



Plant Pathology Journal

ISSN 1812-5387

science
alert

ANSI*net*
an open access publisher
<http://ansinet.com>



Research Article

Distribution and Importance of Sorghum Anthracnose (*Colletotrichum sublineolum*) in Southwestern and Western Ethiopia

¹Binyam Tsedaley, ²Girma Adugna and ²Fikre Lemessa

¹College of Agriculture and Natural Resource, Assosa University, P.O. Box 18, Assosa, Ethiopia

²College of Agriculture and Veterinary Medicine, Jimma University, P.O. Box 307, Jimma, Ethiopia

Abstract

Background: Sorghum (*Sorghum bicolor* L., Moench) is the 5th most important food crop in the world. But its production in Ethiopia is adversely affected by different biotic and abiotic constraints among which sorghum anthracnose caused by *Colletotrichum sublineolum* is the major one. **Methodology:** In this perspective, it is imperative to assess the distribution and severity of sorghum anthracnose along varying agro-ecologies of Southwestern and Western Ethiopia. A total of 117 sorghum farms in 15 districts of 5 administrative zones within two regional states were assessed. **Results:** The disease was found to be widely distributed in all sorghum growing regions of the surveyed areas with 100% incidence. The severity of sorghum anthracnose varied significantly ($p < 0.001$) among the 15 districts. The highest severity index of about 87.3 was recorded in Nejo while the lowest severity of about 59.5 was estimated in Leka Dulecha district. The disease was strongly influenced by altitudinal gradients, cropping system and weed management practices. Isolates of *C. sublineolum* collected from different areas showed variations in both cultural characteristics and conidia morphology, though all of them were pathogenic to sorghum but not to maize plants. **Conclusion:** Since, sorghum anthracnose is highly prevalent and very severe in all regions of Southwestern and Western parts of Ethiopia, giving due attention in developing effective management strategy is critical.

Key words: Anthracnose, conidial morphology, disease incidence, percent severity index, *Sorghum bicolor*

Received: March 15, 2016

Accepted: April 30, 2016

Published: June 15, 2016

Citation: Binyam Tsedaley, Girma Adugna and Fikre Lemessa, 2016. Distribution and Importance of Sorghum Anthracnose (*Colletotrichum sublineolum*) in Southwestern and Western Ethiopia. Plant Pathol. J., 15: 75-85.

Corresponding Author: Binyam Tsedaley, College of Agriculture and Natural Resource, Assosa University, P.O. Box 18, Assosa, Ethiopia
Tel: +251 910 593 262

Copyright: © 2016 Binyam Tsedaley *et al.* This is an open access article distributed under the terms of the creative commons attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sorghum (*Sorghum bicolor* L., Moench) belonging to the Poaceae family is believed to have been originated in Northeast Africa¹. In Ethiopia, sorghum is the 4th most important cereal crop after maize, teff and wheat, cultivated annually on 1.8 million ha of land contributing 4.3 million tonnes to annual grain production of the country². Due to diverse nature of the farming systems and climatic conditions under which sorghum is grown, the production of sorghum in Ethiopian is adversely affected by different biotic and abiotic constraints among which sorghum anthracnose is the major one³. Sorghum anthracnose, caused by *Colletotrichum sublineolum* is one of the major diseases limiting grain production in most sorghum growing regions⁴.

The epidemics of anthracnose in sorghum fields largely depend on host susceptibility and prevailing weather conditions^{5,6}. It is also influenced by inoculum density, pathogenicity of the strains and cultural practices⁷⁻⁹. While, infected plant debris, seeds and alternate hosts serve as sources of the primary inoculum^{10,11}, shifts in planting dates and the choice of cultivars were found to influence the development of anthracnose in the field⁵.

Estimating grain yield losses due to anthracnose can often be difficult¹² but losses as high as 50% have been reported in susceptible cultivars¹³. Disease development before anthesis can have the greatest effect on grain yield with reported losses¹⁴ ranging from 30-67%. In Ethiopia, research findings at Alemaya in Eastern Ethiopia indicated that leaf anthracnose can cause yield loss that ranges from 26-35% in susceptible cultivar¹⁵. However, most of the studies do not provide quantitative measurement in terms of disease incidence

and severity. Chala *et al.*^{3,8} assessed and determined the prevalence and severity of sorghum anthracnose in Northern, Eastern and Southern Ethiopia. However, there is no extensive and quantitative survey data on sorghum anthracnose distribution and importance associated with causal pathogen in most parts of Southwestern and Western parts of Ethiopia. Therefore, the objective of this study was to assess the distribution and importance of sorghum anthracnose along varying agroecologies in Southwestern and Western Ethiopia.

MATERIALS AND METHODS

Description of the survey areas: Field surveys were conducted in Southwestern and Western parts of Ethiopia during 2014 cropping season. The surveyed areas includes a wide range of districts and agro-ecological zones, which lie between 34°54' and 36°1' East longitudes and 7°71' and 10°45' North latitudes with altitudes varying between 1162 and 2368 m a.s.l. (Table 1). The sample farms were taken at 5-10 km interval along accessible roads representing major sorghum growing areas from Jimma to Assosa administrative zones. The descriptions of all the surveyed areas were clearly showed in Table 1.

Sorghum anthracnose assessment: A total of 117 sorghum farms fields in 15 districts of 5 administrative zones within two regional states were assessed for the distribution and severity of sorghum anthracnose. The disease assessment was conducted in October and November, 2014 when the crop was at its flowering to maturity stages in different agroecologies of the surveyed areas.

Table 1: Description of surveyed areas by regional state, administrative zone, districts, number of sample fields with altitude ranges in Southwestern and Western parts of Ethiopia

Regional state	Administrative zone	Districts	No. of farmers field assessed/district	Total No. of farmers field assessed/zone	Altitude range (m a.s.l.)	
Oromia	Jimma	Mana	7	21	1606-2092	
		Goma	7		1607-1775	
		Gumay	7		1564-1714	
	Iluababor	Didessa	Didessa	7	23	1522-2197
			Gechi	7		1901-2229
		Bedele zuria	Bedele zuria	9		1306-1979
			East Wellega	Jimma Arjo		8
	West Wellega	Leka Dulecha	8	2171-2265		
		Diga	8	1162-2246		
		Beneshangul gumuz	Assosa	Gimbi	8	24
	Nejo			8	1784-1960	
	Mendi			9	1443-1747	
Bambasi	8			1383-1476		
Assosa	8			1467-1622		
Total	5	Komosha	8	117	1252-1465	
		15	117			

Disease incidence: Disease incidence was assessed on 30 randomly selected plants in each sample field and was expressed in percent infection, determined by the following formula proposed by Cooke *et al.*¹⁶:

$$\text{Disease incidence} = \frac{\text{No. of plants showing disease symptoms}}{\text{Total No. of plants assessed}} \times 100$$

Disease severity: Disease severity was estimated as the proportion of leaf area infection on 30 randomly selected sorghum plants in each sample field. Each plant was divided into three portions (upper, middle and lower portion) and the average scores of these portions were used to represent the severity of anthracnose per plant. It was assessed using 1-5 disease rating scale suggested by Thakur *et al.*¹⁷, where, 1 = No visible symptoms, presence of chlorotic flecks, 2 = 1-10% leaf area covered with hypersensitive lesions without acervuli, 3 = 11-25% leaf area covered with hypersensitive and restricted lesions without acervuli, 4 = 26-50% leaf area covered with coalescing necrotic lesions with acervuli and 5 = >50% leaf area covered with

coalescing necrotic lesions with acervuli. Severity grades were converted into Percentage Severity Index (PSI) for analysis using the formula suggested by Wheeler¹⁸:

$$\text{PSI} = \frac{\text{Snr}}{\text{Npr} \times \text{Mss}} \times 100$$

Where:

Snr = Sum of numerical ratings

Npr = No. of plants rated

Mss = Maximum severity scale of sorghum anthracnose

The disease symptoms (Fig. 1a-c) on the leaves, sheathes and panicle were taken into considerations during the assessment.

Cultural practices and agronomic data: During the survey, some routine cultural practices and agronomic parameters were recorded and the qualitative data were leveled for quantitative analysis (Table 2).

Table 2: Descriptions of date of sowing (month), weed management and crop growth stage with their qualitative measurement and quantitative levels

Date of sowing (Month)		Weed management		Crop growth stage	
Qualitative measurement	Quantitative level	Qualitative measurement	Quantitative level	Qualitative measurement	Quantitative level
March	3	Heavily infested	1	Flowering	1
April	4	Weeded	2	Full-flowering	2
May	5	Moderately weeded	3	Milky	3
June	6	Slightly weeded	4	Grain-filling	4
		Weed free	5	Hard dough	5
				Maturity	6

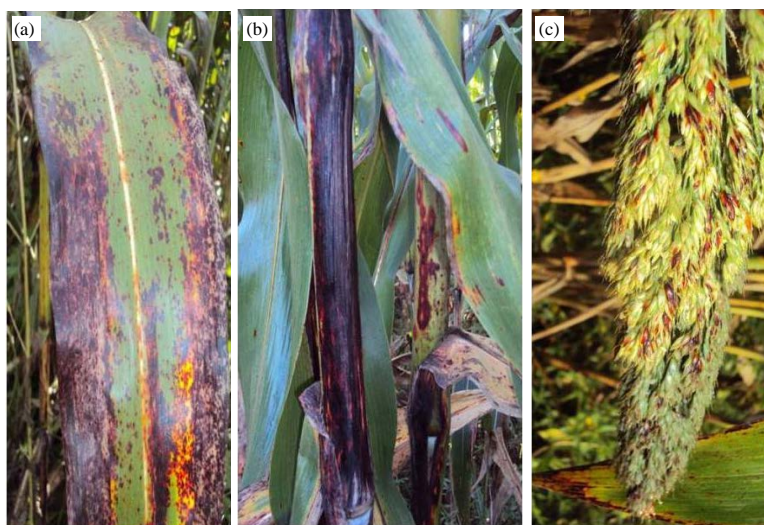


Fig. 1(a-c): Symptoms of sorghum anthracnose on the (a) Leaves, (b) Sheath and (c) Panicle of sorghum plant, respectively

Isolation and identification of the causative agent: Samples of sorghum leaves with anthracnose symptoms collected from 5 administrative zones were cut into pieces (1 cm²), surface sterilized using 5% sodium hypochlorite solution for 30 sec followed by rinsing three times in sterile distilled water. The sections were allowed to dry in a laminar flow hood before plating on Potato Dextrose Agar (PDA) in petri dishes. After incubation for 7 days at 25°C, fungal growth with *Colletotrichum sublineolum* appearance were purified by transferring mycelium discs of 10 mm diameter and incubated for 10 days under continuous fluorescent light. The identity of the fungus was confirmed based on cultural characteristics and conidial morphology.

Pathogenicity test

Preparation of spore suspension: Pathogenicity of 5 *C. sublineolum* isolates that represented from the 5 administrative zones was tested on detached sorghum and maize leaves. The suspension of conidia of each isolate was prepared by suspending mycelia scraped from 7 days old culture, grown in 10 mL of sterile distilled water and stirred vigorously for 90 sec and then filtered through two layer cheese cloth. The concentration of spore suspension was adjusted to 1×10⁵ mL by using haemocytometer before inoculation.

Inoculation to detached leaves: Both apparently healthy leaves were collected from of sorghum and maize in the field, washed and surface-sterilized using 5% sodium hypochlorite solution for 30 sec and rinsed three times in sterile distilled water. The leaves were cut and placed in petri dishes lined with 4 layers of sterilized and moisten tissue papers. The leaves were sprayed with spore suspensions of each isolate and incubated at 26°C until typical symptoms of anthracnose were observed.

Re-isolation of isolated fungal pathogens: The causative agent in the diseased leaf parts was re-isolated on Potato Dextrose Agar (PDA). The characteristics of the re-isolates were compared with that of the original parent cultures.

Data analysis: The field survey data for sorghum anthracnose (incidence and severity) was analyzed using three stage nested design. Mean disease severity of each district and administrative zone was used to make quantitative comparison among the surveyed areas. Quantitative levels of the cultural practices and agronomic data were used for their

mean separation as well as correlation analysis. All the statistical analysis¹⁹ were carried out using SAS software version 9.2. Correlation analysis²⁰ was performed by using SPSS software version 20 to determine the association of anthracnose severity with altitudes, cultural practices and agronomic data obtained at surveyed areas.

RESULTS AND DISCUSSION

Distribution and severity of sorghum anthracnose: Sorghum anthracnose was prevalent in all the surveyed areas with 100% incidence in Southwestern and Western parts of Ethiopia (Fig. 2). The mean percentage severity index of the disease showed significant (p<0.05) (Table 3) and highly significant (p<0.001) (Table 4) differences among the 5 administrative zones and 15 districts, respectively. On the other hand, no significant difference was observed between the two regional states. Among zones, more severity percentages of 83.8 and 80.0 were recorded at West Wellega and Assosa, respectively (Table 3). The highest sorghum anthracnose severity in percentage severity index (87.3 and 87.2) was recorded at Nejo and Gumay districts, respectively, while the lowest (59.5) was observed at Leka Dulecha (Table 4). The result of this survey is in line with Chala *et al.*³, who also reported that sorghum anthracnose was very severe in Jimma.

In every farmers field there was no single sorghum plant which is free of anthracnose. Previously, Girma *et al.*¹⁵ reported that 55-85% sorghum anthracnose incidence was observed in the altitude range of 1350-2150 m a.s.l. But, the present results demonstrate that sorghum anthracnose has 100% distribution in the surveyed areas than was earlier thought and confirms that indeed the disease is a major threat to sorghum production in the country. The survey result is in line with Pastor-Corrales and Frederiksen²¹ who reported that sorghum anthracnose is one of the main grain production constraints in most areas where sorghum is grown. *Colletotrichum sublineolum* is the fungal pathogen responsible for sorghum anthracnose and the disease occurs worldwide in most sorghum producing regions^{4,22-24}.

Table 3: Disease severity of sorghum anthracnose (PSI) recorded across 5 administrative zones in Southwestern and Western parts of Ethiopia

Administrative zone	Disease severity index
Jimma	77.38 ^a
Iluababor	78.26 ^a
East Wellega	65.16 ^b
West Wellega	83.79 ^a
Assosa	80.00 ^a

*Values with the same letter are not significantly different from each other at p<5%

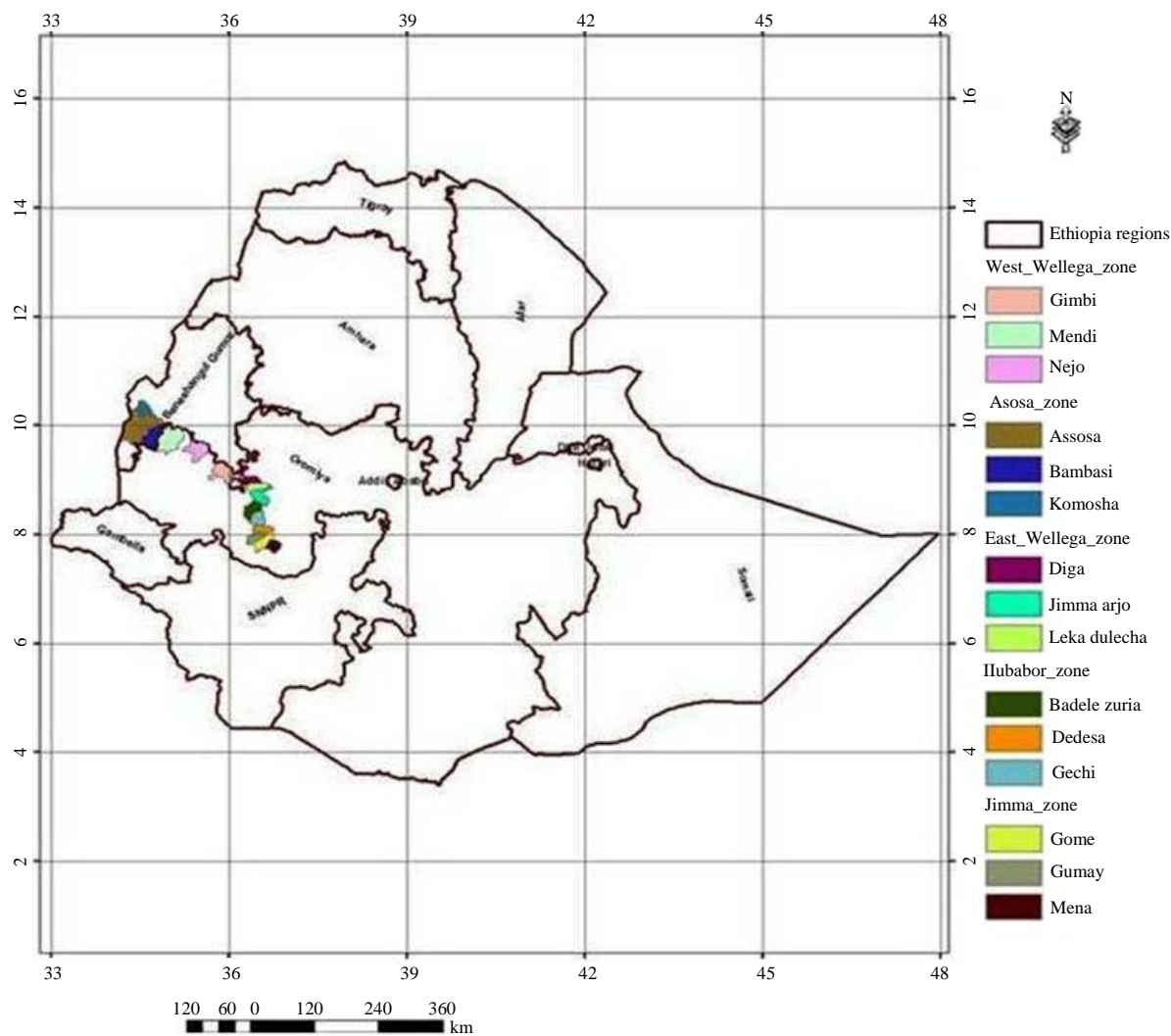


Fig. 2: Distribution of sorghum anthracnose in Southwestern and Western Ethiopia

Table 4: Disease severity of anthracnose (PSI), date of sowing, weed management and crop stages recorded across 15 districts of Southwestern and Western parts of Ethiopia

District	Disease severity	Date of sowing	Weed management	Crop stage
Mana	66.90 ^{abc}	4.14 ^{abc}	3.43 ^{bc}	3.14 ^{ab}
Goma	78.00 ^{abc}	4.43 ^{ab}	3.29 ^c	3.00 ^{ab}
Gumay	87.24 ^a	3.86 ^{cbc}	3.29 ^c	3.43 ^{ab}
Didessa	77.71 ^{abc}	3.86 ^{abc}	4.14 ^{abc}	3.57 ^{ab}
Gechi	74.85 ^{abc}	3.14 ^c	4.14 ^{abc}	3.28 ^{ab}
Bedele zuria	82.22 ^{ab}	3.78 ^{bc}	4.89 ^a	3.44 ^{ab}
Jimma Arjo	63.25 ^{bc}	4.00 ^{abc}	4.13 ^{abc}	3.50 ^{ab}
Leka Dulecha	59.50 ^c	3.38 ^c	3.25 ^c	3.00 ^{ab}
Diga	72.75 ^{abc}	4.13 ^{abc}	4.63 ^{ab}	3.50 ^{ab}
Gimbi	85.00 ^a	4.25 ^{abc}	4.13 ^{abc}	3.75 ^a
Nejo	87.25 ^a	4.25 ^{abc}	3.25 ^c	2.89 ^{ab}
Mendi	79.11 ^{abc}	4.89 ^a	4.33 ^{ab}	2.88 ^{ab}
Bambasi	80.00 ^{abc}	4.88 ^a	3.63 ^{bc}	2.50 ^{ab}
Assosa	75.00 ^{abc}	4.88 ^a	4.5 ^{ab}	2.13 ^b
Komosha	85.00 ^a	4.75 ^{ab}	3.50 ^{bc}	3.13 ^{ab}

*Values with the same letter(s) are not significantly different from each other at p<5%

Part of the reason for the high incidence can be attributed to high inoculum level associated with Ethiopian's farming systems particularly in the surveyed areas. Farmers generally, do not practice appropriate crop rotation systems with non-host plants to the pathogen and grow the crop from year to year. This leads to quick inoculum build-up and higher possibilities of inoculum survivals. *Colletotrichum sublineolum* overwinter in soil and decaying plant residues as mycelium, acervuli, melanized hyphopodia, sclerotia and microsclerotia²⁵. It may survive up to 18 months in crop debris, on or above the soil surface, in alternate hosts and in infected seeds²⁶. Microsclerotia are produced in sorghum stalks of susceptible cultivars and survive in crop debris on the soil surface²⁶. Moreover, alternative hosts and volunteer crops may also provide sources of primary inoculum and seed transmission has been reported for *C. sublineolum*¹¹. These facts suggest that the high incidence detected throughout this study could in fact be compounded by effects of high inoculum buildup, susceptible cultivars cultivated by the farming communities and favorable environmental conditions of all agro-ecologies of the surveyed areas of the country.

Percentage severity index of sorghum anthracnose showed a negative correlation (-0.205) with a significant ($p < 0.05$) difference to different altitude ranges of the surveyed areas (Table 5). In the surveyed area, when the altitude increased, PSI of the disease was decreased. In the highest mean altitude (2221 m a.s.l.) at Laka Dulecha district, the lowest PSI (59.50) were observed. On the other hand in the lowest mean altitude (1363 m) at Komosha district, the highest PSI (85.00) of sorghum anthracnose which is not statistically different with some other districts were observed. This could be related with the differences in relative humidity and temperature variations across different altitudes of the surveyed areas. Anthracnose in sorghum caused by *Colletotrichum sublineolum* is one of the most destructive diseases affecting sorghum production world-wide, especially under warm and humid conditions^{18,27}. This disease is coupled with great losses in tropical belts where high humidity and temperature is conducive for *C. sublineolum* growth, propagules dispersal and sporulation²¹. Anthracnose is a polycyclic and epidemic disease, is favored by high rainfall and humidity, moderate temperatures and the presence of large amounts of inoculum²⁸.

Different cultural practices and sorghum growth stage: In the surveyed areas significant ($p < 0.05$) and highly significant ($p < 0.01$) differences on date of sowing and weed management and sorghum growth stage among different districts were observed (Table 4). At Leka Dulecha and Assosa

districts relatively good cropping system (inter cropping with soybeans and anchote) were observed. Generally most of the farmers in the surveyed area, across administrative zones were not practicing good cropping system (Table 3). Such as crop rotation and inter cropping with non host crops to the pathogen. In highland areas of Southwestern and Western parts of Ethiopia, most of the farmers were sow sorghum in March, 3. Whereas, at mid altitudes and lowland areas they sow sorghum in April, 4 and May, 5, respectively (Table 3). In this study date of sowing has a negative impact on severity of sorghum anthracnose. Other research findings have reported that shifts in planting dates were found to influence the development of anthracnose in the field^{12,13}. Changing in planting date could play a role in reducing anthracnose severity and can serve as an alternative means of managing anthracnose in farmer's field⁹.

Among different farmers of the surveyed area, a great difference on weed management was observed. From these, the best weed management practice was observed at Bedele zuria district followed by Diga and Assosa districts. From the authors observation, farmers fields at Goma and Gumay districts were heavily infested by different weed species. This leads to high severity of sorghum anthracnose in these districts. High weed infestation reduces air movement around the crop canopy, which leads to increased leaf-wetness (Fig. 3). This increases humidity and higher possibility of spore germination and development of the pathogen. Similarly, Leite and Nicholson²⁹ reported that as for most species of *Colletotrichum*, free water plays a major role in the development of this pathogen. Conidia germinate on the leaf surface in thin films of water, develop germ tubes and appressoria and penetrate the epidermis directly or through stomata¹⁷. In addition, under high humidity, the lesions increase in number and they cover most of the leaf area when coalescing, resulting in early water deficiency³⁰.

In this study a negative correlation were observed between severity of anthracnose and weed management (Table 5). This could be due to competitions to nutrients, water, space and sunlight with the weeds. This may be related to increase in vigor growth of the sorghum crop and its ability to physical defiance mechanism to the pathogen. Good cultural practices including altering planting dates, removal of crop residues and alternate hosts (wild sorghum), weed management, planting disease free seeds and crop rotation can serve as important options in preventing sorghum anthracnose^{11,31}. According to Moore *et al.*³², planting sorghum after sorghum significantly increases anthracnose on most hybrids and planting sorghum after rice, maize or soybeans can successfully reduce sorghum anthracnose. Other



Fig. 3(a-b): Farmer's sorghum field infested by high (a) Adey abeba (*Bidens macroptera*) and (b) *Striga* weed in Southwestern and Western parts of Ethiopia

Table 5: Correlations among altitude, PSI, different agronomic practices and crop stage of sorghum

	Altitude	PSI	Cropping system	Crop rotation	Date of sowing	Weed management	Crop stage
Altitude	1	-0.205*	0.097	-0.176	-0.621**	-0.098	0.177
PSI		1	-0.279**	0.043	-0.064	-0.197*	0.268**
Cropping system			1	-0.069	-0.055	0.074	-0.083
Crop rotation				1	0.061	-0.005	-0.114
Date of sowing					1	-0.004	-0.278**
Weed management						1	-0.027
Crop stage							1

**Correlation is significant at 0.01 level (2-tailed), *Correlation is significant at 0.05 level (2-tailed)

management strategies such as sanitation, elimination of alternative hosts and planting clean, healthy seed or seed treated with an appropriate fungicide, coupled with disease resistance should be helpful and perhaps sufficient to avoid or reduce serious losses from grain sorghum anthracnose.

During the survey, in majority of the districts the sorghum crop was at its milky stage. But in some districts especially in the lowland areas the crop was at its full flowering stage. This difference in growth stage could play an important role in severity of the disease. Strong positive correlations were observed between anthracnose severity and sorghum crop stages (Table 4). This positive correlation indicates as the crop stage increased, the severity of the disease also increased. This could be related to crop maturity (senescence). That means as the crop becomes mature it will lose its rigidity as a result the pathogen can easily penetrate and develop on the crop. Previous studies on epidemiology of sorghum anthracnose have indicated that the disease is mostly severe with mature plants^{33,34}. *Colletotrichum sublineolum* epidemics always had higher disease levels at the milk stage (v95) and ended in higher final disease levels at crop senescence¹³. Young

sorghum leaves accumulate phytoalexins in the form of a complex of phenols having fungitoxic activity in response to invasion by both pathogenic and non-pathogenic fungi^{35,36}. An increased susceptibility to anthracnose with plant maturity has been reported in a number of studies on different sorghum cultivars^{33,34,37}, however the mechanism involved with its susceptibility is not well understood.

Correlation of sorghum anthracnose severity with different parameters:

The correlation analysis between Percentage Severity Index (PSI) of sorghum anthracnose with different cultural practices and crop stage were showed significant ($p < 0.05$) and highly significant ($p < 0.01$) interactions in the surveyed area (Table 5). Among the interactions anthracnose severity were showed a negative and strong negative interactions with altitude (-0.205*) and weed management (-0.197*) and cropping system (-0.279**), respectively. On the other hand it also showed a strong positive interaction with crop stage (0.268**). Even-though the interaction is not strong but severity of anthracnose were also

showed negative interaction with date of sowing. The negative interaction indicates the factors that reduce severity of anthracnose on sorghum crop. Whereas, the positive interaction indicates the sorghum growth stage which is favorable for the high level of anthracnose development on the crop. From the results of this study, severity of anthracnose across different agro-ecologies of Ethiopia is affected by altitude, different cultural practices and sorghum growth stage. The different interactions between the disease and the host will help in developing a cast effective and environmentally safe disease management strategy.

Based on the results of this survey, severity of sorghum anthracnose clearly depends on interactions of favorable weather conditions, cultural practices and susceptibility of sorghum cultivars farmer's they cultivated. During the survey program 27 different sorghum cultivars were recorded at different agro-ecological areas of Southwestern and Western parts of Ethiopia. This high availability of different sorghum cultivars in this country could play a great role in developing resistant varieties to this disease. The result is in line with, Sleper and Poehlman³⁸ reported that as a centre of origin and diversity of sorghum, Ethiopia possesses a very diverse sorghum germplasm.

Isolation of the causal pathogen: Colonies of the fungus grown on PDA showed different colors on the upper side as

well as on the reverse side of the petri dishes. The colors were varied from whitish gray and yellow to purple gray on the upper sides of the petri dishes (Fig. 4a), whereas they had, goldenrod, brownish, purple grayish and whitish colors when viewed on the reverse side of the petri dishes (Fig. 4b). It is observed that conidia which are falcate and hyaline but without septa and with black dots (Fig. 4c, d). The fungus was morphologically identified as *C. sublineolum* and the results were in agreement with Souza-Paccola *et al.*³⁹.

Pathogenicity test: Pathogenicity test was carried out for sorghum anthracnose (*C. sublineolum*) isolated from infected sorghum leaves collected from 5 administrative zones of Southwestern and Western Ethiopia. The inoculated detached leaves of sorghum showed anthracnose disease symptom typical of those observed on infected sorghum plants in the field but no infection was found on maize (Fig. 5a-d, 6b, c). The present research result is agree with the findings of Prom *et al.*⁴⁰, which is the isolates of the pathogen were showed positive responses on detached leaves of susceptible sorghum lines (Fig. 5e) but negative on maize (Fig. 6a). From this result the it can be concluded that *C. sublineolum* isolates pathogenic to sorghum are non pathogenic to maize. These result are also agree with findings^{41,42}.

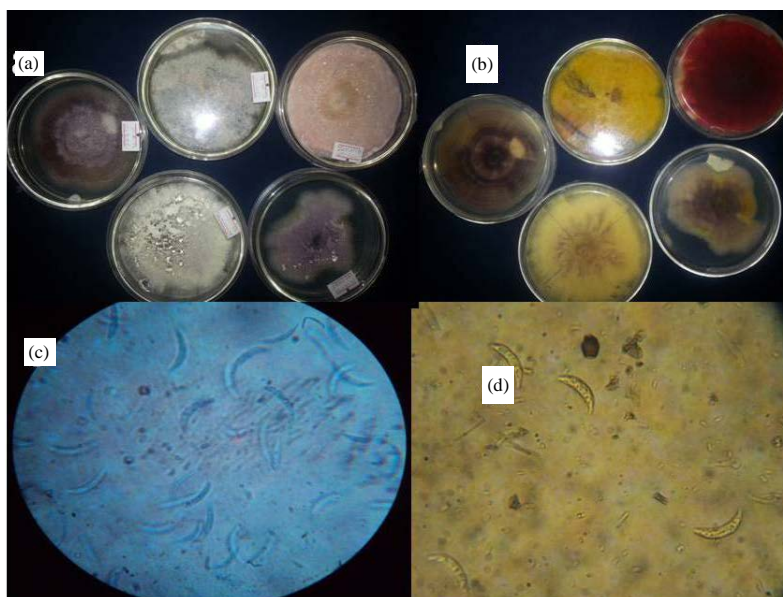


Fig. 4(a-d): *Colletotrichum sublineolum* the causal agent of sorghum anthracnose disease, (a) Upper side view of colony in a petri dish, (b) Reverse side view of the colony and (c, d) Microscopic views of the conidia



Fig. 5(a-e): (a-d) Detached sorghum leaves inoculated with *C. sublineolum* isolates collected from 5 administrative zones of Southwestern and Western Ethiopia and (e) Un-inoculated sorghum leaf

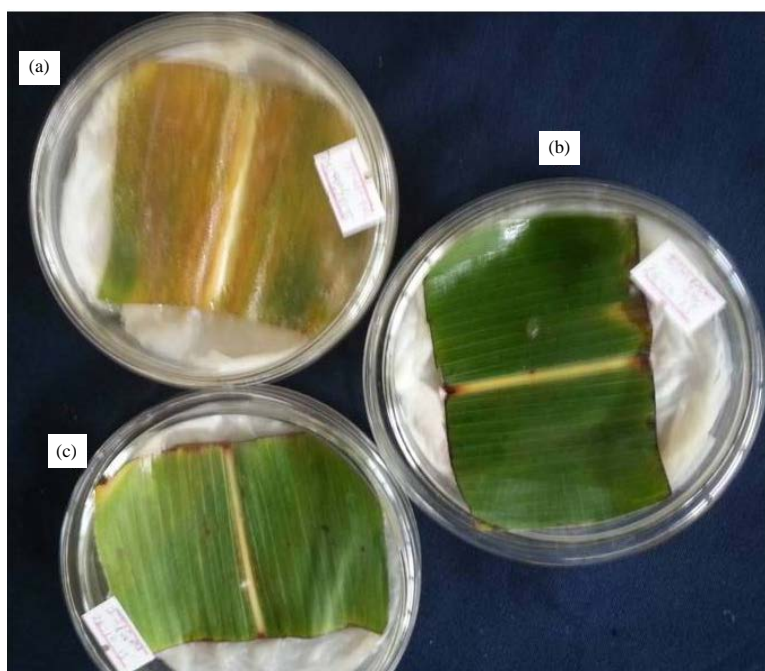


Fig. 6(a-c): (a) Detached maize leaf and (b, c) Sorghum leaves inoculated with *C. sublineolum* isolates collected from 5 administrative zones of Southwestern and Western Ethiopia

CONCLUSION

Sorghum anthracnose caused by *Colletotrichum sublineolum* is one of the most important sorghum diseases limiting grain production in Southwestern and Western parts of Ethiopia. In this area, anthracnose was highly prevalent everywhere the sorghum plant was grown. There was no a single sorghum plant which is free of anthracnose. Sorghum anthracnose severity was strongly correlated with altitude, different cultural practices and growth stage of the plant. These strong correlations help in developing effective and economically sound management strategies of sorghum anthracnose. Isolates of *C. sublineolum* collected in different areas of Southwestern and Western Ethiopia showed variations in both cultural characteristics and conidia morphology. Since sorghum anthracnose is highly prevalent and very severe in all Southwestern and Western parts of Ethiopia and sorghum is the 3rd most important crop in that area, giving do attention in developing effective management strategy of this disease is very critical.

SIGNIFICANT STATEMENTS

- Sorghum anthracnose is highly prevalent and very severe in all regions of Southwestern and Western parts of Ethiopia
- The disease severity was strongly influenced by altitudinal gradients, cropping system and weed management practices
- There was no a single sorghum plant immune to anthracnose in every farmers field

ACKNOWLEDGMENTS

The authors gratefully acknowledge Jimma University, College of Agriculture and Veterinary Medicine for financial support of the study and all participant farmers during the survey program.

REFERENCES

1. Pedersen, J.F., D.B. Marx and D.L. Funnell, 2003. Use of A₃ cytoplasm to reduce risk of gene flow through sorghum pollen. *Crop Sci.*, 43: 1506-1509.
2. CSA., 2015. The federal democratic republic of Ethiopia agricultural sample survey 2014/2015. Report on Area and Production of Major Crops, (Private Peasant Holdings, Meher Season). Central Statistical Agency, USA.
3. Chala, A., M.B. Brurberg and A.M. Tronsmo, 2007. Prevalence and intensity of sorghum anthracnose in Ethiopia. *J. SAT Agric. Res.*, 5: 1-3.
4. Thakur, R.P. and K. Mathur, 2000. Anthracnose. In: Compendium of Sorghum Diseases, Frederiksen, R.A. and G.N. Odvody (Eds.). The American Phytopathological Society, St. Paul, MN., USA., pp: 10-12.
5. Marley, P.S., 2004. Effects of integrating host plant resistance with time of planting or fungicides on anthracnose and grain mould and yield of sorghum (*Sorghum bicolor*) in the Nigerian Northern Guinea Savanna. *J. Agric. Sci.*, 142: 345-350.
6. Erpelding, J.E. and M.L. Wang, 2007. Response to anthracnose infection for a random selection of sorghum germplasm. *Plant Pathol. J.*, 6: 127-133.
7. Pande, S., L.K. Mughogho, R. Bandyopadhyay and R.I. Karunakar, 1991. Variation in pathogenicity and cultural characteristics of sorghum isolates of *Colletotrichum graminicola* in India. *Plant Dis.*, 75: 778-783.
8. Chala, A., M.B. Brurberg and A.M. Tronsmo, 2010. Incidence and severity of sorghum anthracnose in Ethiopia. *Plant Pathol. J.*, 9: 23-30.
9. Chala, A., T. Alemu, L.K. Prom and A.M. Tronsmo, 2010. Effect of host genotypes and weather variables on the severity and temporal dynamics of sorghum anthracnose in Ethiopia. *Plant Pathol. J.*, 9: 39-46.
10. Cardwell, K.F., P.R. Hepperly and R.A. Frederiksen, 1989. Pathotypes of *Colletotrichum graminicola* and seed transmission of sorghum anthracnose. *Plant Dis.*, 73: 255-257.
11. Somda, I., V. Leth and P. Sereme, 2007. Evaluation of lemongrass, eucalyptus and neem aqueous extracts for controlling seed-borne fungi of sorghum grown in Burkina Faso. *World J. Agric. Sci.*, 3: 218-223.
12. Ngugi, H.K., A.M. Julian, S.B. King and B.J. Peacocke, 2000. Epidemiology of sorghum anthracnose (*Colletotrichum sublineolum*) and leaf blight (*Exserohilum turcicum*) in Kenya. *Plant Pathol.*, 49: 129-140.
13. Thomas, M.D. and R.A. Frederiksen, 1995. Dynamics of oval and falcate conidium production of *Colletotrichum graminicola* from sorghum. *Mycologia*, 87: 87-89.
14. Ali, M.E.K., H.L. Warren and R.X. Latin, 1987. Relationship between anthracnose leaf blight and losses in grain yield of sorghum. *Plant Dis.*, 71: 803-806.
15. Girma, T., A. Fekede, H. Temam, T. Tewabech and B. Eshetu *et al.*, 2009. Review of Maize, Sorghum and Millet Pathology Research. In: Increasing Crop Production through Improved Plant Protection-Volume II, Tadesse, A. (Ed.). PPSE and EIAR, Addis Ababa, Ethiopia, pp: 245-301.
16. Cooke, B.M., D. Gareth-Jones and B. Kaye, 2006. The Epidemiology of Plant Diseases. 2nd Edn., Springer, The Netherlands.
17. Thakur, R.P., B.V.S. Reddy and K. Mathur, 2007. Screening Techniques for Sorghum Diseases. Information: Bulletin No. 76. International Crops Research Institute for the Semi-Arid Tropics, Andhra Pradesh, India, ISBN: 978-92-9066-504-5, Pages: 92.

18. Wheeler, B.E.J., 1969. An Introduction to Plant Diseases. 2nd Edn., John Wiley and Sons Limited, London, Pages: 301.
19. SAS., 2008. SAS Guide for Personal Computers. Version 9.2, SAS Institute Inc., Cary, NC., USA.
20. IBM., 2011. IBM SPSS Statistics for Windows, Version 20.0. IBM Corp., Armonk, New York, USA.
21. Pastor-Corrales, M.A. and R.A. Frederiksen, 1980. Sorghum Anthracnose. In: Sorghum Diseases: A World Review, Williams, R.J., R.A. Frederiksen, L.K. Mughogho and G.D. Bergston (Eds). ICRISAT, Patancheru, India, pp: 289-294.
22. Crouch, J.A., B.B. Clarke and B.I. Hillman, 2006. Unraveling evolutionary relationships among the divergent lineages of *Colletotrichum* causing anthracnose disease in turfgrass and corn. *Phytopathology*, 96: 46-60.
23. Commonwealth Agricultural Bureau International, 1988. Distribution map No. 586. In Maps of Plant Diseases 1st Edition. Commonwealth Mycological Institute/Assoc. Applied Biology Kew, Surrey, England.
24. Ali, M.E.K. and H.L. Warren, 1988. Anthracnose of sorghum. Proceedings of the Global Conference on Sorghum Diseases, March 7-11, 1988, Harare, Zimbabwe.
25. Sukno, S.A., V.M. Garcia, B.D. Shaw and M.R. Thon, 2008. Root infection and systemic colonization of maize by *Colletotrichum graminicola*. *Applied Environ. Microbiol.*, 74: 823-832.
26. Tesso, T., R. Perumal, C.R. Little, A. Adeyanju, G.L. Radwan, L.K. Prom and C.W. Magill, 2012. Sorghum pathology and biotechnology-a fungal disease perspective: Part II. Anthracnose, stalk rot and downy mildew. *Eur. J. Plant Sci. Biotechnol.*, 6: 31-44.
27. Upadhyaya, H.D., Y.H. Wang, R. Sharma and S. Sharma, 2013. Identification of genetic markers linked to anthracnose resistance in sorghum using association analysis. *Theoret. Applied Genet.*, 126: 1649-1657.
28. Frederiksen, S., 1986. Revision of taeniatherum (Poaceae). *Nordic J. Bot.*, 6: 389-397.
29. Leite, B. and R.L. Nicholson, 1993. A volatile self-inhibitor from *Colletotrichum graminicola*. *Mycologia*, 85: 945-951.
30. Casela, C.R., N.F.J.A. Pinto, E. Oliveira and A.S. Ferreira, 1997. Doencas do Sorgo. In: Controle de Doencas de Plantas, Zambolim, L. and F.X.R. Vale (Eds.). Universidade Federal de Vicosa, Minas Gerais, Brazil, pp: 1025-1064.
31. Chala, A. and A.M. Tronsmo, 2012. Evaluation of Ethiopian sorghum accessions for resistance against *Colletotrichum sublineolum*. *Eur. J. Plant Pathol.*, 132: 179-189.
32. Moore, J.W., M. Dittmore and D.O. TeBeest, 2009. The effects of cropping history on grain sorghum yields and anthracnose severity in Arkansas. *Crop Prot.*, 28: 737-743.
33. Jamil, F.F. and R.L. Nicholson, 1987. Susceptibility of corn to isolates of *Colletotrichum graminicola* pathogenic to other grasses. *Plant Dis.*, 71: 809-810.
34. Mishra, A., B.S. Siradhana and A. Mishra, 1992. Effect of host age on sorghum anthracnose. *Gujarat Agric. Univ. Res. J.*, 18: 135-136.
35. Lo, S.C., T. Weiergang, C. Bonham, J. Hipskind, K. Wood and R.L. Nicholson, 1996. Phytoalexin accumulation in sorghum: Identification of a methyl ether of *Luteolinidin*. *Physiol. Mol. Plant Pathol.*, 49: 21-31.
36. Singh, M. and K.S. Boora, 2008. Molecular Characterization of Anthracnose Resistance gene in Sorghum. In: Plant Genomics and Bioinformatics, Rao, G.P., C. Wanger, R.K. Singh and M.L. Sharma (Eds.). Stadium Press, Houston, Texas, USA, pp: 373-388.
37. Peacocke, B.J., 1995. Epidemiology and management of anthracnose from sorghum. Ph.D. Thesis, University of Reading, Reading, UK.
38. Sleper, D.A. and J.M. Poehlman, 2006. Breeding Field Crops. 5th Edn., Wiley-Blackwell Publ., New York, USA., ISBN-13: 9780813824284, Pages: 424.
39. Souza-Paccola, E.A., L.C.L. Favaro, C.A. Bomfeti, S.F.P. Mesquita and L.D. Paccola-Meirelles, 2003. Cultural characterization and conidial dimorphism in *Colletotrichum sublineolum*. *J. Phytopathol.*, 151: 383-388.
40. Prom, L.K., H. Cuevas, T. Isakeit and R. Droleskey, 2016. Excised leaf method for high volume evaluation of sorghum germplasm for resistance against *Colletotrichum sublineolum*. *Plant Pathol. J.*, 15: 11-16.
41. Sherriff, C., M.J. Whelan, G.M. Arnold and J.A. Bailey, 1995. rDNA sequence analysis confirms the distinction between *Colletotrichum graminicola* and *C. sublineolum*. *Mycol. Res.*, 99: 475-478.
42. Sutton, B.C., 1980. The Coelomycetes, Fungi Imperfecti with Pycnidia, Acervuli and Stroma. Commonwealth Mycological Institute, Kew, Surrey, UK., Pages: 696.