

Survey of Tea (*Camellia sinensis*) Diseases in Southwestern Ethiopia

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Abstract: Tea (*Camellia sinensis*) is one of the most commonly consumed beverages next to water worldwide. However its production and productivity is constrained by many fungal diseases in Ethiopia. Despite this, there is lack of information on the status of the diseases and lack of knowledge on features of the pathogens associated with the diseases as there have been no any systematic assessments conducted so far. Therefore, the current works were designed with the objectives to assess the distribution of tea diseases and identify the associated pathogens. For this purpose, field surveys were carried out across three tea estate farms (Wushwush, Chewaka and Gumaro) and tea out growers surrounding them in Kafa, Sheka and Ilu Aba Bora zones in Southwest Ethiopia during the 2019 season. Causative pathogens of the diseases were identified using cultural and morphological features. The average Fusarium wilt incidence varied from (0 to 20%), Black rot (7-15%), Bird's eye spot (4-15%), Brown blight (2-5%) and Grey blight (0.5-5%) while mean disease severity of Black rot, Eye spot, Brown blight and Grey blight ranged from 4-11%, 3-9%, 1-5% and 0.5-5%, respectively. Fusarium wilt, black rot disease and eye spot diseases of tea directly related to tea yield loss. Algal leaf spot disease caused by *Cephaleuros virescens* was observed at Gumaro tea estate farm on the older leaves of aged tea bushes. The present study revealed the economic importance of tea diseases in Southwest Ethiopia. Future research should be directed towards the investigation and determination of management options for the control of important diseases of tea in the country.

Keywords: Blight, Eye Spot, Fungal Diseases, Fusarium Wilt, Tea Bushes

1. Introduction

Tea (*Camellia sinensis* (L.) Kuntze) is one of the most commonly consumed beverages next to water by a wide range of age groups in all levels of society [1]. More than three billion cups of tea is consumed every day around the world [2]. It is made from the tender new leaves of the tea plant. In Ethiopia, tea (Assam type) is introduced for the first time in 1927 and grown in Southwest part of a country. In 1927, the first Ethiopian tea garden was established at Oromia Region, Ilu Aba Bora zone in Alle district around Gore town [3]. Tea Company (private company owning both Wushwush and Gumero tea plantations) in 1989 began the commercial production of tea in the Southwest Ethiopia and thereafter, the

tea industry rapidly extended to other parts of the country.

In Ethiopia, tea plantation is totally owned by large-scale investors, except emerging out-growers around the tea companies. Ethiopia produces tea in mono-culture without shade trees in contrast to other countries such as Assam, Ceylon and Indonesia. The crop flourishes best in regions where the annual rainfall is at least 1500 mm with mean air temperature of 18-20°C, average humidity of 70-90% and five hours of sunlight per day [4].

Tea was consumed in Chinese for the first time as medicinal drink and later as refreshment [5]. It consists of over 700 valuable chemicals of which flavanoides, amino acids, vitamins (C, E and K), caffeine and polysaccharides are related to human health [6]. Studies have confirmed that tea may give different medical advantages such as anticipating tooth decay, fight cancer, combat heart disease, reduces blood cholesterol,

blood clotting, lowers blood pressure, impart immunity against intestinal disorders, diminish the blood glucose activity and normalize diabetes [7].

The production and productivity of tea is declining due to unusual weather, climate, adverse conditions of soil, large number of diseases and insect pests. Diseases are very problematic in tea plants and can cause death of tea bushes. Diseases in tea bushes are caused by fungi, bacteria, algae, parasite and virus. Tea bushes can be adversely affected by both primary diseases which can cause death of healthy tissues of tea bushes even under the best conditions and secondary diseases which can be harmful if the health of the tea bushes is damaged due to other cause [8].

About 5-10% crop loss has been estimated due to pest incidence, while crop loss has been increasing which is as high as 15-25% [9]. Pest damage in China decreased the yield by 10-20% in an average a year [10]. Mamun and Ahmed [11] reported 10-15% loss in normal condition and as high as 100% in severe cases.

Tea is a perennial crop grown under monoculture providing favorable conditions for a variety of diseases. Damage to yield and quality of tea caused by leaf, stem and root diseases is serious in tea growing countries [12]. The tea planter is more concerned than growers of other crops are about leaf diseases, for the obvious reason that the plant is cultivated for its leaves. Only the tender new growth is picked; this is advantageous to leaf disease control because these leaves are least likely to be damaged by disease. Nevertheless, some leaf pathogens have short incubation periods, and diseases on older, more mature leaves must be controlled because these leaves represent a source of inoculum for infection of new leaves and because such diseases can reduce the productivity of a plant. Even though many diseases have been described in tea plants in many tea producing countries; there is no any information about diseases affecting tea production and productivity in Ethiopia. Therefore, the present study was initiated with the following objectives:

1. To assess the distribution and significant importance of tea diseases in Southwest parts of Ethiopia
2. To identify diseases causing pathogens in tea bushes

$$\text{Disease incidence} = \frac{\text{Number of infected plant parts (twigs or leaves or berries)}}{\text{Total number of plant parts (twigs or leaves or berries) assessed}} * 100$$

$$\text{Disease severity} = \frac{\text{plant part covered by lesions or rot}}{\text{Total plant part assessed}} * 100$$

$$\text{PSI} = \frac{\text{Sum of all numerical ratings}}{\text{number of leaves observed} * \text{maximum rating}} * 100$$

2.4. Isolations and Identifications of Pathogens

The research was conducted in June - September 2019 at the Laboratory of Coffee and tea Pathology, Jimma Agricultural Research Center. The diseased tea plant part samples were taken from three tea estate area of Wushwush, Chewaka and Gumaro tea farms.

Pathogen was isolated from diseased tea plant samples collected from the main tea growing plantations in Southwest Ethiopia between July and August 2019. The isolates were obtained from infected plants by plating mycelial fans removed

3. To determine the pathogenicity of the pathogen isolates

2. Materials and Methods

2.1. Study Area

Field surveys were conducted in big tea plantations and out-growers gardens located in Oromia and South Nation, Nationality and Peoples' Regions Regional State (SNNPRS) in southwest Ethiopia. The field surveyed tea farms were Wushwush Tea Estate in Kaffa zone in SNNPRS, Chewaka Tea Estate in Sheka zone in SNNPRS and Gumaro Tea Estate in Ilu Aba Bora zone in Oromia regional state.

2.2. Data Collection

The presented data were collected during field survey of mentioned tea estates during July to last August in 2019. During the field survey different sections of mentioned tea plantations and gardens were studied and data were collected.

2.3. Survey of Diseases

A survey was carried out during July to last August' 2019 at the main farm of Southwest Tea producing farms to ascertain the impact of varieties, topography and age of plants on the prevalence and severity of the diseases. Wushwush, Gumaro and Chewaka tea plantations and tea gardens were selected and 10 farms from each plantation and tea gardens were selected. Based on farm size 30-50 tea bushes per farm were selected.

Data on fusarium wilt disease of tea was recorded on the incidence of the disease by observing the typical symptom. Data on leaf diseases were recorded on the prevalence and severity of the diseases by observing the typical symptom. These were done by using the following 0-5 scoring scale [13]. The severity of the disease was expressed in percent disease index (PDI), which was computed following a standard formula as described below [13].

from beneath the bark of roots on Potato dextrose Agar (PDA) for root diseases. The isolations of leaf diseases were carried out by following standard isolation techniques. Rose Bengal and streptomycin were used to avoid contaminants. The isolates were stored on slants of the same medium and maintained in the dark at room temperature (21 - 23°C).

2.5. Pathogenicity Tests

The pathogenicity tests for the Fusarium wilt causing pathogen isolates were performed under greenhouse

condition at Jimma Agricultural Research Center. Pure cultures of each fungal isolates growing on PDA medium were used as inoculum. Plates were incubated for 10-15 days at 22-25°C. Inoculum suspensions were prepared by mixing the contents of six agar plates (9cm diameter) with 600 ml of sterile distilled water in a blender for 3 minutes at high speed. Plant material for pathogenicity tests were obtained from wushwush nursery.

Young rooted cuttings (6 months old, clones BB-35, 1156, 6-8 and 11-4) were inoculated as follows: roots were carefully cleaned under tap water and submerged for five minutes into the inoculum suspension. Then, they were transplanted in plastic pots (12 cm diameter x 9 cm high, one plant per pot) containing 600 ml of previously autoclaved soil (Top soil: sub-soil, 3:1) plus 50 ml of inoculum. Five inoculated plants per fungal isolate plus five control ones were placed in the greenhouse (10-30°C, 40-95% RH) and watered twice a week.

Severity of aerial symptoms was periodically assessed for each plant on a 0-4 scale, according to the percentage of foliage with yellowing or necrosis: (0 = 0%, 1 = 1-33%, 2 = 34-66%, 3 = 67-100%, 4 = dead plant). At the end of each experiment (after three months), root rot was assessed by using 0-4 scale [14].

3. Results and Discussions

As revealed from this study, a number of diseases along with their causative pathogens were identified on tea bushes growing under the southwestern Ethiopia (Table 1). *Fusarium*

wilt disease of tea caused by *Fusarium oxysporum* occurred in almost all tea farms rotting the tea roots, while other diseases like Brown blight, Grey blight, Bird's eye spot, Thread blight (Black rot) and Algal leaf spot caused by *Colletotrichum camelliae*, *Pestalotiopsis theae*, *Cercospora theae*, *Corticium koleroga* and *Cephaleuros virescens*, respectively attacked different parts of the coffee plant in the field.

3.1. *Fusarium* Wilt Disease of Tea (*Fusarium oxysporum*)

3.1.1. Intensity of *Fusarium* Wilt of Tea Across Southwestern Parts of Ethiopia

Fusarium wilt of tea was prevalent in southwest Ethiopia as evidenced from the tea bushes uprooted as infected by the disease (Figure 1A) and tea fields on which tea bushes infected by the disease were uprooted at the study areas (Figure 1B). During the field survey, it was observed that the tea plantations and gardens at Wushwush, Gumaro, Chewaka areas were mostly affected by *Fusarium* wilt of tea disease which attacked about 19.75% of total tea bushes assessed. The disease was the primary disease of tea bushes at all tea growing areas of Southwest Ethiopia which causes death of healthy tissues or bushes even under the best conditions. Tea bushes of all ages were susceptible to this disease. The disease is most damaging if orchards are established in old tea plantations or newly cleared forest sites but not observed in tea gardens of out-growers previously planted with annual crops and appears to be related to the plantation's history.



Figure 1. A) Tea bushes Uprooted as infected by root rot disease at Gumaro tea plantation B) Tea field on which Tea bushes infected by root rot disease were uprooted at Wushwush tea plantation.

Table 1. Tea diseases identified and their intensity in Southwestern Ethiopia.

Location (Farm Name)	Farm type	Disease Type by Intensity								
		Root rot	Black rot (%)		Brown blight (%)		Grey blight (%)		Bird's eye spot (%)	
			Incidence	Severity	Incidence	Severity	Incidence	Severity	Incidence	Severity
WushWush	Big Plantation	19.33	11.77	8.20	1.51	0.90	0.78	0.49	10.00	6.00
WushWush	Out growers garden	20.17	15.28	10.86	3.84	2.73	5.36	3.91	7.00	5.50
Chewaka	Big Plantation	16.67	7.00	4.23	2.10	1.50	4.85	3.87	8.70	5.97
Chewaka	Out growers garden	17.33	8.97	5.77	6.53	4.92	2.82	2.07	4.08	2.68
Gumaro	Big Plantation	9.67	8.00	6.00	2.77	1.88	0.48	0.38	15.18	8.82
Gumaro	Out growers garden	0.00	12.27	8.54	2.05	1.28	2.92	1.90	8.30	6.75

3.1.2. Identification of *Fusarium oxysporum*

(i). Symptomological Identification

Affected bushes occur in patches (Figure 2A), usually around old tree stumps, but sometimes isolated bushes are affected. Plants become weaker and their leaves begin to turn

yellow and finally wilt and defoliate, eventually leading to death of the plant (Figure 2B). Longitudinal cracks were usually present on the collar above the soil level but also on the tap root and lateral roots (Figure 2C). Scrapping of the bark at the collar region revealed sheets of creamy white mycelia

(Figure 2D) and the wood had a strong mushroom like-smell. This was observed at Wushwush Estate in Kaffa zone in 2019.



Figure 2. A) Patches of tea bushes affected by *Fusarium* wilt of tea B) Turning of tea leaves to yellow and weakened tea bush C) Longitudinal cracking of tea stem at collar D) Creamy white mycelia on tea stem.

(ii). Macroscopic and Microscopic Identification

The basic keys for identification of *Fusarium oxysporum* fungus were growth rate, colony color, colony elevation, colony margin on culture media, macroconidial and microconidial morphology and number of septation. In the current work, pure cultures of the isolates were observed under compound microscope and identification was carried out based on morphological characteristics using standard references the fusarium laboratory manual. On the basis of morphological and cultural characters, the fusarium wilt causing fungus was identified as *Fusarium oxysporum*.

A. Macroscopic Identification

The study revealed that there were no considerable colony growth rate variations among *Fusarium oxysporum* isolates

collected from different Tea producing regions of Ethiopia. The growth rate of the isolates was ranging between 8.38 and 9.00 mm/day, with a mean of 8.68 mm/day in diameter (Table 2). Isolates in the present study depicted periodic change in their growth rate. All the isolates showed an increasing trend in growth rate from 3 days to 8 days but growth rate decreased afterwards.

Colony color, form, elevation and margin did not differ very much among the tested isolates of *F. oxysporum* on PDA medium (Table 2 and Figure 3). *F. oxysporum* isolates produced mycelia with floral white front and back side color, circular in form, flat in elevation, filiform margins and produced in abundance.

Table 2. Cultural characteristics of *Fusarium oxysporum* isolates.

Location	Isolate	Colony					Groth rate (cm) ⁻¹ day on PDA
		Color		Form	Elevation	Margin	
		Front	Back				
Wushwush	RtRt1	F. white	F. white	Circular	Flat	Filiform	8.38
Chewaka	RtRt2	F. white	F. white	Circular	Flat	Filiform	9.00
Gumaro	RtRt3	F. white	F. white	Circular	Flat	Filiform	8.67

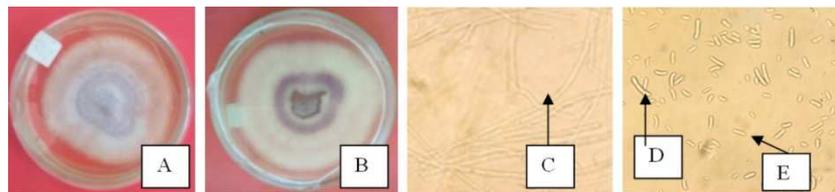


Figure 3. Colony morphology of a 7-day-old culture of isolate from wushwush A) Front side B) Back side, C) Hyphae of *F. oxysporum* under microscope, D) Macroconidia E) Microconidia under 40x objective compound microscope of isolate from Wushwush.

B. Microscopic Identification

The result of this study indicated that the macroconidial shape of all the isolates of *F. oxysporum* was slightly curved with curved

apical shape, footed basal shape and an average of 3 septa per macroconidia (Table 3). Microconidial shape of all isolates of *F. oxysporum* was fusiform without septation (Table 3).

Table 3. Morphological characteristics of *F. oxysporum* isolates collected from Tea producing areas of Ethiopia in 2019 cropping season.

Location	Isolates	Macroconidial					Microconidia		
		Morphology		Septa			Morphology		
		Conidial shape	Apical	Basal	Range	Average	Shape	Septa	
Wushwush	RtRt1	Slightly curved	Curved	Foot	2-4	3	Fusiform	0	
Chewaka	RtRt2	Slightly curved	Curved	Foot	2-4	3	Fusiform	0	
Gumaro	RtRt3	Slightly curved	Curved	Foot	2-4	3	Fusiform	0	

(iii). Pathogenicity Tests

To ascertain the pathogenic ability of the isolates, *F. oxysporum* (wushwush, Chewaka and Gumaro) were tested

for pathogenicity with six month young tea seedlings. Observation of the symptoms after 60 days of inoculation showed that leaf color of the inoculated tea plants turned

from green to yellowish-green and wilting symptom of the tea leaves occurred. After 90 days of inoculation, whole tea leaves of the inoculated plants became completely wilted; most of the tea feeder roots became rotten with black wood discoloration (Figure 4). The pathogen was then re-isolated from the infected roots of the inoculated tea seedlings and its morphological characteristics (Figure 3) were compared with the original *F. oxysporum* isolates.

There was significant difference among tea clones tested for fusarium wilt isolates in disease development and severity. Tea clone seedlings 11-56, BB-35 and 11-4, exhibited greater diseases incidence which indicates highly susceptible reactions to fusarium wilt disease under laboratory conditions (Table 4). However, few seedlings of 6-8 tea clone showed lowest diseases incidence as compared to other tea clones. With regarding to *F. oxysporum* isolates, the

isolate from Wushwush and Gumaro were the most aggressive isolates, whereas the isolate from Chewaka was the least aggressive one.

Table 4. Pathogenic reactions symptom of fusarium wilt disease isolates on seedlings of different tea clones.

Tea clone	Isolates from different farms			Water sprayed
	Wushwush	Chewaka	Gumaro	
BB-35	***	**	***	NA
11-56	***	***	***	NA
6-8	**	*	**	NA
11-4	***	**	***	NA
11-56	NA	NA	NA	-

NA= not applicable, scored as - =0% infection,+ =50-75% death of seedlings,++ =76-99% death of seedlings and +++ = 100% Death of all seedlings



Figure 4. Pathogenic reactions of fusarium wilt isolates on seedlings of different tea clones A. susceptible tea clones inoculated with aggressive isolates B. 6-8 tea clone inoculated with Chewaka isolate C. Water sprayed tea seedlings of clone 11-56.

3.2. Black Rot (*Corticium Koleroga*)

3.2.1. Intensity of Black Rot Across Southwestern Parts of Ethiopia

Black rot of tea caused by *Corticium koleroga* was prevalent in all tea growing areas of wushwush, Gumarro and Chewaka as evidenced from the typical disease symptoms on

leaves and twigs of tea bushes (Figure 5 A and B). It attacks the leaves and twigs causing gradual deterioration of the bush and consequent crop loss. Next to Fusarium wilt of tea, black rot of tea was the most devastating disease that causes yield reduction and quality deterioration in all tea clones at all growth stage of tea bushes. The average disease incidence varied from 7% to 15% while mean disease severity ranged

from 4% to 11%. The disease incidence and severity were highest at wushwush tea gardens followed by Gumaro tea gardens while disease incidence and severity were lowest at Chewaka tea plantation and noticed from July to August.

3.2.2. Identification of the Pathogen

(i). Symptomatology Identification

In the field, black rot disease on tea bushes appear as thread-like black plus whitish strands of internodes of the tea

branches (Figure 5A). The blackening of leaf petiole later spread to leaf blade predominantly on the lower surfaces of leaves (Figure 5B). The strands always branch off from the leaf petioles to leaves and then spread out into numerous fine ones (Figure 5C). The fine strands initiated dark-ashen necrosis and as the whole leaf became involved, the leaf separated at the petiole but usually remained hanging from mycelial strand that grew over the petiole from the branch.

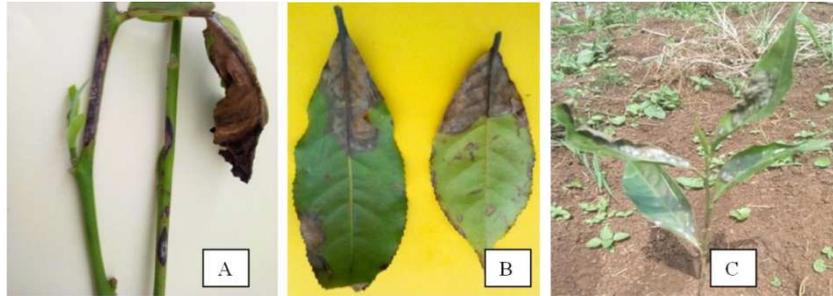


Figure 5. Black rot disease on tea bushes was seen as thread-like white to ashen strand on A) tea branches, B) leaves and C) tea seedlings at Chawaka.

(ii). Macroscopic and Microscopic Identification

The basic keys for identification of *Corticium koleroga* fungus were growth rate, colony color, colony elevation, colony margin on culture media, hyphal color, basidial (color, shape, type) of basidiospores [15]. In the current work, pure cultures of the isolates were observed under compound microscope and identification was carried out based on morphological characteristics using standard references [16, 15]. On the basis of morphological and cultural characters, the black rot causing fungus was identified as *C. koleroga*.

A. Macroscopic Identification

The study revealed considerable colony growth rate variations among *C. koleroga* isolates collected from different tea producing regions of Ethiopia. Isolates differed in terms of growth rate in diameter ranging between 7 and 8

mm/day, with a mean of 7.8 mm/day in diameter (Table 5). An Isolates from wushwush had the fastest growth rate (8.14 mm/day on average) followed by an isolate from Gumaro (7.80 mm/day in diameter) while isolates from Chewaka grew slowly (mean growth rate of 7.48 mm/day in diameter). Isolates in the present study depicted periodic change in their growth rate. All the isolates showed an increasing trend in growth rate from 2 days to 8 days but growth rate decreased afterwards.

Colony color, form, elevation and margin did not differ very much among the tested isolates of *C. koleroga* on PDA medium (Table 6 and Figure 6). *C. koleroga* isolates produced mycelia with white to floral white front and back side color, entire margins, raised in elevation and circular in form and produced in abundance.

Table 5. Cultural characteristics of *Corticium koleroga* isolates.

Location	Isolate	Colony Color		Form	Elevation	Margin	Growth rate (cm) ⁻¹ day
		Front	Back				
		On PDA					
Wushwush	BIRt1	White	F. white	Circular	Raised	Entire	8.14
Chewaka	BIRt2	White	F. white	Circular	Raised	Entire	7.46
Gumaro	BIRt3	White	F. white	Circular	Raised	Entire	7.8

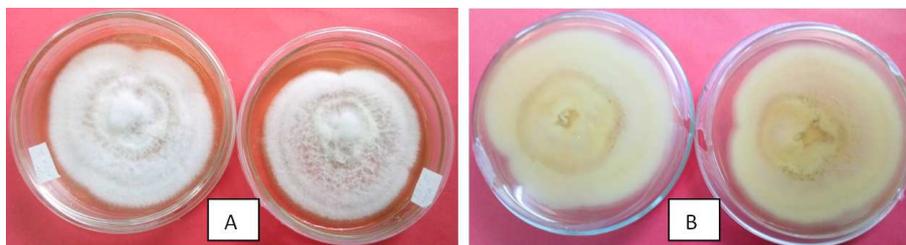


Figure 6. Colony morphology of *C. koleroga* isolate from wushwush A) Front side and B) Back side.

B. Microscopic Identification

Pure cultures of *C. koleroga* showing long, hyaline, wide angled branching mycelia (Figure 7A) were observed under microscope. Burt (1918) also characterized mycelium of this

pathogen in similar way. According to his report, the mycelium of *C. Koleroga* is characterized as long, slender, mycelial strands of uniform diameter, composed of loosely interwoven, hyaline or slightly coloured, thin-walled, even,

rigid hyphae measuring 4.5 to 6 μ in diameter, not nodose-septate and branching at right angles. The texture of the hyphae of *C. koleroga* seems too filamentous because mostly the mycelia of all the isolates are found in compacted form in

groups. Once the pathogen starts to produce basidiospores, the basidiospores were found scattered over the surface of the hyphae, which is probably due to the presence of gelatinous materials over the surface of hyphae.

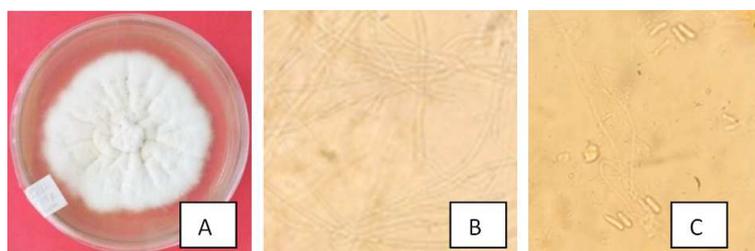


Figure 7. A) Colony morphology of a 8 days old culture of isolate from Chawaka, B) Hyphae of *C. koleroga* under microscope, C) Basidiospore under 40x objective compound microscope for isolate from Chawaka.

Corticium koleroga is characterized by basidia, which are ellipsoid to oblong in shape, hyaline in color, not septate, thicker than width of supporting hyphae on which 4-6 basidiospores were directly fixed. This result is supported by previous reports [16-19].

Basidiospores produced by isolates of *C. koleroga* collected from different parts of south western Ethiopia were fusiform in shape. Basidiospores of *C. koleroga* appeared as smooth, hyaline, narrow and fusiform in shape. The basidiospores were found to adhere frequently in groups of four to six, which would indicate that most probably basidia have six basidiospores which agreed with the work of [20] and Hoehnel [21]. The mycelia and basidiospores of *C. koleroga* appear to be attached together into a layer, so that not a basidiospores or mycelium can be removed from the mass without difficulty as described by Rogers [18].

According to Cooke [22] and Burt [17], the presence of the gelatinous element which binds together the threads and spores into a thin pellicle, which is easily separable from the matrix when moist, is an important feature in determining the affinities of the *Corticium koleroga* in the genus *Corticium*. Burt [17] concluded that the cell walls of the hyphae of the *C. koleroga* are gelatinous in nature. This was in agreement with what was observed in the current study as the

basidiospores are scattered over the surface of hyphae and seated on it and separated from each other with difficulty. Basidiospores are attached and scattered over the mycelia at irregular intervals on the threads without any visible pedicel.

3.3. Bird's Eye Spot (*Cercospora Theae*)

3.3.1. Intensity of Bird's Eye Spot Across Southwestern Parts of Ethiopia

Bird's eye spot disease attacks the leaves of tea bushes of all ages, but its impact is most serious on young tea plants both in fields and in nurseries. The disease on tea was prevalent in southwest Ethiopia as evidenced from the tea young and maintenance leaves (Figure 8 A and B). Next to Fusarium wilt and black rot of tea, bird's eye spot was the most devastating disease that causes yield reduction and quality deterioration in all growth stage of tea bushes. The average disease incidence varied from 4% to 15% while mean disease severity ranged from 3% to 9%.

3.3.2. Identification of the Causative Pathogen

(i). Symptoms of Bird's Eye Spot in the Field

The symptoms which appear on the leaves are round, grey-brown spots approximately 10mm in diameter and with a lighter colored dot in the center (Figure 8 A and B).



Figure 8. Bird's eye spot disease on tea bushes was seen as circular brown eyeon A) young tea leaves and B) maintenance tea leaves at Gumaro.

(ii). Cultural Characteristics of the Pathogen

Isolates of *Cercospora theae* differed in terms of growth

rate in diameter were ranging between 7 and 8 mm/day, with a mean of 7.51 mm/day in diameter (Table 6). An Isolates

from Gumaro had the fastest growth rate (8.00 mm/day on average) followed by an isolate from Chewaka (7.43 mm/day in diameter) while isolates from wushwush grew slowly (mean growth rate of 7.10 mm/day in diameter).

Colony color, form, elevation and margin did not differ among the tested isolates of *Cercospora theae* on PDA

medium (Table 6 and Figure 9). *Cercospora theae* isolates produced mycelia with white front colony color and grey back side colony color, undulate margins, irregular in elevation and irregular in form and produced in abundance. Long and hyaline hyphae were observed under microscope on pure culture of *C. theae* (Figure 9C).

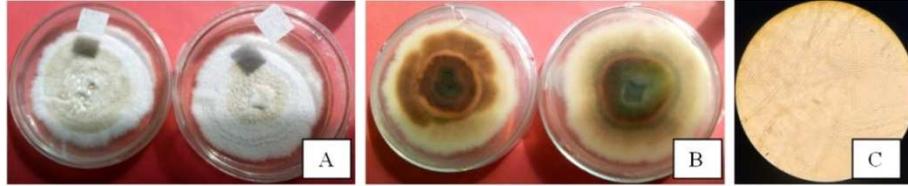


Figure 9. Colony morphology of *Cercospora theae* from Gumaro A) Front side and B) Back side and C) Hyphae of *C. theae* under microscope.

Table 6. Cultural characteristics of *Cercospora theae* isolates.

Location	Isolate	Colony Color		Form	Elevation	Margin	Growth rate (cm) ⁻¹ day
		Front	Back				
		On PDA					
Wushwush	EySt1	White	Grey	Irregular	Irregular	Undulate	7.10
Chewaka	EySt2	White	Grey	Irregular	Irregular	Undulate	7.43
Gumaro	EySt3	White	Grey	Irregular	Irregular	Undulate	8.00

3.4. Brown Blight (*Colletotrichum Camelliae*)

3.4.1. Intensity of Brown Blight Across Southwestern Parts of Ethiopia

Brown blight *Colletotrichum camelliae* was very common leaf disease and occurred in every tea field. However, it does not cause economic loss because it is not related to harvestable young leaves. It appears in weakened or injured bushes as a result of hard plucking, herbicide injury, hail, frost, sun scorch, water logging and bushes affected by stem

and root diseases. The average disease incidence varied from 2% to 7% while mean disease severity ranged from 1% to 5%.

3.4.2. Identifying Characters of Brown Blight

(i). Symptoms of Brown Blights in the Field

Yellowish green spots developed on young leaves. Circular irregular spots develop on the leaves with red and dray mycelium. Old leaves are affected by these diseases.



Figure 10. Brown Blight disease symptoms on tea leaves on A) underside of tea leaves and B) Upper side tea leaves at Chewaka.

(ii). Cultural Characteristics of the Pathogen

The study revealed considerable colony growth rate variations among *Colletotrichum camelliae* isolates collected from different tea producing areas of Ethiopia. Isolates differed in terms of growth rate in diameter ranging between 7.80 and 9 mm/day, with a mean of 8.38 mm/day in diameter (Table 7). An Isolates from Gumaro had the fastest growth rate (9.00 mm/day on average) followed by an isolate from

wushwush (7.43 mm/day in diameter) while isolates from Chewaka grew slowly (mean growth rate of 7.80 mm/day in diameter).

Colony color, form, elevation and margin did not differ very much among the tested isolates of *Colletotrichum camelliae* on PDA medium (Table 7 and Figure 11). *Colletotrichum camelliae* isolates produced mycelia with white front colony color and Floral white back side colony

color, Entire margins, Umbolate in elevation and irregular in form and produced in abundance.

Table 7. Cultural characteristics of *Colletotrichum camelliae* isolates.

Location	Isolate	Colony Color		Form	Elevation	Margin	Growth rate (cm) ⁻¹ day On PDA
		Front	Back				
		Wushwush	BrBt1				
Chewaka	BrBt2	White	Floral white	Irregular	Umbolate	Entire	7.80
Gumaro	BrBt3	White	Floral white	Irregular	Umbolate	Entire	9.00



Figure 11. Colony morphology of *Colletotrichum camelliae* from Gumaro A) Front side and B) Back side.

3.5. Grey Blight (*Pestalotiopsis Theae*)

3.5.1. Intensity of Grey Blight Across Southwestern Parts of Ethiopia

Grey blight is caused by *Cercospora theae* is also very common leaf disease which usually occurs together with Brown blight disease. Similar to brown blight it also appeared in weakened or injured bushes by herbicide injury, hail, frost, sun scorch, hard plucking and bushes affected by stem and root diseases. The average disease incidence varied

from 0.5% to 7% while mean disease severity ranged from 0.5% to 4% (Table 1).

3.5.2. Identifying Characters of Grey Blight

(i). Symptoms of Grey Blight in the Field

Light brown or dark brown, circular or oval shaped patches observed on the leaves (Figure 12 A and B). The concentric rings of mycelium are distinctly visible. And on the dorsal surface of leaves fruit bodies are located in concentric rings.

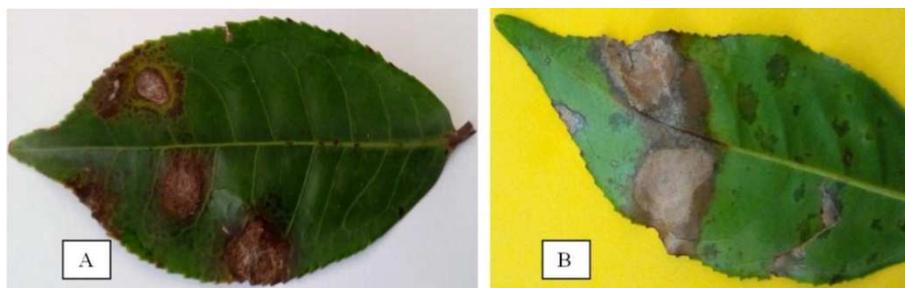


Figure 12. Grey blight disease symptoms on tea leaves on A) Upper side of tea leaves and B) underside tea leaves at Wushwush.

(ii). Cultural Characteristics of the Pathogen

The study revealed considerable colony growth rate variations among *Pestalotiopsis theae* isolates collected from different tea producing areas of Ethiopia. Isolates differed in terms of growth rate in diameter ranging between 6 and 8 mm/day, with a mean of 7 mm/day in diameter (Table 8). An isolate from Wushwush had the fastest growth rate (8.41mm/day on average) followed by an isolate from Gumaro (6.88 m/day in diameter) while isolates from

Chewaka grew slowly (mean growth rate of 6.10 mm/day in diameter).

Colony color, form, elevation and margin did not differ very much among the tested isolates of *C. koleroga* on PDA medium (Table 8 and Figure 13). *Pestalotiopsis theae* isolates produced mycelia with white front colony color and Floral white back side colony color, Entire margins, Umbolate in elevation and irregular in form and produced in abundance.

Table 8. Cultural characteristics of *Pestalotiopsis theae* isolates.

Location	Isolate	Colony Color		Form	Elevation	Margin	Groth rate (cm) ⁻¹ day On PDA
		Front	Back				
		Wushwush	GrBt1				
Chewaka	GrBt2	White	Floral white	Irregular	Flat	Entire	6.10
Gumaro	GrBt3	White	Floral white	Irregular	Flat	Entire	6.88



Figure 13. Colony morphology of *Pestalotiopsis theae* from Chewaka A) Front side and B) Back side.

3.6. Algal Leaf Spot (*Cephaleuros Virescens*)

3.6.1. Intensity of Algal Leaf Spot Across Southwestern Parts of Ethiopia

Algal leaf spot disease caused by *Cephaleuros virescens* was observed at Gumaro tea estate farm on an old leaves of old tea bushes. The disease did not cause economic loss to

the crop because it occurred on a very old leaves of neglected old tea bushes.

3.6.2. Symptoms of Algal Leaf Spot in the Field

Leaves develop lesions that are roughly circular, raised and purple to reddish to brown. Algal leaf spots were circular in shape, and somewhat raised from the leaf surface.



Figure 14. Algal leaf spot disease symptoms on upper side tea leaf at Gumaro.

4. Conclusions

Many diseases caused by fungal pathogens are important constraints of tea production and productivity at tea producing Southwest of Ethiopia. Fusarium wilt, Black rot, Bird's Eye spot, Brown blight, Grey blight and Algal leaf spot diseases caused by *Fusarium oxysporum*, *Corticium koleroga*, *Cercospora theae*, *Colletotrichum camelliae*, *Cercospora theae* and *Cephaleuros virescens*, respectively were identified on tea bushes in Ethiopia. The average fusarium wilt incidence varied from (0 to 19%), Black rot (7-15%), Eye spot (4-15%), Brown blight (2-5%) and Grey blight (0.5-5%) while mean disease severity of Black rot, Eye spot, Brown blight and Grey blight ranged from 4-11%, 3-9%, 1-5% and 0.5-5%, respectively. Fusarium wilt, black rot disease and eye spot diseases of tea directly related to tea yield loss. Algal leaf spot disease caused by *Cephaleuros virescens* was observed at Gumaro tea estate farm on the older leaves of aged tea bushes. The present study revealed the economic importance of tea diseases in Southwest Ethiopia. Future research should be directed towards the investigation and determination of management options for the control of important diseases of tea in the country.

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