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Biology, Dispersal and Management of Coffee Berry Disease: A Review

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Abstract
Colletotrichum spp. are the most important plant pathogenic fungi affecting tissues of leaves, flowers, fruit, stems and crown parts of different crops. They are predominantly found in tropical and subtropical rejoins of humid and sub-humid areas. From these, coffee berry disease (CBD) caused by the fungus Colletotrichum kahawae which is one of the predominant challenges in coffee production. Hence, this review is valuable in providing better insights into the extent spread, and biology of CBD pathogen from different findings and helpful for the selection of better management strategies for this disease. The slow growth form of C. kahawae is varied metabolically by its inability to use either citrate or titrate as a sole carbon source, and conidial production, dispersion and germination takes place in the presence of moisture. Also, the conidia from mummified berries and twig barks disseminated by rain splashes are the primary inoculums sources. Also, spore movement is down ward in tree canopies with the guide of water movement. Passive vectors that can carry viable spores like man, insects, vehicles and birds assist long distance movement, and free movement of coffee planting materials from CBD infected origin fasten frequent distribution of the disease. In spite of little attention received at the early stage of its emergence, African coffee growers soon observed a rapid dissemination throughout important Arabica coffee growing areas which causes 75% losses in Kenya within short time of its appearance. Moreover the impact due to this disease can cause100% losses in the area where effective management options like cultural practices, h*ost plant resistance*, biological control and chemical control are not applied. So, in order to improve the income gained from coffee sector especially in the areas where it highly produced and offer as essential economic source like Ethiopia needs great emphasis of disease diagnosis as well.
Keywords: Coffea arabica, Disease management, Disease symptoms, Epidemiology, Life cycle
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INTRODUCTION

Coffee is the major sources of currency for different states that produce it and serve as a means of livelihood with a significant economic, social and spiritual impact on many communities with diverse cultural and/or psychological backgrounds (Labouisse *et al*., 2008; ITC, 2011; Chauhan *et al.,* 2015). It is the world's second most traded commodity next to petroleum and serves as a direct source of income for the growers in different parts of the world (Kiwanian, 2013; FAO, 2015). As well, it is the pillar for Ethiopian economy which contributes about 27% of external transaction in comes via>25% rural and urban employment (ICO, 2018).

Nowadays, coffee is grown in more than 80 countries with >10 million hectares of land coverage (Etana, 2018). Ethiopia is the primary center of origin and diversity of Arabica coffee and ranks 1st and 5th in Africa and the world respectively (ICO, 2018). The existence of ideal and diverse agroecologies together with forest, semi forest, garden, and plantations production systems in Ethiopia made coffee to be the top agricultural produce in the country (Workafes and Kasahun, 2000).

However, coffee production has been challenged by several biotic and a biotic factors in several African countries (Rakotoniriana *et al.,* 2013; Cristobel *et al*., 2017).Coffee berry, coffee wilt and coffee leaf rust diseases triggered by *Colletotrichum kahawae, Gibberella xylarioides* and Hemileia *vastatrix* respectively are the major threats of coffee in tropical and subtropical areas. These diseases mainly attack fruits, leaves, stems and roots (Derso and Waller, 2003; Adugna *et al.,* 2009a).

Also, CBD *(C. kahawae)*(Waller and Bridge, 1993) affects the economic parts of green coffee berries and becomes the leading concern across coffee producing African countries(Van der Vossen *et al.*, 2015; Alemu *et al.*, 2016). The first record of this disease was in Kenya in 1922 which later distributed to Angola, Cameroon, Malawi, Ethiopia, Tanzania and Uganda with in short time (Weir *et al.,* 2012; Alemu, 2013). The losses due to CBD on individual farms vary considerably (up to 100%) where no control measures are undertaken in the high rainfall and high altitude areas (Van der Graff, 1981). While, use of cultural practices, biological, chemical control and resistant varieties play a significant role in combating the disease (Adugna *et al.*, 2008).

So, CBD management by reliable methods preferred by farmers that bring tangible change on their economy with increasing productivity as well as effective control of CBD while minimizing production costs and reducing potential consequences on human health and the environment is crucial. Therefore, this review is important to provide key information on the level of distribution, biology and management of the disease from different findings and documentations

Ethiopian economy and the coffee sector

Commercial production of coffee depends on two major species, *Coffea arabica* and *Coffea canephora* Pierre which account for 65% and 35% of production respectively (Chauhan *et al.*, 2015). Coffee production by exporting countries has been on a gradual increase and is subjugated to the top three producing countries (Brazil, Vietnam and Colombia)by 30%, 15% and 12% respectively (USDA, 2018). Brazil is the largest Arabica coffee producer from the world, while Vietnam, which is a relatively new candidate and now the world's largest Robusta producer (ICO, 2016).

Ethiopia is the birth place and also major producer and consumer of *C. arabica,* that ranks 1st from Africa **5th** in the world (ICO, 2018). From agricultural sectors, coffee industry is the back bone of the country's economy and has contributed vital role in the national income (Grabs, 2017). Coffee in Ethiopia offers 40% of total export, 10% of government revenue (Temesgen and Getachew, 2016) and income sources for more than 15 million people (16% population) whom directly or indirectly engaged in the production, processing and trading (CSA, 2017)
The report from CSA in 2017 indicates that coffee is the most essential Ethiopian's green gold; largest export commodity and shares 4.94% of the area under all crops which delivers significant impact on the source of revenue on people and economic development of the country. It contributes as immeasurable amount of Ethiopian export earnings and plays an important role in social gathering and local consumptions, more than half of the Ethiopian's coffee produce is consumed locally (Tadesse *et al.,* 2014).

Coffee production systems in Ethiopia

Coffee is largely cultivated in the Southern, South Western and Eastern parts (Amano, 2014). The country has wider ecologies containing indigenous germplasm which offers the greatest opportunity to produce superior *C. arabica* that allowed Ethiopia to be competitive in the world market. About 700,447 ha of the land have been cropped with coffee (CSA, 2017). Kaffa, Illubabor, Jimma, Wollega, Sidamo, Gedeo, Yirgachefe and Hararghe are the topmost coffee growing and producing areas (Chauhan *et al.,* 2015; Garuma *et al*., 2015). The four most dominant production systems (forest, semi-forest, and garden and plantation coffee) have practiced in Ethiopia (Workafes and Kasahun, 2000) and the contribution of each production system is 10%, 35%, 50% and 5%% respectively(Petty *et al*., 2004).

The level of CBD intensity is varying among production systems due to several factors such as human intervention, shade level and crop diversity (Zenebe, 2019). For instance, homogenous coffee cultivation and frequent human interferences (management strategies, cropping type, etc.) which could attribute the increament of disease level are commonly practiced under garden and plantation production systems (Cerda *et al*., 2017). While, semi forest and forest production systems composed of heterogeneous coffee genotypes, shade levels and low human interference that reduce disease level as well (Bieysse *et al*., 2009). Bedimo *et al*. (2008) and Kebati *et al*. (2016) have reported that shading creates microclimatic conditions that help to delay fruit ripening that leads to a shift in the period of berry susceptibility in relation to high disease pressure. Similarly, Alemu *et al*. (2016) have reported variation in CBD intensity which was high in the garden production followed by semifrorest and forest production systems conducted in different coffee growing areas of Ethiopia.

Coffee production challenges

Coffee production is challenged by several biotic and a biotic factors. Due to this factors, its average yield is very low (about 748 kg/ha) in contrast to the achievement in Latin America and Asia. Moreover, the limited use of improved technologies and best cultural practices by producer's as well as environmental change aggravate the occurrence of insect pests, diseases and coffee weeds and discourages coffee production especially in Ethiopia (Adugna *et al*, 2009b; Teferi and Ayano, 2017). Mainly, coffee berry disease (*Colletotrichum kahawae*)*,* Coffee wilt disease (*Gibberella xylarioides*), coffee leaf rust (*Hemileia vastatrix*) and Coffee thread blight (*Corthicium koleroga*) which lead to higher losses in coffee yield by attacking the green berries, vascular tissues (Xylem and phloem) and photosynthetic part (the leaf) respectively (Belachew *et al*., 2016; Teferi and Belachew, 2018). Currently, Alemu *et al*. (2016), have reported a national average CBD incidence and severity of 52.5% and 29.9%, respectively.

Coffee berry disease and its distribution

The main cause of yield loss in Arabica coffee is due to CBD caused by *C. kahawae* in Africa (Pires *et al*., 2015). The disease is considered as coffee anthracnose because it causes great economic damage on expanding green coffee berries by encouraging premature fruit drop and/or fruit mummification (Mohammed and Jambo, 2015; Emana, 2015).The disease was first noticed and identified by McDonald in Kenya 1922 and up to 75% losses were reported soon after first appearance. In spite of little attention received at the first stage of it emergence, African coffee growers soon observed a rapid dissemination of CBD throughout coffee growing areas. Later, it was reported in Angola in 1930, Zaire in 1937, Cameroon 1955-1957, Uganda 1959, Tanzania in 1964 and Zimbabwe, Malawi and Zambia 1985 (Weir *et al*., 2012; Belachew and Teferi, 2015). Five decades later it was reported in Ethiopia in the Sidamo zone then, spread very quickly in all coffee growing areas until 1978 with remarkable losses (Hindorf and Omondi, 2011). The effect is more important at high altitude plantations in tropics (Fino, 2014). Occasionally, it will have occurred in the lower altitude having cold and damp weather conditions similar to climatic conditions in the higher altitudes (Zeru *et al.*, 2009).

Depending on host susceptibility, pathogen aggressiveness and favorable weather conditions, the occurrence and intensity of CBD varies from place to place and season to season (Alemu *et al.*, 2016). Hence, 51 and 81% at Melko and Wondogent (Ejetta, 1986) respectively, 38.8 and 17.2% in SNNP in 1994 (Zeru *et al*., 2012) losses respectively have been reported. Furthermore, the survey conducted in 1997 and 1998 in six major coffee growing zones of Oromiya region revealed 31 and 32 % average CBD severity in the respective years (Jirata and Asefa, 2000); in 10 zones and 31 woredas of the SNNP reported 40 and 22.8% of incidence and severity, respectively (Negash and Abate, 2000).

The impact of CBD is still more prevalent in the African continent, but has not given critical focus as the major problem elsewhere. Since its emergence, it causes severe yield losses and preventing cultivation of Arabica coffee in the highland regions. In African countries that grown *C. arabica*, crop losses of 20-30% are common, but can exceed 80% in extremely wet years if no control measures are applied (Silva, 2010). Prevalence of low temperature with high rainfall for extended period of time favors CBD development and increases disease occurrence that can results to rots and fruit falling with post-harvest losses ranging from 40 to 80% (Hindorf and Omondi, 2011).

Free movement of coffee planting materials from CBD infected areas can fasten frequent distribution of the disease (Zeru, 2006). Alemu *et al.* (2016) reported that all coffee producing Ethiopian coffee ecosystems are suffered with severe impact of CBD more importantly in Borena (10-80%), Gedio and Hararghe (40-100%), Illubabor (10-90%) Jimma and Sidama (30-90%) and West Wollega (30-80%) of CBD incidence in each assessed zones during 2014 cropping seasons. CBD results 24 to 30% national average losses on the susceptible landraces when environmental conditions favored disease development, the loss due to CBD may reach 100% (Adugna *et al.,* 2009a).

Pathogen (C. *kahawae*) Taxonomy

The former taxonomic description and position of *C. kahawae* was subject to confusion from the range of *Colletotrichum* spp. which are isolated from coffee plants, four groups (*C. coffeanum* mycelia, *C. coffeanum* acervuli. *coffeanum* pink and coffee berry disease (CBD) strains) are described initially based on their morphological traits (Gibbs, 1969). From these, the 4th group was the only species which able to infected the green berries. *C. gloesporioides* and *C. acutatum* are the former groups which are non-pathogenic for green coffee berries (Hindorf, 1970). However, *C. coffeanum* was described in 1901 in Brazil from diseased coffee berries (Hyd *et al*., 2009). Gichuru (2007) and Prihastuti *et al. (*2009) found that *C. gloesporioides* occurred as saprophyte (weak pathogen) synonym with CBD pathogen which is more aggressive on ripe coffee berries and coffee tissues with the symptoms of whitish to dark grey discoloration. The causative agent of CBD (*C. kahawae)* was first identified by Waller and Bridge in 1993 and it is also a distinct species based on morphological, cultural and biochemical character (Batista *et al*., 2017). Currently, the fungus is under Kingdom: Fungi, Phylum: Ascomycota, Class: coelomocytes, Order: *Melanconiales,* Family: melanconiaceous, Genus: Colletotrichum m, Species: *kahawae* (Owaka, 2011).

Biology, Epidemiology and Disease symptoms

Plant infecting fungi comprises diverse groups of organisms with different life cycles and methods by which they infect and colonize their hosts (Silva *et al*., 2017). The unstable groups of fungi can use different tissues of the hosts as alternate habitat, and it makes difficult in pathogen identification even if distinction at the sub specific level is provided (Batista *et al.,* 2017). Pathogen diversity can be limited by lack of perfect state which promotes sexual recombination (Omondi, 1998). So, understanding the complex life style patterns of *Colletotrichum* spp. (Fig.1) and the dynamic state of their host relationship has important implication for management.

The life style of the pathogen can be distinguished metabolically by its inability to use either citrate or titrate as a sole carbon source (Loureiro *et al.,* 2012). The pathogenesis including conidial production, dispersion, and germination is takes place in the presence of rain /water. Asexual spore (conidia) from mummified berries and twig barks disseminated by rain splash are the primary inoculums sources (Griffith *et al.,* 1991; Waller and Bridge, 1993). The spore movement is down ward in tree canopies with the guide of water (moisture) movement whereas long distance movement is via passive vectors like man, insects, vehicles and birds which can carry viable spores or via the movement of infected plant materials (Biratu, 1995). This is the reason why coffee CBD spores on the coffee crowns are laterally dispersed between trees and branches by wind slashing. With this regard, downward movement is considered the primary inoculum movement (Silva *et al*., 2006).

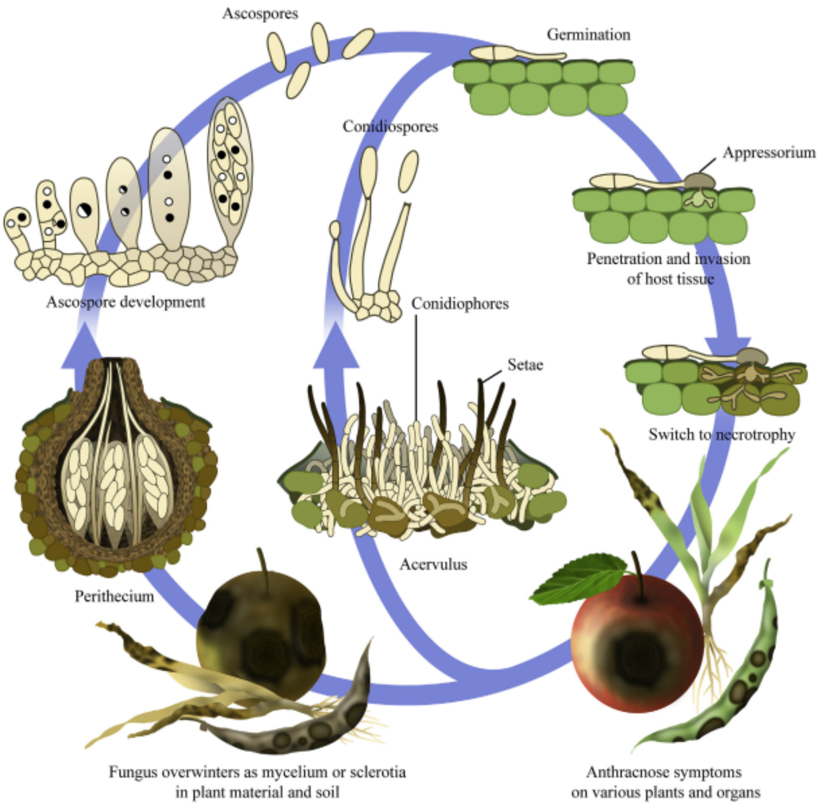

Figure1. General life cycle of *Colletotrichum* species (Silva *et al*., 2017)

In the infection process, *C. kahawae* uses hemibiotrophic strategy that includes post penetrative asymptomatic bio trophic phase (attacks the host cell without killing them) followed by destructive necrotrophic phases (involves in the increament of wall degrading enzyme that encourage pathogenicity which culminate the appearance of disease symptoms and fungus reproduction (Loureiro *et al*., 2012). Tissue colonization is associated with sever cell wall alterations and death of the host protoplast (MouneBedimo *et al*, 2010). Infection starts with conidial germination (asexual spore). After contact with the host plant tissue, follows germ tube elongation in the apical selection and differentiates in to melanized apresorium which functions as plant cell cuticle penetration (Fig. 2) directly via turgor pressure (mechanical pressure), secretion of cutin degrading enzymes or the combination of the two processes (Silva *et al*., 2006; MouneBedimo *et al.,* 2010).

The first disease symptom is dark brown slightly sunken spots in favorable situations. The spots enlarge to cover the whole berries and will form visible masses of conidia with black and shriveled lesions on the beans, whereas, infection on ripe berries will be seen as dark sunken patches that spread rapidly through whole berries coverage. Under favorable conditions, the pathogen rapidly sporulates by forming mass of conidia and enters inside the berries via penetration and infection takes place in expanding green berries, leading to premature dropping and mummification of berries (Waller *et al.*, 2007).

Based on resistant or susceptibility response of coffee genotypes, two types of symptoms (scab lesions and active lesions) can be occurred. Scab lesions are plants resistance response that restricts fungal development allows only small black spots formation. But, the deeper layers of the fruit are not invaded that appears as stationary lesion not affecting the normal development of the green berry. However, in the susceptible plants active lesion development is observed starting as little black spots; in the presence of good conditions it can form dark, sunken, active lesions that rapidly expand and destroy the entire fruits (Fino, 2014; Diniz, 2018)

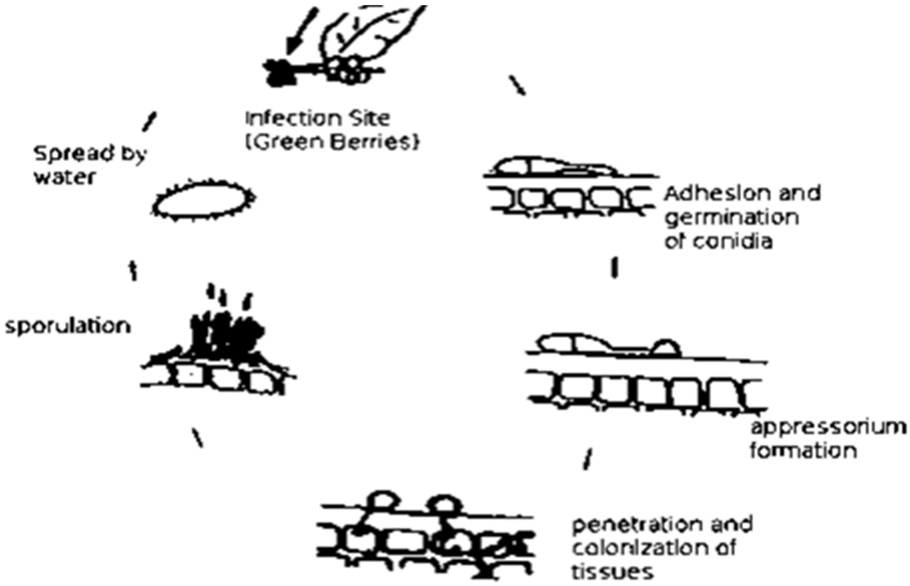

Figure 2. The systemic infection process of Colletotrichum kahawae (Silva, 2010)

Characteristics and variability in *C. kahawae* isolates in various collections

McDonald had described the first cultural characteristics of *C. kahawae* in 1926. The main distinguishing characteristics of the pathogen include slow growing, cottony and dark grey to greenish mycelium mainly in the young culture. These features are become variable in old cultures (Waller *et al*., 1993; Omondi, 1998). This common cultural characteristic used as distinct features from other groups of pathogens linked with ripening coffee berries, branches and leaf symptoms. Gibbs (1969) described four main strains of *Colletotrichum* species collected from coffee with the base of their colony characters and able to separate between the saprophytic strains (mycelia with and without acervuli and pinkish form) in the conidia of *C. kahawae* borne directly on the hyphae (Gibbs, 1969). The detailed morphological study of *Colletotrichum* spp. collected from different ecosystem was made by Hindorf in 1970 in Kenya.

Moreover, CBD pathogen has distinctive features which enables it to occupy a unique ecological niche and separates it on a functional basis from all other *Colletotrichum* species. One is its pathogenicity towards developing green coffee berries (attached and detached berries) and seedling hypocotyls. In places where *C. arabica* is grown most extensively in the highlands, the pathogen *C. kahawae* did reach the wild population in which much of it was susceptible to the disease (Batista *et al.,* 2017).

Variation between *C. kahawae* isolate collections can be existed due to aggressiveness and cultural characteristics like sporulation, conidial size and shape, appearance on culture, growth rate of the isolates on different media (Rodrigues *et al*., 1991). These morphological criteria are used as accurate classification of *Colletotrichum* spp. that invading coffee genotypes (Omondi, 1998). They are varying in growth rate and conidial length when they grow in different media. Zeru (2006) reported 4.4 mm/d of average growth rate, 14.1 and 4.2µm of the conidial length and width respectively when it cultured in different media. The conidia of *C. kahawae* can be distributed by water splashes because it requires the presence of water or 100% relative humidity and optimum temperature of about 22 ^{0}C for germination. Additionally, correct identification and characterization of disease causing fungal pathogens need to detect the morphological features such as mycelial color, growth rate, conidial production in the invitro conditions and testing the pathogenicity on the berries or hypocotyls (Hindorf *et al*., 1997).

Aggressiveness can be considered as quantitative measure of the level of disease reached over time. Most of the aggressive pathogen reached at the specific disease level faster than the less aggressive and can be measured by spore production, infection size, latent periods and its severity on the host (Luzolo *et al*., 2010; Pires *et al*., 2016). Factors like geographical origins have attributed for aggressiveness of *C. kahawae* populations. But isolates collected from different geographical locations may showed similar reaction but varies in their aggressiveness on the inoculated genotypes (Fredrik *et al.,* 2015). Besides, variation in sporulation and rate of growth of the pathogen can lead to variation in aggressiveness of *C. kahawae* isolates (Kilambo, 2008).

Beynon *et al.* (1995) reported that *C. Kahawae* strains collected from Cameroon, Zimbabwe, Kenya, Burundi, Tanzania and Ethiopia and the strains from Malawi were the most virulence and cause severe disease in comparison to others. Furthermore, variation within pathogen population can be appeared due to migration or gene flow followed by mutation or recombination (Margaret, 2011). Virulence tests of *C. kahawae* isolates used to detect the exhibited variation among aggressiveness isolates (Fredrick *et al.,* 2015). Also, susceptible genotypes are clear indicators of aggressiveness difference among pathogen isolates (Castiblanco *et al.,* 2018).

Host resitance mechanisms
Defense responses of the genotypes are considered to be dependent on the pathogen lifestyle and the genetic constituent of the host (Adolf and Ercolano, 2015; Ma and Ma, 2016). Pre-formed and induced mechanisms are among the most mechanisms in the host response for pathogen. In coffee resistance for CBD can be characterized by partial fungal development allied by means of host resistance like hypersensitive reaction (HR) which is the rapid localized cell death, formation of structural barriers and antifungal compounds like accumulation of callose, lignin-like and phenolic compounds (Silva *et al.,* 2006; Loureiro *et al.,* 2012). Some of these mechanisms are likely to be pathogen nonspecific and could induced by mechanical injury. It may be possible to develop some of the observed biochemical and structural changes into methods of screening for CBD resistance. Traits of interest in permanent crops like disease resistance can be observed and screened more importantly at late stages of development and require assessment over a number of years at different location. Besides, the susceptibility of green berries for *C. kahawae* is varied with the development stages (Vieira *et al*., 2018); hence, evaluation at green berries expanding stage is better than at green berries mature.

Research achievement in resistance development for CBD in Ethiopia
In Ethiopia, CBD resistance selection program was designed soon after the outbreak of CBD in 1971. High genetic variability among coffee genotypes were observed through massive selection programs on indigenous resistance coffee populations basically with four critical steps, selection and testing of coffee mother trees without or with a very low CBD infection via visual assessment and berry count in the natural infested fields and attached or detached berry tests, screening of their progeny and multiplication in large blocks (Ejetta, 1986). Robinson (1976) found that 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. Genetic resistance appears to be partial in *C. arabica* and complete in *C. canephora* (Van der Vossen *et al.,* 2015).

Breeding strategies for resistance selection provides sustainable and extended regulation of the disease in different coffee producing countries (Alemu *et al*., 2018). However, the application methods vary from country to country depending on the genetic variability, ecological conditions and production problems (Belachew, 2001). As Ethiopia is the center of origin and diversity of Arabica coffee, initial emphasis of breeding was agroechological based resistant development by subsequent evaluation of mother trees at their place of origin and the progenies at laboratory and experimental plots. Furthermore, pure line selection and intra specific hybridization methods are used commonly in Ethiopia till now (Benti, 2017).

During the past four decades, genetic based resistant variety development and identification research works have conducted via great struggles. For 1st time, from 218 promising selections 13 CBD resistant varieties were identified and released within five years (1972-1978) in the country (Van der Graff, 1981). These released varieties have played significant role in the coffee industry and the varieties are still under production at diverse agroecologies (Belachew, 2001; Benti, 2017). From long time effort, about 31 pure lines of CBD resistant cultivars had been released and are in production in coffee growing areas of the country today (Belachew *et al.,* 2015; Benti, 2017).

Disease (CBD) management approaches
It is clear that CBD is a great threat in the coffee ecology. So, in order to improve the income gained from it, there must be a need to manage using different options that minimize the risk (Van der Vossen *et al.,* 2015; Alemu *et al.,* 2016). Some of the approaches are listed below
Cultural practices: Cultural practices are likely to reduce losses due to CBD. There are some reports that promote good aeration and rapid drying of the canopy, such as adequate pruning and wide spacing can reduce disease incidence. Likely, pruning is an agricultural operation commonly practiced in tree crops. These practices used as to correct the tree stand and assimilating scheme, stimulate new reproductive organs and controlling numerous diseases. On the other hand, pruning during the vegetative growth period can leads to the effective means of removing diseased branches, berries, susceptible and old trees can reduce the initial inoculums sources through maintenance pruning and mummified berry removal (Holb, 2005; Bedimo *et al*., 2007). Furthermore, use of irrigation in coffee farm can shift the susceptible stage of berry development and attributed for the reduction of disease incidence (Gidisa, 2016).

As coffee trees are shade lovers, proper shading of coffee trees considerably reduced CBD development. Because, shade minimizes light intensity and plays crucial usage for modification of the micro environmental conditions (reduce temperature fluctuations, air movements and could limit the rain intensity) and work as a barrier, limits the dispersal and development of the pathogen (Jha *et al*., 2014). According to Bedimo *et al*. (2008) findings, shade can reduce more than 30% CBD incidence in coffee plantation.
Host plant resistance: There is a strong agreement that host resistance (HR) is the most preferred, appropriate, cost effective, biologically save and sustainable way of controlling diseases and pests (Margaret, 2011). But, growing resistance varieties need strong work in identifying the sources of genetic resistance form existed coffee

germplasm. Resistance to CBD in *Coffea arabica* most probably is horizontal/ quantitative in nature and controlled by three to five recessive genes (Van der Graff, 1984).

Likewise, resistant variety development in Ethiopia started after the outbreak of CBD in 1971 and is still in use as the best disease management option. Finding of stable (durable) resistance could guarantee sustainable production for the growers. Availability of varieties with durable resistance to CBD could provide economically and environmentally attractive and alternative for costly fungicide spraying (Van der Vossen and Walyaro. 2009). It also avoids residual effects of fungicides to the sprayers and saves the time spent for spraying. In particular, it is a useful resource for poor smallholder farmers of main coffee producers in Ethiopia. Development of resistant varieties increases the productivity and production of coffee, also saves the nation a considerable amount of foreign exchange that spent for purchasing fungicides (Habte, 2005).

The exhaustive testing of materials for CBD resistance selection from the mother trees and in their progenies in laboratory where the disease epidemic is not only severe but also regularly present is very vital (Derso *et al*., 2000). In African countries such as Tanzania, Cameroon, Kenya, Ethiopia HR approach is in practical till now (Bedimo *et al*., 2008). Masaba and Van der Vossen (1982) reported that formation of cork barriers as the mechanism of resistance to CBD based on the stability against changes in pathogen populations. In Ethiopia, Jimma Agricultural Research Center has developed 42 coffee varieties characterized by high yielder, with the better quality for different Ethiopian agroecollogies (Dawit and Daba, 2020; under publication)). Among these varieties, 31 of them are CBD resistant selections.

Biological control: implies the involvement and use of antagonistic microorganisms such as fungi and bacteria having specialized and modified genes or gene products to attack /control/ plant pathogens causing diseases. Plant pathogenic pathogens (the pathogens that cause diseases on corps) have several influences in the crop ecology and will cause total crop loss.

Biological control of plant pathogens is the primary factors in disease suppression, but the possibility in the sustainable context becomes the major contradiction issues among researchers (Weller *et al*., 2002). Bio agents in the world provides unlimited source to control pathosystem. They are also more robust than disease control with synthetic chemicals. The complexity of the organism interactions, the involvement of numerous mechanisms of disease suppression by a single microorganisms and the addictiveness of most bio control agents to the environment in all contribute to the belief that as more durable than synthetic chemicals (Serani *et al*., 2007; Rodriguez, 2016).

Soil microbes have hostile behaviors towards pathogens. Like Bacillus/Paenibacillus and Pseudomonas spp. which used as bio agents that receive much attention and tested on a varied variety of plant species for their ability to control diseases. The worldwide interest in these groups of bacteria was sparked by studies initiated for sustainable production systems. They are the main candidates for the biological control of diseases induced by fungal pathogens and they have been applied successfully to suppress Fusarium wilts of various plant species (Mulatu, 2012; Rodriguez, 2016).

For instance, Asfaw *et al*. (2018) collected 348 specimens (from leafs, twigs and berries) from Oromiya and SNNPs areas to test as the bio-agents for CBD management options under invitro conditions. After stepwise testing of these isolates, they have reported 33 bio agents (10 anti-biotic bacteria, 10 antibiotic yeast, 10 antibiotic filamentous fungi and 3 lytic bacteria) as effective bio agents under invitro conditions. This directs that, if we give great concern for biocontrol agents for CBD management we will get effective result likewise under in vivo conditions especially in our country Ethiopia.

Induction of systemic resistance: this linked with gene induction, creation of resitance means and the fabrication of broad array protection composites which result in metabolic and structural changes inside plants against pathogens (Sillero. 2012). This is an extensive happening that has been intensively considered by means of value to the fundamental indication path for potential use in plant protection (Saikia *et al*., 2003). Different authors reported that, application of plant defense inducing chemicals are used to triggering host resistance against pathogens (Ata *et al*., 2008; Aleandri *et al*., 2010). These plant inducing chemicals are also important in triggering resistance in *C. arabica* against CBD.

Recently in Ethiopia, Alemu *et al*. (2018) conducted an experiment on the effects of inducing chemicals (Jasmonic acid, Monopotassium phosphate, Di potassium phosphate and Salicylic acid) against the development of CBD via artificially inoculated coffee hypocotyls and have reported that all the tested chemicals are successful in the decline of CBD index. The experiment have the indication that the application of these multifaceted chemicals in different concentration can give the best result as the best alternative potential tools for future CBD management also at in vivo conditions.

Chemical control: The use of chemicals are the primary management tactic which can give immediate control of anthracnose diseases like CBD, but cultivation methods and yield levels can limit its application. It is often difficult to sprays trees which are unpruned and irregularly spaced. Many areas are inaccessible during the rainy season. Therefore, areas which have above average yield prospect, suffer due to severe losses and the disease remains unchecked. The proper uses of chemicals are heavily subsidized to make treatment attractive in the suitable areas

(Vander Graff, 1981).

Yet, the high cost of fungicides (45% of production cost including the labors), appearance of resistant pathogen biotype and other social and health related problems in the environment of conventional agriculture will delivers immense topics when thinking to increase the interest of sustainable agriculture and biodiversity conservation (Swami and Alane, 2013). Several farmers are challenging with low coffee expenditure and growing interest in purely grown coffee across the globe. So, the inadequacy of such elaborate control measures, losses of the potential crop becoming high (50%) under unfavorable weather condition (Waller, 2007). Moreover, it is costly in a context of smallholdings struggling to cope with an unprecedented economic crisis (Alwora and Gichuru, 2014; Etana, 2018). Different copper-based fungicides, organic fungicides, as well as mixtures of the two are recommended to control CBD. These problems make it essential to look for alternative strategies that can ensure competitive and save habits of coffee production systems (Abera *et al.,* 2011; Ngouegn *et al*., 2017).

Summary and Conclusion

Coffee has significant economic, social and spiritual impact on many communities that favors diverse cultural and/or psychological backgrounds. Yet, coffee producers have been challenged with various biotic and a biotic factors. Coffee berry disease (*Colletotrichum kahawae*)*,* coffee wilt disease (*Gibberella xylarioides*) and coffee leaf rust (*Hemileia vastatrix*) attacking fruits, leaves, stems and roots, respectively are the leading influences especially in tropical and subtropical areas. Essentially, CBD caused by C. *kahawae* which affect the green berries is the great threat of the coffee sector/ industry/ today.

Correspondingly, in African continent that produce coffee as the main sources of hard currency as Ethiopia, the primary cause of yield loss in Arabica coffee is due to CBD induced by C. *kahawae.* This pathogen causes great economic damage on expanding green coffee berries by encouraging premature fruit drop and/or fruit mummification and considered as coffee anthracnose. Due to limited emphasis given to this disease it has distributed in many countries within a short time and has suffered coffee producers. Different research report revealed that CBD can cause more than 80% when no control measures are undertaken. With this regards, application of appropriate management options like host resitance, cultural practices, and biological control agents can reduce the risk of production. Even if some research technologies are available, they are shelfed due to weak extension system that links the farmers with technologies especially in Ethiopia which fasten disease spreading in different coffee ecology easily.

In general, knowledge of life styles of the pathogen (*C. kahawae*), use improved technologies like resistant varieties, biocontrol agents, integrated management options, cultural practices and chemicals as last option and strong extension systems can be mitigate the risk of the disease across the coffee production areas. With this respects, study on the detailed knowledge on the biology, dissemination and the nature of interaction (host pathogen interaction) of CBD pathogen should be future research focus. Moreover, there are many fungal and bacterial bio agents that are not given great intention as CBD management options. Yet, their effectiveness needs great efforts of the experts and integration experimental works of disciplines.

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