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Current status of coffee berry disease (*Colletotrichum kahawae* Waller & Bridge) in Ethiopia

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ABSTRACT

The current status of coffee berry disease (CBD) caused by *Colletotrichum kahawae* was intensively assessed and examined in 152 sample coffee farms from 22 districts across major coffee growing regions of Ethiopia. The results showed that CBD was prevalent with significantly ($p < 0.001$) varied intensity of damage among fields, districts and zones. The highest disease incidence of 70.7, 65.3 and 59.3% was recorded in Hararghe, Gedeo and Jimma, with correspondingly higher severity of 42.7, 46.7 and 32.0%, respectively. The national average incidence and severity of CBD was 52.5 and 29.9% that indicated the present status of the disease is remarkably on increasing trend. The increased intensity of CBD was strongly associated with reduced disease management practices ($r = 0.50$), altitude ($r = 0.42$), coffee cultivars ($r = 0.23$) and production systems ($r = 0.28$). This empirical evidence shows that CBD is on an upsurge and remains a major challenge to Arabica coffee production in Ethiopia.

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KEYWORDS
Arabica coffee; CBD; incidence; prevalence; severity

Introduction

Ethiopia has the longest tradition of coffee production and consumption in the world with inimitable coffee ceremony (Adugna 2004). The country is believed to be the origin of Arabica coffee (*Coffea arabica* L.) that makes over 70% of the world's production (Adugna et al. 2009). Ethiopia is the first in Africa and the fifth largest Arabica coffee producer in the world (ICO 2012). The average annual production amounts to more than 350,000 tones (Alemayehu et al. 2008) and 90% of the produce comes from garden, semi-forest and forest coffee systems grown by small-scale farmers, while nearly 10% of the produce is from large-scale plantation coffee (Workafes & Kassu 2000). Coffee is one of the most important

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cash crops that have been contributing a lion's share to the country's economy (Adugna et al. 2009).

Despite the largest share in export and economic contribution, numerous constraints have been mentioned that affect the production and utilisation of coffee. Of these constraints, coffee diseases are the most serious issue that calls for immediate control measures. The crop is prone to a number of diseases that attack fruits, leaves, stems and roots, and reduce the yield and quality of the produce (Derso 1997). The major coffee diseases in Ethiopia are coffee berry disease (CBD), coffee wilt disease and coffee leaf rust though CBD is the most economically important disease of Arabica coffee in Ethiopia (Derso & Waller 2003; Adugna 2004; Adugna et al. 2009).

CBD, caused by a fungal pathogen *Colletotrichum kahawae* (Waller & Bridge), is an anthracnose of green and ripe berries of coffee (Van der Graaff 1981; Biratu 1995). The disease has direct impact on yield and quality of the coffee as it affects the harvestable crop. CBD is highly destructive at high altitude areas and in valleys where the weather is favourable for disease development. Thus, it is economically important in almost all coffee producing regions of the country where more than 90% of the coffee populations are landraces that remain susceptible to this disease (Adugna et al. 2009). The overall national average loss due to CBD is estimated to range from 24 to 30% and the loss may reach 100% during favourable season in some areas of Ethiopia (Van der Graaff 1981; Biratu 1995; Derso 1997; Derso & Waller 2003; Adugna et al. 2009).

These nationwide studies were conducted some 20 years back, except assessment of coffee diseases including CBD in forest coffee system by Zeru et al. (2009). Since then there has been shift in the status of CBD over the last two decades associated with variation in aggressiveness among the pathogen populations that might be influenced by the change in climatic conditions and production systems including coffee variety composition and agronomic practices (Adugna et al. 2008). Thus, it is imperative to assess and update the distribution and extent of damage caused by CBD in major coffee growing areas of Ethiopia. This paper provides insight on the current status and relative importance of CBD that calls for strengthening disease management strategies in coffee producing regions of the country.

Materials and methods

Description of the study areas

The study areas represented the southern, western, southwestern and eastern major coffee producing regions of Ethiopia (Figure 1). These involved three sample districts in Jimma zone (Mana, Gomma and Gera); five districts in Illubabor (Ale, Bedele, Chora, Mettu and Yayu); and two in West Wollega zone (Haru and Gimbi). In the southern region, Wonago and Yirgachefe (Gedeo zone), Aletawondo,

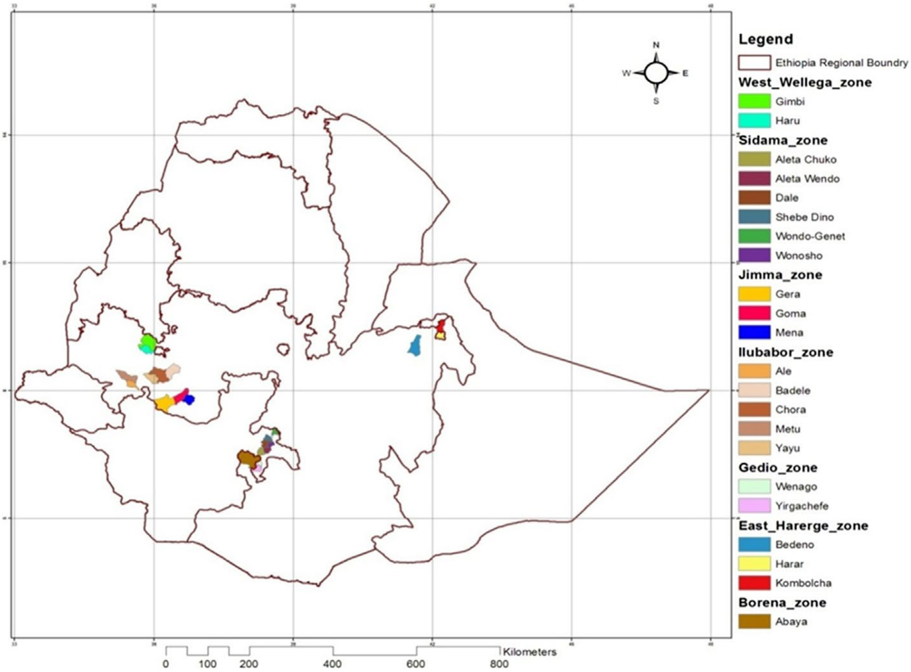

Figure 1. Description of geographical location of coffee berry disease study areas in Ethiopia.

Aletachuko, Dale, Shebedino, Wondogenet and Wonsho (Sidama zone) and Abaya (Borena zone), while East Hararghe (Bedeno, Hararzuriya, Kombolcha) zone in the eastern Ethiopia. Yayu and some parts of Gimbi, represented forest coffee, sample fields from Jimma, Illubabor and West Wollega zones were grouped under semi-forest, whereas farms from Gedeo, Sidama, Borena and Hararghe were typical garden coffee production system.

Sample unit

The assessment of CBD was conducted in 152 sample fields in 22 districts (*weredas*) from seven zones in two regional states (Oromia and Southern Nations) of Ethiopia, with potential of more than two-third of the country's coffee production and export. Two to three peasant associations (*kebeles*) per district and three coffee farms from each *kebele* were considered at every 15–20 km intervals for the study.

Disease assessment methods

Two types of disease assessment methods namely berry count and visual estimation per individual sample coffee tree were followed as described by Van der Graaff (1981). In berry count method, five coffee trees were randomly selected in "W" path from each sample farm and each coffee tree was divided into three strata (top, middle and bottom). Two middle branches with berries were chosen from each stratum for data collection. The number of CBD infected and healthy berries were counted and recorded and finally percentages of diseased berries were calculated using the following formula:

$$\text{Severity of coffee berry disease (\%)} = \frac{\text{Total number of diseased berries}}{\text{Total number of assesed berries}} \times 100$$

In the visual assessments, 10 trees from each farm were randomly taken and diagnosed for presence and absence of the disease on each tree. Thereafter, disease incidence was calculated using the following formula:

$$\text{Incidence of coffee berry disease (\%)} = \frac{\text{Total number of diseased trees}}{\text{Total number of observed trees}} \times 100$$

Agronomic parameters such as field history, altitude, production systems, cultivars type, seedling source, spacing between plant and disease management practices were recorded from each farm to determine the relationship with intensity of the disease.

Statistical analysis

Data on disease incidence and severity were analysed using three-stage nested design. Analysis of variance (ANOVA) was performed using SAS V 9.2 software package (SAS 2008). Means were separated using Tukey's test. The associations of disease incidence and severity with independent variables *viz.* altitude, production systems, and coffee cultivars under production and disease management practices were computed using simple correlation analysis to establish their relationships. Each of the independent variable was tested with incidence and severity of CBD as the dependent variable. Linear regression analysis was conducted by plotting disease severity against altitude. Determination of regression intercept, slope and coefficient of determination were done using Excel microcomputer statistical software.

Results and discussion

Occurrence and intensity of CBD

CBD was prevalent in all assessed coffee producing regions of Ethiopia. The magnitude and extent of damage caused by the disease varied significantly ($p < 0.001$) among zones and from one district to the other. At administrative zone level, the disease incidence ranged between 10 and 80% in Borena, 40–100% in Gedeo and East Hararghe, 10–90% in Illubabor, 30–90% in Jimma and Sidama, and 30–80% in West Wollega (Figure 2). Higher CBD incidence was recorded in East Hararghe (71%) and Gedeo (65%); both zones are known to have susceptible coffee in

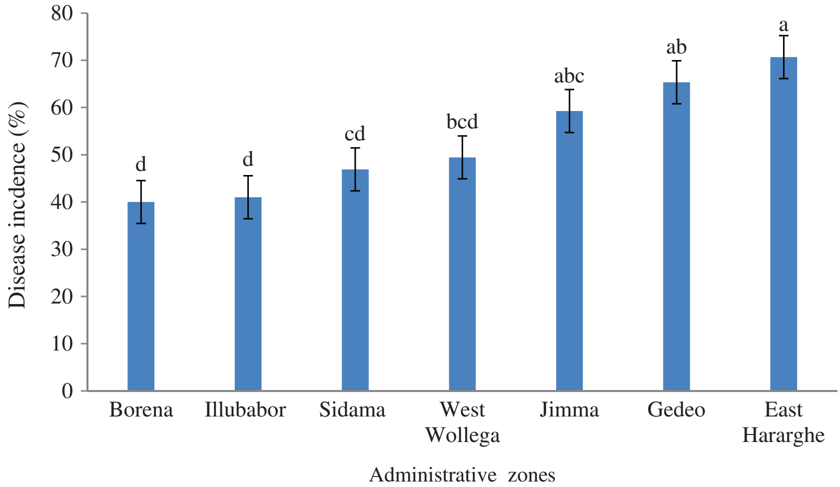

Figure 2. Mean incidence of coffee berry disease across the surveyed zones in Ethiopia during 2014 cropping season. Bars with the same letter (s) are not significantly different according to Tukey's test ($p < 0.05$).

the garden production system, which was not significantly different from Jimma (59%). On the other hand, the lowest disease incidence (40%) was estimated for Borena and Illubabor zones (Figure 2).

There was a significant difference ($p < 0.001$) among districts in incidence of CBD. The mean disease incidence ranged from 23.3 to 80.0%. Nearly sixty per cent of the surveyed districts had significantly higher levels of CBD incidence that ranged from 50 to 80% (Table 1). Among others, there were markedly increased proportions of CBD infected coffee trees in Bedeno, Kombolcha and Gomma districts with respective incidence of 80.0, 75.6 and 70.0%, which was statistically similar disease infection with Gera, Hararzuriya, Gimbi, Yirgachefe and Wonago districts. Likewise, Ale, Bedele, Mettu, Aletawondo, Shebedino, Wonsho and Wondogenet districts exhibited higher levels of disease incidence that ranged from 46.7 to 54.4%. The lowest disease incidence (<25%) was recorded at Chora and Dale districts (Table 1). The typical symptoms of CBD observed in the study area are presented in Figure 3.

Severity of CBD varied significantly ($p < 0.001$) among and within districts and administrative zones. At zonal level, the highest disease severity was recorded in Gedeo followed by East Hararghe, with respective value of 47 and 43% (Figure 4). Jimma zone has shown moderate level of disease severity ranging from 24.7 to 38.7%, which was statistical similar with West Wollega and Sidama zones. However, Borena and Illubabor exhibited relatively low level of about 20% of disease severity (Figure 4).

There was a significant ($p < 0.001$) difference among districts in terms of severity of CBD. Higher disease severity was recorded in Bedeno, Yirgacheffe and Wonago districts that ranged from 36.6 to 71.0%, 37.3 to 66.2%, and 24.5 to 80.9%,

Table 1. Incidence of coffee berry disease in major coffee growing regions of Ethiopia in 2014 cropping season.

Region	Zone	District	Altitude (m.a.s.l)	Disease incidence (%)	
				Range	Mean
Oromia	Borena	Abaya	1520–1574	10–80	40.0[cd]**
	Illubabor	Ale	1811–1947	30–80	50.0[a–d]
		Bedele	1898–1983	10–90	48.9[a–d]
		Chora	1533–1935	10–60	24.4[d]
		Mettu	1583–1773	30–60	46.7[a–d]
		Yayu	1386–1758	10–90	43.3[cd]
	Jimma	Gera	1939–2048	40–80	63.3[a–c]
		Gomma	1786–2102	60–90	75.6[ab]
		Mana	1654–1958	30–50	38.9[cd]
	East Hararghe	Bedeno	2036–2119	70–100	80.0[a]
		Hararzuriya	1668–1992	40–90	62.0[a–c]
		Kombolcha	2127–2176	60–90	70.0[a–c]
	West Wollega	Gimbi	1852–1882	40–80	55.6[a–d]
		Haru	1732–1812	30–70	43.3[cd]
SNNPR*	Gedeo	Wonago	1639–1967	40–100	66.7[a–c]
		Yirgachefe	1860–2190	40–80	64.0[a–c]
	Sidama	Aletawondo	1723–1821	40–70	50.0[a–d]
		Aletachuko	1705–1897	10–30	23.3[d]
		Dale	1722–1846	30–60	43.3[cd]
		Shebedino	1726–1964	30–70	54.4[a–d]
		Wondogenet	1715–1822	30–90	52.5[a–d]
		Wonsho	1835–1956	30–90	57.8[a–c]
Mean					52.5
SE					3.11

*SNNPR = Southern Nations Nationalities and Peoples Region.
**Values with the same letter(s) within the column are not significantly different according to Tukey's test ($p < 0.05$).

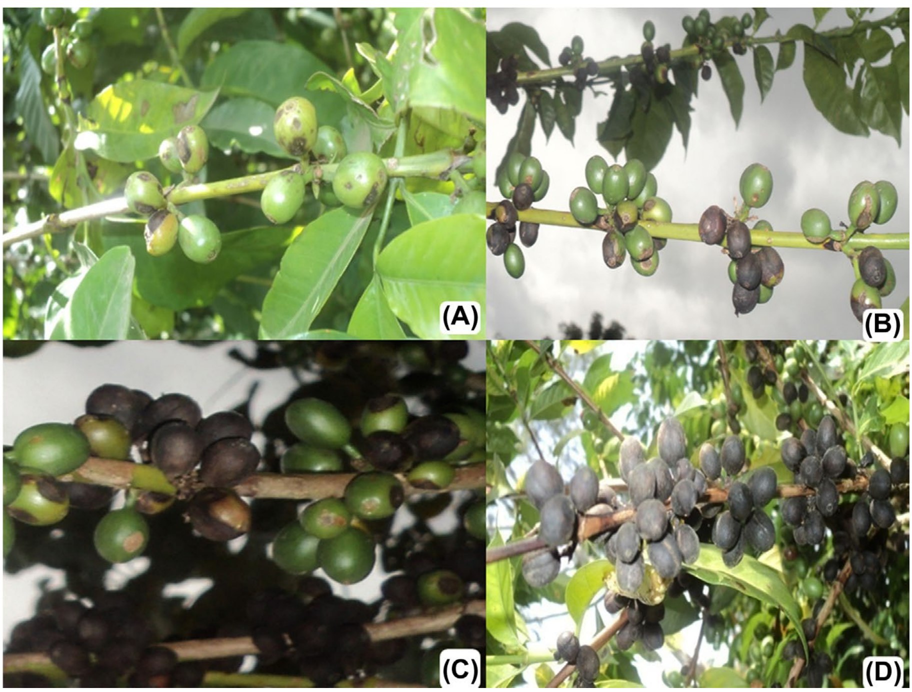

Figure 3. Symptoms of coffee berry disease on developing green berries in Ethiopia, (A and B) active lesions of CBD and (C and D) mummified berries.

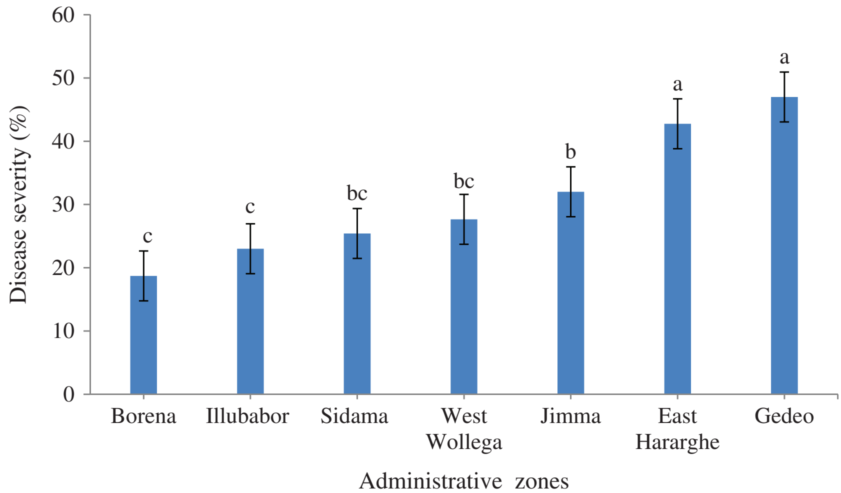

Figure 4. Mean disease severity (%) of coffee berry disease across the surveyed zones in Ethiopia. Bars with the same letter (s) are not significantly different according to Tukey's test ($p < 0.05$).

Table 2. Severity of coffee berry disease in major coffee growing areas of Ethiopia in 2014 cropping season.

Region	Zone	District	Altitude (m.a.s.l)	Disease severity (%)	
				Range	Mean
Oromia	Borena	Abaya	1520–1574	7.51–34.06	18.7[c]
	Illubabor	Ale	1811–1947	17.01–51.70	30.2[a-c]
		Bedele	1898–1983	10.82–57.75	28.7[bc]
		Chora	1533–1935	8.88–16.39	13.1[c]
		Mettu	1583–1773	13.39–23.92	19.7[c]
		Yayu	1386–1758	12.07–35.84	21.9[c]
	Jimma	Gera	1939–2048	23.51–42.45	32.6[a-c]
		Gomma	1786–2102	23.89–62.37	38.7[ab]
		Mana	1654–1958	18.56–32.43	24.7[bc]
	East Hararghe	Bedeno	2036–2119	36.57–71.04	51.1[a]
		Hararzuriya	1668–1992	23.64–64.58	37.8[a-c]
		Kombolcha	2127–2176	25.70–53.74	39.2[ab]
	West Wollega	Gimbi	1852–1882	19.01–56.31	35.9[a-c]
		Haru	1732–1812	10.69–47.15	19.4[c]
SNNPR*	Gedeo	Wonago	1639–1967	24.47–80.89	44.9[ab]
		Yirgachefe	1860–2190	37.30–66.21	48.4[ab]
	Sidama	Aletawondo	1723–1821	14.3–40.34	24.5[bc]
		Aletachuko	1705–1897	5.82–17.48	12.8[c]
		Dale	1722–1846	16.8–33.37	26.1[bc]
		Shebedino	1726–1964	21.62–41.46	30.0[a-c]
		Wondogenet	1715–1822	14.08–40.59	25.5[bc]
		Wonsho	1835–1956	21.47–60.60	33.6[a-c]
Mean					29.9
SE					2.27

Values with the same letter(s) within the column are not significantly different according to Tukey's test ($p < 0.05$).
*SNNPR = Southern Nations Nationalities and Peoples Regions.

respectively (Table 2). Kombolcha, Hararzuria, Gera, Gomma, Ale, Shebedino and Wonsho districts also exhibited moderately high levels of disease severities varying from 30.0 to 39.2%, with no significant difference with the former districts. On the other hand, Aletachuko, Chora, Abaya and Mettu districts showed relatively low level (below 20%) of disease severity (Table 2).

The present study showed increased incidence and severity of CBD in major coffee growing regions of Ethiopia, with respective mean per cent values of 52.2 and 28.8 in Oromia and 56.1 and 36.0 in Southern Nations Nationalities and Peoples Region (SNNPR), as compared to results of previous surveys. In 1994 crop season, mean per cent CBD incidence of 38.8 and 17.2 were recorded in Oromia and the SNNPR, respectively (IAR 1997). Jirata and Assefa (2000) reported average disease severity of 31.5%, in six major coffee growing zones of Oromia while respective incidence and severity of 40.0 and 22.8% were estimated in 10 zones of SNNPR (Negash & Abate 2000). Zeru et al. (2009) recorded CBD incidences of about 40.0, 26.3, 18.6 and 6.0% in forest coffee areas of Bonga, Yayu, Harrena and Berhan-konter, respectively.

The increase in intensity of CBD in our report conceivably emanated from the extensive planting of susceptible local coffee landraces aggravated by non-application of fungicides to control the disease over the past two decades. In line with this, some of the released good yielding and moderately resistant cultivar (1377) gradually became susceptible after planting by many growers in southern Ethiopia (Belachew & Teferi 2015) that might contribute to rise in CBD incidence in the SNNPR. In addition, the recent climatic changes like increased amount and duration of rainfall have reasonably predisposed and favoured the coffee berries to infection by CBD pathogen.

Relationship between CBD and altitude

There was a highly significant ($p < 0.001$) and positive correlation between altitude and incidence ($r = 0.35$) and severity ($r = 0.42$) of CBD indicating strong relationship between altitude and intensity of the disease in this study (Table 3). The disease incidence and severity increased with elevated altitude (Figure 5), and districts such as Bedeno, Kombolcha, Wonago, Yirgacheffee, Wonsho, Gimbi, Gomma and Gera which are situated in mid- to higher altitude (>1750 m.a.s.l)

Table 3. Correlation analysis between major factors and intensity (incidence and severity) of coffee berry disease in 2014 cropping season in Ethiopia.

Variables	DI	DS	ALT	CPS	SBP	CCP	CSS	DMS
DI	1.00	0.79**	0.36**	0.24**	−0.13	−0.27**	−0.29**	−0.47**
DS		1.00	0.43**	0.28**	−0.11	−0.23**	−0.30**	−0.50**
ALT			1.00	0.28**	−0.14	−0.14	−0.15	−0.12
CPS				1.00	−0.03	−0.20*	0.13	−0.04
SBP					1.00	0.06	−0.08	0.13
CCP						1.00	0.72**	0.18*
CSS							1.00	0.20**
DMS								1.00

Notes: Where, DI = Disease incidence, DS = Disease severity; ALT = Altitude; CPS = Coffee production system; SBP = Spacing between plant; CCP = Coffee cultivar; CSS = Coffee seedling source; DMS = Disease management strategy. *,
** Significant levels at $p < 0.05$ and $p < 0.01$, respectively.

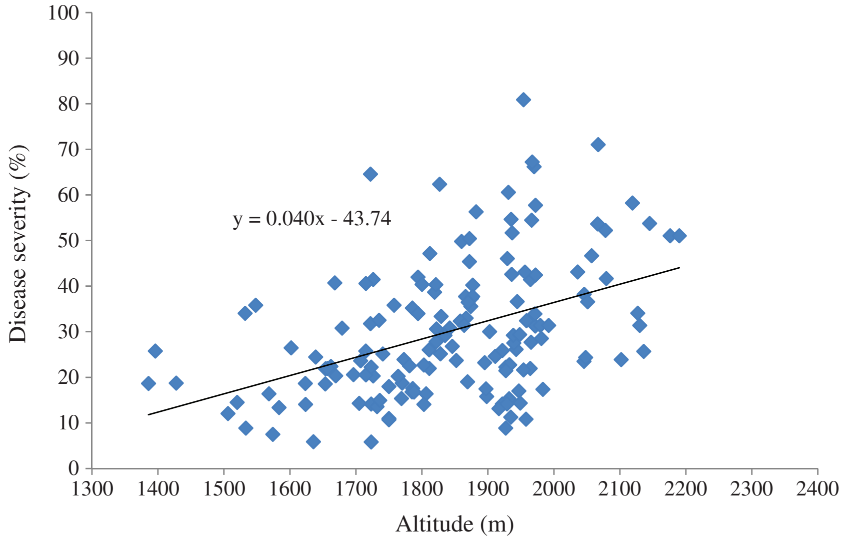

Figure 5. Relationship between severity (%) of coffee berry disease and altitude (metre above sea level) in Ethiopia.

resulted in higher levels of CBD that ranged from 35.9 to 51.3%. Those districts like Abaya, Chora and Yayu are found at low altitude (<1500 m.a.s.l) had relatively low disease values of less than 22% (Figure 5).

The positive relationship between altitude and level of CBD is also demonstrated by Mulinge (1971) and Phiri et al. (2001), who found that the CBD pathogen was more abundant at high altitudes resulting in increased intensity of CBD. Zeru et al. (2009) also found that CBD was more common in higher elevations although there were occasional outbreaks at lower altitudes of Illubabor zone. The relationship between altitude and disease severity is likely to be linked with rainfall and temperature. Mulinge (1971) explained that high rainfall, humidity or wetness and relatively low temperatures that persist for long periods favour CBD development and the disease is invariably severe at higher altitudes where these conditions generally prevail (Nutman & Roberts 1969; Phiri et al. 2001). In addition to altitude, the production system, the type of cultivar used in production, the source of seedling and disease management practices also affect the extent of damage caused by CBD significantly (Table 3).

Relation between coffee production system and disease intensity

In this study, there was highly significant ($p < 0.001$) and positive correlation between coffee production systems and incidence ($r = 0.24$) and severity ($r = 0.28$) of CBD (Table 3). The relationship pattern showed that the disease became more intense in garden followed by semi-forest and forest coffee production systems and as well summarised in Figure 6, correspondingly higher average disease incidence

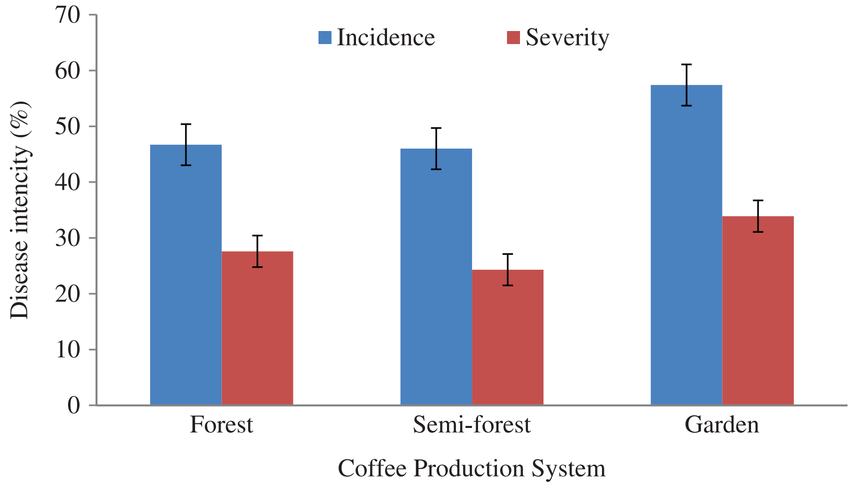

Figure 6. Intensity of coffee berry disease under different production systems in major coffee growing regions of Ethiopia.

(57.0%) and severity (33.9%) was recorded in the garden followed by forest (46.7 and 27.6%) and semi-forest (46 and 24.3%) production systems, respectively (Figure 6). The highest disease intensity in garden production system could be due to the fact that the farms are composed of homogenous coffee populations like Harar coffee types. The heterogeneous nature of the coffee populations coupled with the low inputs and low human inference in forest and semi-forest coffee production systems could attribute to the relatively reduced disease levels. Bieysse et al. (2009) noted frequent human interference hastened the spatial and temporal dispersal of CBD pathogen.

The other probable reason for the variation in intensity of CBD among the different production systems could be the effect of shade. In the garden system, majority of the coffee trees are with or without shade which may attribute to high disease intensity. In case of forest and semi-forest production systems, coffee trees are self-grown under spontaneously regenerating natural forest cover where different species of trees provide shade to the coffee. Vaast et al. (2006) reported that shading creates microclimatic conditions that helped to delay fruit ripening, which might have led to a shift in the period of berry susceptibility in relation to high disease pressure. Bedimo et al. (2007) also suggested that shade can affect and modify certain rainfall characteristics, which might influence conidial dispersal. The canopy of these plants might intercept certain raindrops, divert others from their route or reduce the speed of those droplets that were to reach the coffee trees.

Relationship between CBD and coffee cultivars

There was a highly significant ($p < 0.001$) relationship between coffee cultivars used in production and intensity of CBD (Table 3). There were two major categories of coffee cultivars (local cultivars and improved varieties) recorded in the study areas. The local cultivars "landraces" have the age of 10–40 years and are most preferred by coffee growers for their quality and relatively better yield but highly susceptible to coffee beery disease as believed by most of the interviewed farmers. The local cultivars constituted more than 20% of the surveyed farms whereas improved varieties in the form of plantation were only 7.2%. The majority of the surveyed farmers (nearly 70%) were found to grow mixture of the local cultivars with the improved coffee varieties as the latter ones are mostly preferred for their resistance to CBD and giving more yield. However, as pointed out by Wolfe (1985), the susceptible local cultivars may increase the disease pressure on improved varieties in the mixed landrace-variety growing conditions.

Correlation between CBD and disease management practices

The overall analysis of the data gathered during the survey showed that the level of CBD infection differed significantly ($p < 0.001$) depending on the crop management practices (Table 3). This is explained by negative association of disease management practices and incidence ($r = -0.47$) and severity ($r = -0.50$) of CBD. Relatively, higher disease severity was recorded on those coffee farms where there were no disease management practices than that of coffee farms with different cultural practices like pruning, removing and burning of infected/dead branches during the growing season and removal of mummified berries at the end of harvest season. Removal of such plant organs helped to reduce the potential sources of primary inoculum when the disease began, because the mummified berries and branches harboured the pathogen during the offseason (Gibbs 1969; Nutman & Roberts 1969; Bedimo et al. 2007).

Nevertheless, it should be noted that cultural practices alone could not be as efficient and effective as application of fungicides in controlling CBD. During the present study, none of the interviewed farmers used chemical fungicides to control CBD. Similarly Getachew et al. (1993) and Shibru et al. (2008) stated that the proportion of farmers that used to apply fungicides decreased from 26% in 1992 to 0.0% in 2002 in west and southwest Ethiopia.

In conclusion, CBD is still the number one disease in many coffee growing regions of Ethiopia. The varietal composition, coffee production systems above all disease management practices including lack of fungicide application have prominent impact on the incidence and severity of CBD with direct implication on the quantity and quality of coffee yield. Thus, there should be a strong effort to speed up distribution of the already released resistant coffee varieties together with developing more and more new CBD resistant coffee varieties. In addition, safe and effective disease management options such as biocontrol agents and plant resistance inducing chemicals should be studied.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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