1961). In Ethiopia, large genetic diversity of *C.arabica*, high level of horizontal (non specific) resistance to CLR and availability of at least some incomplete resistance likely protects coffee against rust under prevailing conditions. Meseret (1996) identified coffee plants with partially (incomplete) resistance to CLR from lowland forest coffee of south-western Ethiopia.

4. Coffee berry disease (CBD)

4.1 Occurrence and distribution of coffee berry disease (CBD)

CBD is a major cause of crop loss of arabica coffee in Africa and a dangerous threat to production elsewhere. The disease is an anthracnose of green and ripe berries induced by *Colletotricum kahawae*. McDonald first detected CBD in 1922 in Kenya causing about 75% crop loss (Gibbs, 1969). Since then the disease was found in many estates of the Rift valley in Kenya. By the 1950s CBD had established in the east, the main coffee growing areas (Rodrigues *et al*., 1992).

Apparently, the free movement of coffee plant materials from CBD infected areas has been the main factor in distribution of this disease throughout all important arabica growing areas in Africa. The disease was reported in Angola around 1930, Zaire in 1937, Cameroon 1955-1957, Uganda in 1959, Tanzania in 1964, Ethiopia 1971(Van der Graaff, 1981) and in Malawi in 1985 (Lutzeyer *et al*., 1993). CBD was also confirmed in Malawi, Zimbabwe and Zambia in 1985 (Masaba and Waller, 1992). It is not known outside of Africa, although a leaf spot and ripe berry anthracnose caused by related *Colletotrichum* species has been reported from Guatemala and Brazil (Griffiths *et al*., 1991).

In Ethiopia CBD first reported in 1971 (Mulinge, 1973; Van der Vossen and Walyaro, 1980). Then spread to all major coffee producing regions within very short period except to the lower altitude less than 1500 m.a.s.l. All coffee production systems like plantations, garden, Semi-forest and forest coffee, with and without shade all were infested with the CBD in all extent (Tefestwold Biratu, 1995).

Merdassa Ejetta (1985) reported yield losses of 51% at Melko and 81% at Wondo Genet due to CBD. In 1994 crop season prevalence of CBD was conducted in Oromiya Region and Southern Nations Nationalities and Peoples Region (SNNPR) and the result indicated 38.8 and 17.2% of mean percent prevalence of the disease, respectively (IAR, 1997). According to the result, CBD pressure was very high at higher altitudes in the southwest region, while severe disease was recorded in valleys of Sidama zone. According to Tefestewold Biratu (1995) CBD severity varied from year to year and among areas. In Amhara region of Northern Ethiopia where CBD occurs, survey result showed that an average severity for the 1996/97-crop season was 38% (Tesfaye Alemu and Ibrahim Sokar, 2000).

Survey conducted in 1997 and 1998 in six major coffee growing zones (in 32 Districts) of Oromiya region showed an average of 31% and 32% disease severity for the respective years (Melaku Jirata and Samuel Assefa, 2000). CBD incidence and severity assessment in 10 zones and 31 woredas of Southern Nations Nationalities and Peoples Region (SNNPR), conducted in September 1998, resulted with 40% and 22.8% mean incidence and severity of the disease, respectively (Tesfaye Negash and Sinedu Abate, 2000).

Following the advent of CBD and modernization of the crop production system leads to the replanting of limited number of CBD resistant cultivars, which brought deforestation and rehabilitation of diverse coffee population. Side by side modern cultural practices are widely employed (Van der Graaff, 1981; Eshetu, 2000; Eshetu *et al*., 2008). Coffee berry disease alone is known to reduce coffee yields between 25-30 % (Eshetu *et al,* 2000). Hararghe coffee is susceptible to CBD; as a result it is under threat of genetic erosion mainly because of the losses caused by the disease and farmers prefer growing alternative cash crops such as chat to planting coffee (Arega *et al.*, 2008; Birehanu, 2014).Climatic factor significantly influence the occurrence and distribution of CBD. Adugna (1995) stated that the prevalence of low temperature in conjunction with high rainfall total and longer number of rainy days could trigger CBD infection.

The existing knowledge also revealed that the developing coffee berry is most susceptible in the course of rapid expansion stage (Mulings, 1970; Gaseret, 1976; Muller, 1984, Girma *et al.,* 2008). Nutman and Roberts (1960) reported that temperature between 17 and 22 ^{0}C in the presence of water or completely saturated atmosphere are responsible for moderate CBD infection under laboratory condition. Similarly, Masaba and vander Vosen (1982) observed formation of scabs on some CBD resistance coffee cultivars under such weather conditions favoring CBD.

A partial regression-correlation analysis on disease parameters (severity and incidence of CBD recorded for ten years on progenies of thirteen CBD resistant selections and a susceptible standard at Gera (CBD hot spot area) as dependent variable against major weather factors such temperature, rainfall and relative humidity revealed prevalence of low temperature about 21.5^{0}c accompanied by high rainfall (>700mm) extended over long period (>74days) favored CBD development and increased disease intensity (Adugna, 1995).

Analytical result of the relationship between climatic variable and percentage of CBD infected berries of two coffee cultivars 741 and 7440 grown at Gera show that the variability of infection function of seasonal and special weather condition. April to July mean daily maximum temperature with r^2 of 37% and 36%

influence incidence of CBD (Girma *et al.,* 2008). Likewise, the total number of rainy daies of the same season has accounted for 23% of the variability in the infection of berries of 741 and 51% for 7440 (Girma *et al.,* 2008). Acordinf to Adunga (1995) compared to high temperature, the prevalence of low temperature of in the order of 21.5^{0}C in conjunction with high rainfall total and longer number of rainy days could trigger CBD infection. In general, there is ample theoretical knowledge in seasonal climate variability verses CBD incidence (Girma *et al.,* 2008). Losses due to CBD on individual farms vary considerably, in low night temperature with high rainfall and high altitude areas, losses may reach up to 100% (Van der Graaff, 1981, Girma 1995).

*4.2. Biology of CBD pathogen (***Colletotrichum kahawae***)*

Colletotrichum kahawae can infect all stages of the coffee berry from flowers to the ripe fruits and occasionally leaves, but maximum crop losses occur following infection of green berries with the formation of dark sunken lesions with sporulation. The perfect state for some species of *Colletotrichum*, occurring on coffee, has been proved to be the ascomycete *Glomerella cingulata*. These fungi are generally polyphagous. In 1901 Noack detected for the first time *Colletotrichum acutatum* in Brazil causing leaf spots and dieback (branches) of *C. arabica* L. (Hindorf, 1975). But it was not pathogenic to green coffee berries. Rayner (1952) had confirmed distinct forms that referred to *Colletotrichum coffeanum*, in the context of a fungus causing CBD, which was first detected by McDonald (1922).

Gibbs (1969) and Hindorf (1970) tried to identify *Colletotrichum* species from various parts of coffee in Kenya. Gibbs (1969) categorized the isolates (from coffee berries and bark) into four groups of which three were non-pathogenic and the fourth one invariably infected both wounded and unwounded berries and caused CBD. Based on sporulating capacity (conidia production), shape and size of conidia, production of acervuli and pathogenecity on berries, who assigned and described the CBD pathogen isolate ('var. virulans') as slow growing, profuse grayish-black aerial mycelium, and conidia borne directly on hyphae.

Hindorf (1973) classified the isolates using detailed cultural and morphological characteristics and relating his findings to Gibbs (1969). Hindorf (1970) grouped *Colletotrichum* isolates from Kenya coffee into 3, viz. *C. coffeanum* (now it is *C. kahawae*) as the only isolate causing CBD, *C. acutatum* (never causes serious damage to coffee but found on the host part damaged by biotic or abiotic factors) and *C. gloeosporioides* (causes anthracnose of leaves, die-back of branches, and brown blight of ripe berries). It was reported that *Glomerella cingulata* is the perfect form of *C. gloeosporioides* and never be for *C. kahawae* (which perhaps is a clone of *Glomerella cingulata* that fails to produce the perfect state in vitro). The pathogenic fungus produced conidia that were variable in size and shapes, at the tip of solitary hyphae, never in acervuli. According to Sutton (1980) the fungus that cause CBD produces colonies of dense or floccose pale chocolate brown aerial mycelium, sometimes grayish with a lighter center, reverse greenish gray, lacking acervuli and sclerotia, and setae are usually absent.

The germination of the one-celled, cylindrical and hyaline conidia of *C. kahawae* takes place only in the presence of free water (Hindorf, 1975). Optimum temperature appears to be at 22^{0}C (18-23^{0}C *in vivo*, 15-25^{0}C *in vitro*). After germination, germ-tubes grow rather slowly, and 4 to 5 hours later, dark brown thick-walled appressoria are formed at their tips. The appressoria stick strongly to the host cuticle and penetrate it by means of infection pegs. Inter-cellular mycelium is formed sparsely. The incubation period lasts from 5 days to 3 weeks, average being around 8 days. Soon after a black necrotic lesion develops, the fungus produces fruiting bodies, the acervuli in which masses of pink conidia are formed.

C. kahawae and *C. gloeosporioides* were the only two species of fungus isolated from coffee tissue samples collected from Habro and Kuni districts in Harerge region (Tefestewold Biratu and Mengistu Hulluka, 1989). The absence of perithecia, its slow growth rate, and its pathogenic ability were the distinct characteristics of *C. kahawae*, while *C. gloeosporioides* produced fertile perithecia (perfect stage) and was unable to cause coffee berry disease.

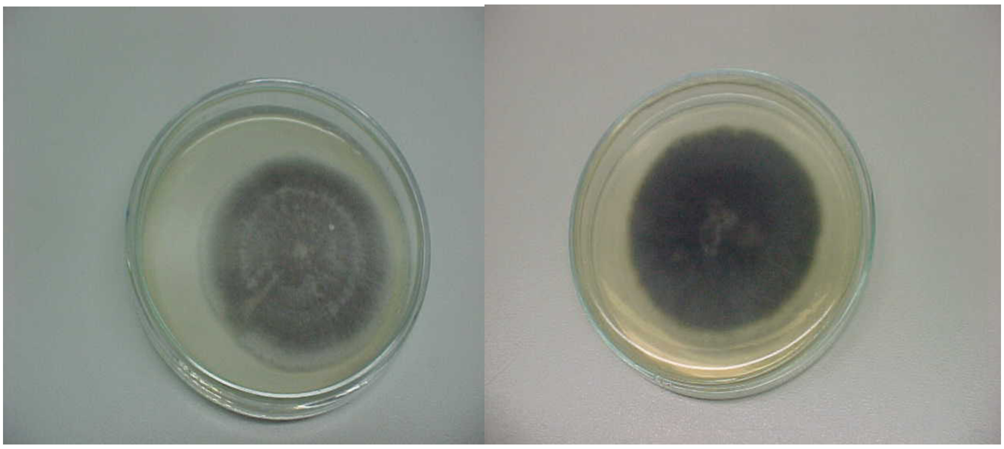
Tefestewold Biratu (1995) studied variations/similarities among *Colletotrichum* isolates collected from Harerge, Illubabor, Kaffa and Sidamo areas and found 3 spp. viz. *C. kahawae*, C. *gloesporioides* and *C. acutatum*. Variation of a representative range of *Colletotrichum* isolates from diseased coffee berries (collected from Yirgachefe, Gore, Gera and Limu garden coffee areas) was further studied using morphological and pathological criteria and the result showed that both *C. kahawae* and *C. gloeosporioides* occur in diseased berries, probably as sequential colonizers of diseased tissues (Eshetu Derso and Waller, 2003). They indicated that *C. kahawae* isolates were pathogenic to hypocotyls of susceptible coffee cultivars where as *C. gloeosporioides* isolates were not pathogenic.

4.3. Cultural and morphological variation within **Colletotrichum spp.** *occurring on coffee*

Based on cultural and morphological characteristics, Hindorf (1970) described the 3 *Colletotrichum* spp. occurring on *C. arabica* in Kenya. CBD pathogen strain culture becomes initially white mycelium changed after 4-6 days to gray and eventually to dark olive brown and its conidia shape and size are variable. Average radial growth of colony and conidia size recorded from CBD pathogen (*C. kahawae*) isolates were 1.9 ± 0.5 mm/24h and 13.1 ± 0.6 x 3.87 ± 0.2, respectively (Hindorf, 1970 and 1973; Hindorf and Muthappa, 1974). They indicated that shape of conidia variable, mostly straight, cylindrical, and rounded at both ends. Hindorf (1973) and Tefestewold Biratu (1995) described the most frequent shapes of conidia and assigned as standard shapes of conidia of *Colletotrichum* spp: 1 = cylindrical and round at both ends, 2 = cylindrical acute at one and round at the other end, 3 = clavate-round at both ends starts attenuating from ¼ of its length, 4 = reniform or kidney shaped, 5 = oblong-elliptical, types.

The culture of *C. kahawae* from Kenya grows slowly, changes the color into complete black produces conidia sparsely on solitary hyphae (only in darkness) and is able to infect green coffee cherries very easily. In contrary the fast growing culture, remaining whitish producing a large number of conidia in black acervuli and being not pathogenic to green coffee cherries, these are the typical characteristics of *C. gloeosporioides* (Hindorf and Muthappa, 1974). Based on colony color and ability to form saltation the first group, *C. kahawae* further subdivided in to two: 'dark mycelium' which showed little variation in the group, i.e. green and grayish to bluish white which later turned to dark green or olive brown to brown as the mycelia got older where as the second subgroup comprises 'grayish mycelium' form, which showed light grayish to white color other than the colony color by forming saltation (Tefestewold Biratu and Mengistu Hulluka, 1989). As they indicated the rate of mycelial growth was distinctly slower in *C. kahawae* (6.5-6.7 mm/24 hr) than in the *C. gloeosporioides* mycelium form (6.7-12.9 mm/24 hr) and sizes and shapes of *C. kahawae* were variable, and the average size of the conidia was 15.3 x 3.5 µm from *C. kahawae* isolates where as 13.6 x 3.4 µm from *C. gloeosporioides*.

Eshetu Derso and Waller (2003) observed that *C. gloeosporioides* isolate from Limu (non pathogenic to green coffee berries) produced a faster growing grayish aerial mycelium and developed a black color in the substrate where as the pathogenic isolate (*C. kahawae*) from Yirgachefe showed slow growth and grayish aerial mycelium.



A *B*

Figure 1. Aerial mycelial (colony) colors of *Colletotricum spps* from obverse side: gray (A) and dark olive green (B).

4.4. Development of CBD Resistance **Coffea arabica** *Variety in Ethiopia*

Many explorers (Meyer, 1965) and (Sylvian, 1958; Melaku Werede, 1984; Bayetta Belachew, 2001; Eshetu et al., 2008) indicated that the genetic variability within arabica coffee populations, in the Southwestern highlands of Ethiopia, is extremely high. Immediately after the outbreak of CBD in the 1971 and 1972 the genetic potential of the forest, semi forest and garden coffee populations, a survey programme was initiated in those populations where epidemics of the disease had occurred. It was observed that within the coffee populations there was a wide range of variation; from complete susceptibility to high levels of resistance. Resistant trees occurred at frequencies of 0.1% to 1% and one tree in every 10,000 possessed both resistance and high yield and quality (Robinson, 1976). Based on this survey a massive selection programme for resistance was launched using these indigenous populations. In the group of mother trees at Gera, certain trees had consistently more disease than others (Van der Graaff, 1981).

Partial to complete dominance of the susceptible genes to the resistant genes was consistently found and 3 to 5 major genes of an additive nature were suspected to be involved in the control of resistance to CBD in the arabica coffee population, in Ethiopia (Mesfin Ameha and Bayetta Belachew, 1984; Bayetta Belachew, 2001). The resistance nature of coffee Arabica for CBD cultivars could be considered as horizontal and or for some non-race specific (Tefestewold Biratu, 1995). Since the inception of CBD resistant selection and breeding program at Jimma National coffee Research center, 37 CBD resistant cultivars were released and disseminated for growers (Table 1). From those commercial coffee varieties three of them are hybrids and eleven are developed for specialty coffee growing areas of Ethiopia (Table 1).

CBD resistant cultivars have been identified and commercialized for immediate use, and currently different works have been carried out on the genetic improvement of arabica coffee. Nevertheless, the amount of work is not in proportion to the crop's economic importance and the amount of genetic diversity available for improvement in its center of origin (Bayetta Belachew, 2001).

Table 1. Commercial Coffee Varieties Released by Jimma Agricultural Research Centre

No	Variety	Year of release	Recommended altitude	No	Variety	Year of release	Recommended altitude
1	741	1978	1550–2100	20	Wush wush	2006	≥1500
2	744	1980	1550–2100	21	Merda cheriko	2006	≥1500
3	7440	1980	1000–1550	22	Buno washi	2006	≥1500
4	7454	1981	1000–1550	23	Angefa	2006	≥1500
5	7487	1981	1550–2100	24	Manasibu	2010	1550–2100
6	74110	1979	1550–2100	25	Challa	2010	1550–2100
7	74112	1979	1550–2100	26	Haru-1	2010	1550–2100
8	74140	1979	1550–2100	27	Sende	2010	1550–2100
9	74148	1980	1550–2100	28	Mocha	2010	1550–2100
10	74158	1979	1550–2100	29	Mechara-1	2010	1550–2100
11	74165	1979	1550–2100	30	Bultuun	2010	1550–2100
12	754	1981	1550–2100	31	Hamsa	2010	1550–2100
13	75227	1981	1550–2100	32	Catimor J-19	1998	1000–1550
14	Desu	1998	1000–1750	33	Catimor J-2	1998	1000–1550
15	Feyate	2010	1550–2100	34	Gesha	2002	1000-1550
16	Odicha	2010	1550–2100	35	Ababuna*	1998	1550–1750
17	Koti	2010	1550–2100	36	Melko CH2*	1998	1550–1750
18	Yachi	2006	≥1500	37	Gawe*	2002	1550–1750
19	Mioftu	2002	1550–1750				

Note:- *, Hybrid coffee varieties, Source: - Bayetta (2001); Jafuka *et al.,* (2012)

5. Climate Change and Its Potential Effects on Dynamics Coffee Berry disease

CBD is very sever and causes appreciable yield loss in areas and/or seasons where the weather is favorable. Temperature and rainfall (amount and duration), and relative humidity are decisively determine the occurrence , prevalence and severity of the diseases (Van der Graaff, 1981; Girma, 1995; Arega *et al.,* 2008; Grima *et al.,* 2008). A partial regression-correlation of diseases parameters recorded for ten years on progenies of thirteen CBD resistant selections and susceptible standard at Gera as dependent variable against measure weather factors such as temperature, rainfall and relative humidity documented during diseases development period as independent variable were analyzed. Among the metrological elements, the mean maximum temperature showed significantly negative coreations with CBD severity in berry count (r=-0.88) and visual assessment (r=-0.76), while the total number of rainy days (r= +0.72) and relative humidity (r=-0.71) exhibited significantly positive relationship (Girma, 1995). The analysis demonstrated prevalence of low temperature of about 21.50C accompanied by high rainfall (> 700 mm) extended over along period (> 74 days) favored CBD development and increased the diseases intensity (Girma, 1995). It is accepted fact that low temperature between 20 and 22 ^{0}c and relative humidity close to 100% or presence of water droplets at least for 5 hours should be maintained in growth room during CBD seedling hypocotyle inoculation test (Nutman and Roberts, 1962; Van der Graaff, 1981; Tesfestewold, 1995)

Climatic factor significantly influence the occurrence and distribution of CBD. According to Adunga (1995), low temperature usually favors the development of CBD, specially at higher altitudes and valley bottoms. The existing knowledge also revealed that the developing coffee berry is most susceptible in the course of rapid expansion stage (Mulings, 1970; Gaseret, 1976; Muller, 1984, Girma *et al.,* 2008). Nutman and Roberts (1960) reported that temperature between 17 and 22 ^{0}c in the presence of water or completely saturated atmosphere are responsible for moderate CBD infection under laboratory condition. Similarly, Masaba and vander Vosen (1982) observed formation of scabs on some CBD resistance coffee cultivars under such weather conditions favoring CBD.

Climate Change cause substantial but largely un-quantified losses to coffee production that inevitably increase coffee's global environmental footprint. Recent upsurges in Coffee berry diseases (CBD) on released moderately resistant coffee cultivar (1377) in south Ethiopia have been reported in highland areas where the climatic condition is highly suitable for growth and development of the pathogen affected production (Demelash and Kifle, unpublished data).

6. CONCLUSION

The issue of climate variability has become more threatening not only to food security and sustainable development of any nation, but also to the totality of human existence. Agriculture, which is highly sensitive to climate variability, is the driver of Ethiopian economy as it accounts for half of Gross Domestic Product (GDP) and 80% of employment. Thus, the dependence of Ethiopia on agriculture makes its economy extremely vulnerable to the risks associated with climate variability. Moreover, the projected higher temperature and variable precipitation levels will unequivocally depress crop yields through direct effects as well as indirect impact by triggering insect pests, diseases and weeds. Coffee is a vital crop in social, cultural and national economy of Ethiopia. Despite coffee plays dominant role in social, cultural and national economy, the country's coffee industry is potentially at risk due to climate change. Climate change impact negatively on suitability of coffee production areas with change in diseases and insect pest pattern. Areas that are currently still suitable for Arabica coffee require adaptation and mitigation strategies in order to sustain the livelihood of farmers depending on Arabica coffee production. There is a need to investigate further information and researches on change in biology of CBD pathogen, resistant ability of previously released CBD commercial cultivars, coffee farming systems (usage of improved resistant cultivars and practices) and their influences on coffee berry disease prevalence, awareness of farmers about climate change and other related issues. Thus, the frequency and severity of climatic extremes are increasing and making adaptation an absolute necessity through using current information on climate variability to develop long term plans for sustainable management of coffee berry disease via reducing the vulnerability of Ethiopian coffee growers to continued changes in climate.

7. REFERENCES

Amsalu, A. and Ludi, E. (2010), The Effect of Global Coffee Price Changes on Rural Livelihoods and Natural Resource Management in Ethiopia: A Case Study from Jimma Area. NCCR North-South Dialogue 26, Bern.

Arega Z., Demelash T., Chala J., Sysay T., Mesfin S. and Girma A. (2008), Success Stories in Managing Coffee Berry Disease in Ethiopia. In: In: *proceedings of the National workshop on four decades of coffee research and development in Ethiopia*, pp. 239-249 14-17 August 2007, Addis Ababa, Ethiopia.

Arega zeru. (2006), Diversity of Arabica coffee populations in Afromontane rain forests of Ethiopia in relation to Colletotrichum kahawea and Gibberella xylariodes. MSc thesis. Addis Ababa university, Ethiopia, PP 80

Bayetta Belachew (2001), Arabica coffee breeding for yield and resistance to coffee Berry disease (*Colletotrichum kahawae* sp.nov.). *Doctoral Dissertation*. Imperial College at Wye University of London. 272 pp.

Bayetta Belachew, Behailu Atero and Fekadu Tefera (2000), Breeding for the resistance to coffee berry disease in arabica coffee: progress since 1973. In: In: *proceedings of the workshop on control of coffee berry Disease (CBD) in Ethiopia*, pp. 85-97. 13-15 August 1999, Addis Ababa, Ethiopia.

CABI.(2003), Surveys to assess the extent of coffee wilt disease in East and Central Africa. *Final technical report*. CABI Regional Center, Nairobi, Kenya. 49 pp.

CSA (Central Statistical Authority). (2010), Agricultural sample survey. Report on landutilization, Federal Democratic Republic of Ethiopia, Addis Ababa, Ethiopia.

Eshetu Derso (1997), Coffee diseases and their significance in Ethiopia. *ASIC* 17(I): 723-726.

Eshetu Derso (2000), Preselection method for coffee berry disease (CBD) resistance in Ethiopia. In: *proceedings of the workshop on control of coffee berry Disease (CBD) in Ethiopia*, pp. 47-57. 13-15 August 1999, Addis Ababa, Ethiopia.

Eshetu Derso and Waller, J.M. (2003), Variation among *Colletotrichum* isolates from diseased coffee berries in Ethiopia. *Elsevier Science crop protection.* 22: 561-565.

Flood, J., (2009), Concluding remark. In: Coffee wilt disease, Flood J (Eds). CAB International. UK: Wallingford.

Gassert, W. L. (1979), *Research on coffee berry disease in Ethiopia: Epidemiology and control.* GTZ, Eschborn. 65 pp.

Gadgil, S., P.R. Seshagiri and S. Sridhar. (1998), Modeling impacts of climate variability on rain fed groundnut. Bangalore, India: Indian Institute of Science. pp: 11.

Gibbs, J. N. (1969), Inoculum sources for coffee berry disease. *Ann. Appl. Biol*. 64: 515-522.

Girma Adunga. (1995), The influence of Climate condition on resistance level of released coffee types to coffee berry disease (CBD). In: proceeding of the 2nd Annual conference of Crop Protection Society of Ethiopia (CPSE): 26-27 April 1994. Addis Ababa, Ethiopia.

Girma Mamo, Grima A., Mezgebu G., Gizachew L., Degefie T. and Daneal A. (2008), Agromeotrology and geographic Information System to Enhance Coffee research and development. In: In: *proceedings of the National workshop on four decades of coffee research and development in Ethiopia*, pp. 130-139.

14-17 August 2007, Addis Ababa, Ethiopia.
Girma Adugna (2004), Diversity in pathogenicity and genetics of *Gibberella xyilarioides Fusarium xylarioides*) population and resistance of coffee spp. in Ethiopia. *Doctoral Dissertation*. Hoen Landwirtschaftlichen Fakult'a' der Rheinischen riedrich-Wilhelms-Universit'a't zu Bonn. 81 pp.

Girma Adugna, Mengistu Hulluka and Hindorf, H. (2001), Incidence of tracheomycosis, *Gibberella xyilarioides* (*Fusarium xylarioides*), on Arabica coffee in Ethiopia. *J. Plant Dis. and Pro.* 108 (2): 136-142.

Griffiths, E., Gibbs, J.N. and Waller, J.M. (1991), Control of coffee berry disease. *Ann. of Appl. Biol*. 67: 45-74.

Hindorf, H. (1970), *Colletotrichum* spp. isolated from *Coffea arabica* in Kenya. *Z. Pflanzenkrh. Pflanzenschutz*. 77: 328-331.

Hindorf, H. (1973), *Colletotrichum*-population on *Coffea arabica* L. in Kenya: II. Qualitative and quantitative differences in the *Colletotrichum*-population. *Phytopath. Z*. 77: 216-234.

Hindorf, H. (1975), *Colletotrichum* occurring on *Coffea arabica*: A Review. *J. Coffee Res.*5(3/3): 43-56.

Hindorf, H. and Muthappa, B. N. (1974), Comparison of *Colletotrichum coffeanum* Noak from South India and Kenya. *Phytopath. Z*., 80: 9-12.

IAR (Institute of Agricultural Research).(1997), Jimma National Coffee Research Center progress report for the period 1994 (Part 1 Coffee). Melko.

Jefuka C., G. Adunga, D. Teferi, A. Zeru, S. Bogale, A. Adem. (2012), Development and Release of Coffee Berry Disease Resistant Varieties to Specialty Coffee Producing Regions in Ethiopia. *ASIC* 24(I): 636-644.

Lutzeyer, H. J., Pulschen, L., Compart, W. and Scolaen, S. (1993), Neue Erkenntnisse uber pflanzenschutz in plantagenkulturen darjestellt am beispiel kaffee. Weltforum verlag, koln.

Masaba, D.M. and Waller, J.M. (1992). Coffee berry disease: the current status. In: *Colletrotrichum: Biology, pathology and Control,* pp. 237-249, (Bailey, J.A. and Jeger, M.J., eds). CAB International, Wallingford, UK.

McDonald, J. (1922), A preliminary account of a disease of green coffee berries in Kenya colony. *Trans. Br. Mycol. Soc*. 11:145-154.

MCTD (1992), Report on Yield Assessment Survey: Planning, Monitoring and Evaluation Team, MCTD, pp. 5-60. Addis Ababa, Ethiopia.

Melaku Jirata and Samuel Assefa (2000), Status of CBD in Ormiya region. In: *proceedings of the workshop on control of coffee berry Disease (CBD) in Ethiopia,* pp. 9-17. 13-15 August 1999, Addis Ababa, Ethiopia.

Melaku Werede (1984), Coffee genetic resources in Ethiopia conservation and utilization particular reference to CBD resistance. In: *Proceedings of the first regional workshop on coffee berry disease*. 19-23 July 1982, Addis Ababa, Ethiopia. pp 203-211.

Merdassa Ejetta. (1985), A review of coffee diseases and their control in Ethiopia. In: *Proceedings of the first Ethiopian crop protection symposium,* PP. 179-195.Tsedeke Abate, ed.). 4-7 February 1985. IAR, Addis Ababa, Ethiopia.

Mesfin Ameha and Bayetta Belachew (1984), Resistance of the F1 to coffee berry disease in six parent diallel crosses in coffee. In: *Proceedings of the first regional workshop on coffee berry disease*. 19-23 July 1982, Addis Ababa, Ethiopia. pp 167-177.

Meyer, F. G. (1965), Notes on wild *Coffea arabica* from Southwestern Ethiopia, with some historical considerations. *Economic Botany* 19: 136-151.

Mamo, G., (2005), Using seasonal climate outlook to advice on sorghum production in the central Rift valley of Ethiopia. PhD Thesis, Blomefontein, Republic of South Africa.

MoA (Ministry of Agriculture).(1998), Agro ecological zones of Ethiopia. Ministry of agriculture. Addis Ababa, Ethiopia.

MoARD (Ministry of Agriculture and Rural Development), (2007), Ministry of agriculture and rural development crop development crop variety register. Addis Ababa, Ethiopia, 7: 104.

Muller, R. A. (1984),Changes in susceptibility of coffee berries during their development, and consequences. In: *Proceedings of the first regional workshop on coffee berry disease*. 19-23 July 1982, Addis Ababa, Ethiopia. pp 271-280.

Muller, R. A., D. Berry, J. Avelino, and D. Biesse, (2004), Coffee disease. In: J. Wintgens (ed.). Coffee growing, processing, sustainable production: A guidebook for growers, processors and producers). WILEY-VcH Verlag GmbH & Co. kGaA. Weinheim.

Mulinge, S. K. (1970), Development of coffee berry disease in relation to the stage of berry growth. *Ann. Appl. Biol.* 65: 269-276.

Mulinge, S. K. (1973), Outbreaks and new records. Ethiopia, coffee berry disease. *FAO Plant Protection Bulletin*. 21: 85-86.

NMSA (National Meteorology Service Agency) (1996), Climatic and agro-climatic resources of Ethiopia. *Meteorological research report series* Vol. 1, No. 1. National Meteorology Service Agencyof Ethiopia, Addis Ababa. 137 pp.

Nutman, F. and Roberts, F. M. (1960), Investigations on a disease of *Coffea arabica* caused a form of *Colletotrichum coffeanum* Noack. II. Some factors affecting germination and infection and their relationship to disease distribution. *Tans. Br. Mycol. Soc.* 43: 643-659.

Osullivan, E. and Kavanagh, J. A. (1991), Characteristics and pathogenicity of isolates of Rhizoctonia spp. associated with damping-off of sugar beet. Pl. Pathol. 40:128-135.

Paulos Dubale and Demel Teketay (2000), Coffee production systems in Ethiopia. In: *Proceedings of the workshop on control of coffee berry disease (CBD) in Ethiopia,* pp 99-107. 3-15 August 1999, Addis Ababa, Ethiopia.

Pieters, R. and Van der Graaff, N.A. (1980), *Gebberrella xyilarioides* on Arabica coffee: evaluation of testing methods and evidence for the horizontal nature of resistance. *Neth. J. Pl. Path*. 86:37-43.

Rutherford, M., (2006), Current knowledge of coffee wilt disease, a major constraint to coffee production in Africa. Phytopathology Journal, 96(1): 663–666.

Rayner, R. W. (1952), Coffee berry disease. A survey of investigations carried out up to1950. *E. Af. Agr. For. J.* 17: 130-158.

Robinson, R.A. (1976), Plant pathosystems. Springer verlag, Berlin. 184 pp.

Rodrigues, C.J., Varzea, V.M. and Mederios, E.F. (1992), Evidence for the existence of physiological races of *Colletotrichum coffeanum* Nock sensu Hindorf. *Kenya coffee* 57: 1417-1420.

Rodrigues, C.J.Jr., A.J. Bettencourt and L. Rijo, (1975), Races of the pathogen and resistance to coffee rust. *Annaual Review of Phytopathelology:* 13:49–70.

Senbeta Wakjira, F. (2008), Biodiversity and Ecology of Afromontane Rainforests with wild Coffee arabica L. Populations in Ethiopia. Ph.D. Dissertation, Ecology and Development Series No. 38, Cuviller Verlag, Gottinge, 144 p. Sutton, B. C. (1980). *The Coelomycetes*. CMI, Kew.

Sihen, G., A. Girma, L. Fikre and H. Hindorf (2012), Coffee wilt disease (Gibberella Xylarioides Heim and Saccas) in forest coffee systems of southwest and southeast Ethiopia. Plant Pathol. Plant Pathol. J., 11(1): 10-17.

Sylvian, P.G. (1958), Ethiopian coffee its significance to world coffee problems. *Economic botany*. 12: 111-139.

Technoserv (2011), Photo: Image Used with Permission from Technoserv. http://www.flickr.com/photos/50183375@N08/ 5546602122/in/photostream/

Tefestewold Biratu (1995), Studies on *Colletotrichum* population of *Coffea arabica* L. in Ethiopia and evaluation of the reactions of coffee germplasms. *Doctoral Dissertation.* Hohen Landwirtschaftlichen Fakultat der Rheinschen Friedrich- Wilelms-Universitӓt Zu Bonn. 231 pp.

Tefestewold Biratu and Mengistu Hulluka (1989), Colletotrichum species associated with coffee berry disease in Hararge. *Eth.J. Agri. Sci*. 11: 1-6.

Tesfaye Alemu and Ibrahim Sokar (2000), The status of coffee berry disease in minor coffee growing regions. In: *proceedings of the workshop on control of coffee berry Disease (CBD) in Ethiopia,* pp. 29-34.13-15 August 1999, Addis Ababa, Ethiopia.

Tesfaye Negash and Sinedu Abate (2000), Status of CBD in SNNP. In: *proceedings of the workshop on control of coffee berry Disease (CBD) in Ethiopia,* pp. 18-28.13-15 August 1999, Addis Ababa, Ethiopia.

Van der Graaff, N.A. (1981), Selection for Arabica coffee types resistant to CBD in Ethiopia. Mededelingen Landbouwhogeschool.Wageningen. Nederland. 110 pp.

Van der Graaff, N. A. (1983), Durable resistance in perennial crops. In: *Durable resistance in crops*, pp. 263-276, (Lamberti, L., Waller, J. M. and Van der Graaff, N. A., eds.). Plenum Press, New York.

Van der Vossen, H.A.M. and Walyaro, D.J. (1980), Breeding for resistance to Coffee berrydisease in coffee arabica-II. Inheritance. *Euphytica*. 29: 777-791.

Wellman, F.L., (1961), Coffee; botany, cultivation and utilization, Leonard Hill, New York. 488p.

Workafes, W. and Kassu, K.(2000), Coffee production systems in Ethiopia. In: *proceedings of the workshop on control of coffee berry Disease (CBD) in* Ethiopia, pp 99-107. 13-15 August 1999 Addis Ababa, Ethiopia.

Wolde-Sadik, W. and Kebede, K. (2000), Coffee Production System in Ethiopia Addis Ababa. *Proceedings of the Workshop Control of Coffee Berry Disease* (CBD), IAR (Then Name of EIAR, Ethiopian Institute of Agriculture), Addis Ababa, 13-15 August 1999, 99-106.

Woldemariam, T., Denich, M., Gatzweler, F., Balcha, G. and Tekatay, D. (2008), In Situ Conservation of Genetic Resources of Wild Arabica Coffee in Montane Rain Forest Ethiopia. In: Adugna, G., Shimber, B.B.T., Taye, E. and Kufa, T., Eds., *Coffee Diverslly & Know Ledge*, EIRO, Addis Ababa, 29-343.