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Incidence and Severity of Sorghum Anthracnose in Ethiopia

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Abstract: A two year survey was conducted to determine incidence and severity of sorghum anthracnose in different sorghum growing regions in Ethiopia. A total of 487 fields in 49 districts were surveyed in each of the 2005 and 2007 production season. Incidence of sorghum anthracnose was assessed as the percentage of plants with visible symptoms in a field and anthracnose severity was evaluated as the percentage of leaf area with symptoms. Also, the relationship of the incidence and severity of the disease to the altitude of the fields and weather conditions were determined. Results from the 2 years survey revealed that sorghum anthracnose is present in most (84%) of the survey districts. However, both incidence and severity of the disease varied significantly ($p<0.0001$) among the survey areas. Anthracnose incidence ranged from 0 to 77% and severity of the disease varied between 0 and 59% on average for the two years. The two year average anthracnose severity classes ranged from trace (<5%) to severe (up to 59%) and the disease was generally more severe in the Southwest and South regions. However, some districts in the East and North Ethiopia also had fields with severe anthracnose infection. It was also found out that the prevailing weather conditions especially rainfall has a significant impact on both anthracnose incidence and severity.

Key words: *Colletotrichum sublineolum*, epidemics, *Sorghum bicolar*, spot

INTRODUCTION

Sorghum (*Sorghum bicolar* L. Moench) is one of the most important cereal crops supporting the lives of millions of people across the globe and particularly in the developing world. Sorghum is known for withstanding harsh environmental conditions including high temperature, moisture deficit and water stagnation but it is susceptible to chilling (Sleper and Poehlman, 2006).

Sorghum production in the world including in Ethiopia is affected by different biotic and abiotic constraints among which sorghum anthracnose, caused by *Colletotrichum sublineolum*, is an important one, which is now considered as one of the most destructive diseases of sorghum in most sorghum growing regions of the globe. The disease can affect all aboveground parts of the plant including stems, leaves, peduncle, inflorescence and seeds (Thakur and Mathur, 2000; Casela *et al*., 2001). Foliar infections are the most common type of infection with characteristic symptoms of circular to elliptical red spots with few to numerous acervuli on lamina. However, symptoms of the disease vary depending on the host-pathogen interaction, the physiological state of the host and environmental conditions (Pastor-Corrales and Frederiksen, 1980).

Earlier reports have shown the importance of sorghum diseases including anthracnose in the world at large and in Africa in particular (Thomas, 1992; Thakur and Mathur, 2000; Ngugi *et al*., 2002). It has been reported as a disease of primary importance in West and Central Africa (Pande *et al*., 1993; Marley *et al*., 2001). The disease has also been identified as one of the most important diseases infecting sorghum in East African countries including Ethiopia and Kenya (Ngugi *et al*., 2002; Chala *et al*., 2009). However, most of the studies in Africa and particularly in Ethiopia, fall in short of providing a quantitative measurement of anthracnose incidence and severity. Nevertheless, such information is of paramount importance as it can be related to yield loss and hence economic impact of the disease (Teng, 1983; Jeger, 1990; Ngugi *et al*., 2002).

Assessment of the incidence and severity of plant diseases is important to determine the geographic distribution and status of the disease throughout a region

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in order to prioritize research. To get an accurate picture on the status of any disease, such studies, should give due consideration to the impact of geophysical and associated climatic and edaphic variations between regions. Ngugi *et al*. (2002) have determined the prevalence and severity of sorghum anthracnose along with other foliar diseases of sorghum in West Kenya. The objective of this survey work was to determine the geographic distribution, incidence and severity of sorghum anthracnose in different parts of Ethiopia.

MATERIALS AND METHODS

Survey area: Field surveys were conducted in Northern, North-Western, Southern, South-Western, Western and Eastern parts of Ethiopia in 2005 and 2007 production seasons. Survey areas were selected based on their accessibility and as they represent the bulk (more than 80%) of sorghum producing areas in Ethiopia. Surveyed areas include a wide range of administrative districts and agro-ecological zones, which lie between 5°40' and 14°18' North latitudes and between 35°44' and 42°06' East longitudes. The areas also varied in terms of weather conditions (Table 1) and altitude (1054 to 2337 m). The survey route followed major roads to towns and localities in 49 districts of five regional states. Survey areas were categorised into 6 different geographic regions.

Ethiopia is divided into five agro-climatic zones based on altitude, annual rainfall and temperature (USDA, 2002). Taking this classification scheme into consideration, we classified 20 of the 49 surveyed districts, for which temperature and rainfall data are available, into three climatic zones by combining the prevailing rainfall and temperature conditions. Zone 1 includes areas with moderate rainfall (800-1200 mm) and intermediate temperature (16-30°C), zone 2 has areas with moderate rainfall and high temperature (>30°C) and zone 3 represents areas with high rainfall (>1200 mm) and intermediate temperature.

Table 1: Ten year weather data of selected areas included in the survey program

Locality	Annual rainfall (mm)	Mean temperature (°C) (Minimum-Maximum)
Alaba	610-1241	13.5-27.6
Alamata	675-1063	14.6-30.3
Bita	1801-2200	15.1-22.5
Sekachekorsa	1142-2516	NA[1]
Chena	1801-2000	17.6-25
Chiro	560-1265	14.6-28
Damotgale	1001-1400	17.6-22.5
Dedo	1172-2844	11.4-23.1
Gimbo	1401-2000	15.1-22.5
Goroogutu	1078-1450	NA
Harbu	836-1124	13.3-31
Haramaya	607-1103	10.1-22.7
Hararzuria	493-1088	12.8-25.5
Kaloo	823-1640	13.8-30.9
Kombolcha	764-1319	12.4-26.8
Konta	1401-1800	15.1-27.5
Loma	1401-1800	15.1-25
Meeso	463-993	15.3-31.1
Mereka	1401-1800	15.1-25
Qarsa	1087-1735	NA
Quni	773-1322	12.4-27.8
Tehuledere	871-1441	10.8-26.4
Tulo	862-1088	10.3-27.8

NA: Data not available

Anthracnose assessment: The survey program covered the most important sorghum growing regions in Ethiopia with frequent stopping at different intervals depending on the variability of fields in terms of altitude, cropping system and sorghum types grown (based on crop morphology). Size of the district and availability and accessibility of sorghum fields were also given due consideration in deciding where to stop on the survey route. Three to five fields were assessed at each stop and hence up to 17 fields were assessed per district. The total number of surveyed fields was 487 in each year. The sorghum crop was between milk and hard dough stage during the survey in most of the fields although there were some fields with sorghum at maturity stage.

Disease assessment was made in 5 to 10 randomly selected spots in each field. Anthracnose incidence was assessed as the percentage of sorghum plants in a field showing visible symptoms out of 50 randomly selected plants whereas severity was determined as average leaf area covered by symptoms for 30 randomly selected diseased plants per field. In addition, data were recorded on altitude, latitude and longitude and weather data were obtained from the National Meteorological Agency.

Data analysis: The mean incidence and severity data were calculated for each district. Mean anthracnose incidence and severity of each district were used to make quantitative comparison between the survey districts.

The survey areas were also categorized into three altitude groups and anthracnose incidence and severity were obtained for each group by averaging the records from fields within the different groups. The same process was followed to determine anthracnose incidence and severity for the different geographic regions and agro-climatic zones.

All the statistical analysis were carried out using SAS Institute Inc. (9.1, 2003) and the Least Significant Difference (LSD) test was used for mean comparisons.

RESULTS AND DISCUSSION

Anthracnose incidence and severity across geographic regions: The survey program covered a wide range of

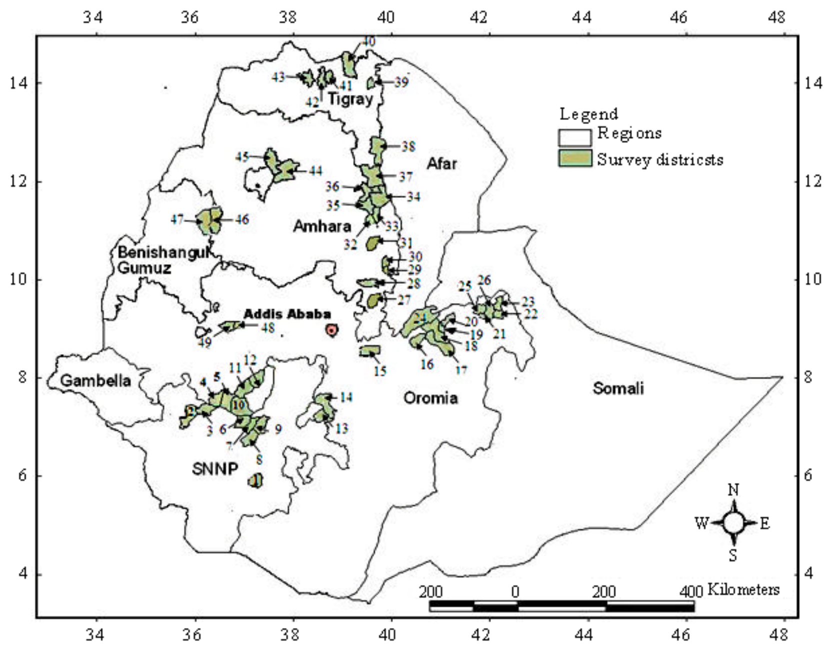

Fig. 1: Map of Ethiopia showing districts included in the survey program. 1: Gidole; 2: Chena; 3: Bita; 4: Gimbo; 5: Shebesombo; 6: Konta; 7: Loma; 8: Damotegale; 9: Mereka; 10: Dedo; 11: Qarsa; 12: Sekachekorsa; 13: Alaba; 14: Arsinegelle; 15: Welenchiti; 16: Meeso; 17: Quni; 18: Gemechis; 19: Tulo; 20: Gorrogutu; 21: Meta; 22: Hararzuria; 23: Kombolcha; 24: Chiro; 25: Kersa; 26: Haramaya; 27: Kewet; 28: Efratanagidem; 29: Jiletumuga; 30: Dewachefa; 31: Kaloo; 32: Tehuledere; 33: Ambassel; 34: Kobo; 35: Habroo; 36: Gubalafto; 37: Alamata; 38: Rayaazebo; 39: Kiliteawlalo; 40: Gantaafeshum; 41: Medebayzana; 42: Laelaymachew; 43: Taetayquoraro; 44: Libokemkem; 45: Gondarzuria; 46: Mandura; 47: Pawe; 48: Cheliya; 49: Bako. South: 1, 6, 7, 8, 9, 13, 14; Southwest: 2, 3, 4, 5, 10, 11, 12; East: 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 25; North: 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45; Northwest: 46, 47; West: 48, 49

areas located in different parts of Ethiopia (Fig. 1). A total of 6 geographic regions (North, Northwest, South, Southwest, West and East) were included in the survey program and sorghum anthracnose was prevalent in all the surveyed regions but with varying intensity. Incidence of anthracnose in the different regions varied from 19 to 74% in 2005 and it ranged from 7 to 70% in 2007 (Fig. 2a), with the greatest incidence in the Northwest and Southwest. Over all, sorghum anthracnose was most severe in the Southwest (47% and 37% in 2005 and 2007, respectively) (Fig. 2b) and least severe in West and North Ethiopia.

Disease incidence and severity across districts: Although, sorghum anthracnose appeared to be prevalent in many areas of Ethiopia, both incidence and severity of the disease varied significantly across the districts (Table 2). Of the 49 districts surveyed in two years, sorghum anthracnose was recorded in 41 districts in at least one of the two years, thus anthracnose was present in ca. 84% of the survey districts. The disease was observed in 31 districts in both years and six districts in only one of the two survey years. Eight districts showed no apparent anthracnose infection in either survey year. Five districts were included in the survey program only in 2007 and four of them were found to have fields affected by anthracnose. Anthracnose incidence varied across districts from 0 to 80% and 0 to 74% in 2005 and 2007, respectively, while severity of the disease was in the range of 0 to 78% and 0 to 40% in 2005 and 2007, respectively.

Average disease incidence across the whole country was almost the same for the two years being 31.6 and 31.4% in 2005 and 2007, respectively. However, average anthracnose severity across the whole country was lower in 2007 (13%) than in 2005 (20.7%). The two year average disease incidence was highest (77%) in districts of Dedo and Shebesombo followed by Bita, Dewachefa and Gimbo, which had 71 to 72% anthracnose incidence. These areas are all located in the Southwest and South Ethiopia except Dewachefa, which is located in the North. Average anthracnose severity was the highest in Bita (59%)

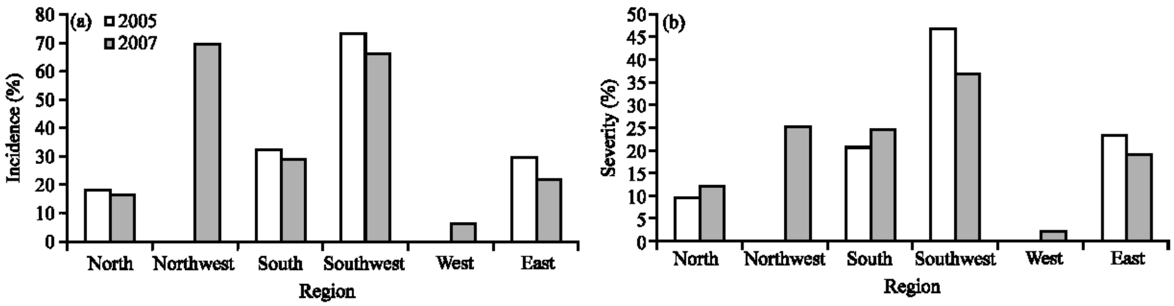

Fig. 2: (a) Incidence of sorghum anthracnose in different geographic regions of Ethiopia and (b) severity of sorghum anthracnose in different geographic regions of Ethiopia. The Northwest and West regions were not surveyed in 2005

Table 2: Incidence and severity of sorghum anthracnose in different districts of Ethiopia

Region	District	No. of farms surveyed	Altitude (m)	Incidence 2005	Incidence 2007	Incidence Mean[1]	Severity 2005	Severity 2007	Severity Mean
South	Alaba	5	1795	25.8	22.5	24.1ijk	31.7	9.5	20.6f-k
	Arsinegelle	5	1944	25.5	35	30.2hi	16.2	13	14.6i-q
	Damotgale	8	1947-1952	56.8	53.8	55.3e	42.2	25.5	33.9cde
	Gidole	15	1297-1590	-	69.4	-	-	13.8	-
	Konta	10	1154-1640	43.3	36	39.7gh	21.2	16.4	18.8g-l
	Loma	10	1247-1945	50	53	51.5ef	34.4	18	26.2e-i
	Mereka	7	1240-1550	61.2	57.5	59.4cde	31.9	28	29.9d-g
Southwest	Bita	12	1837-1953	75	66.7	70.8ab	77.8	40	58.9a
	Chena	15	1794-2014	70.2	67.5	68.9ab	45.7	27	36.4cde
	Dedo	15	1934-2283	78.3	75	76.7a	54.7	34.3	44.5bc
	Gimbo	15	1762-1938	72.6	70	71.3ab	62.5	42.5	52.5ab
	Qarsa	10	1728-1807	72.1	66	69.1abc	54.7	27	40.8bcd
	Sekachekorsa	8	1797-1940	68.9	62.5	65.7bcd	37	27.5	32.3c-f
	Shebesombo	6	1522-1738	80.2	73.3	76.8a	34.1	23.3	28.7d-h
East	Chiro	15	1764-2310	20.4	16.7	18.5jkl	14.3	4.5	9.4l-q
	Gemechis	5	1925-1926	4.8	2.5	3.7opq	2.9	1	1.9opq
	Gorоogutu	10	2113-2275	10.2	5	7.6m-q	2.2	2.5	2.3opq
	Haramaya	10	2027-2077	40.1	36.7	38.4gh	22.5	18.3	20.4g-k
	Hararzuria	5	1940	10.7	10	10.3l-p	13.3	3	8.2l-q
	Kersa	10	2045-2134	55.4	51	53.2ef	18	15	16.5h-n
	Kombolcha	5	2225	55.3	35	45.2fg	38.4	20	29.2d-h
	Meeso	15	1360-1397	8.2	0	4.1opq	14.3	0	7.2l-q
	Meta	8	2265-2334	0	0	0q	0	0	0q
	Quni	10	1744-1764	18.9	21	19.9jkl	16.7	20	18.3g-l
	Tulo	10	2169-2337	18	15	16.5klm	14.3	3.2	8.7k-q
	Welenchiti	10	1460-1474	0	0	0q	0	0	0q
North	Alamata	15	1476-1516	45.1	66.7	55.9e	21.8	14	17.9g-m
	Ambassel	12	1546-1734	10.2	0	5.1 opq	8.2	0	4.1n-q
	Dewachefa	15	1433-1488	68.1	74.4	71.2ab	35.8	25.6	30.7d-g
	Efratanagidem	10	1477-1564	20.1	40	30.1hi	13.5	10	11.7j-q
	Gantaafeshum	5	2035	2.1	0	1pq	1.6	0	0.8q
	Gondarzuria	8	1938-2088	5	0	2.5pq	2.3	0	1.1pq
	Gubalafto	12	1496-1828	12.2	8.3	10.3l-p	5	2	3.5opq
	Harbu	17	1578-1870	0	0	0q	0	0	0q
	Jiletumuga	15	1158-1492	53.3	60.6	57de	29	28.8	28.9d-h
	Kaloo	10	1569-1684	21	17.5	19.3jkl	6	4	5m-q
	Kewet	5	1426	12.1	0	6.1n-q	8.3	0	4.2n-q
	Kiliteawlalo	5	2229	7	1	4opq	1	1.5	1.3pq
	Kobo	15	1490-1730	25.1	30.6	27.9ij	37.6	11.5	24.5e-j
	Laelaymachew	8	2055-2166	0	0	0q	0	0	0q
	Libokemkem	5	1881	0	0	0q	0	0	0q
	Medebayzana	5	2216	2.3	0	1.2pq	1.6	0	0.8q
	Rayaazebo	10	1670-1768	0	0	0q	0	0	0q
	Taetayquoraro	5	1968-1972	0	0	0q	0	0	0q
	Tehuledere	15	1669-1978	20.1	10	15k-n	11.2	8.2	9.7k-q
Northwest	Mandura	15	1061-1465	-	66.4	-	-	20.7	-
	Pawe	15	1054-1180	-	73.3	-	-	30	-
West	Bako	6	1654-1704	-	13.3	-	-	5	-
	Cheliya	5	2073-2160	-	0	-	-	0	-

Means in a column followed by the same letters are not significantly different according to LSD at 5% probability level. Areas not surveyed in 2005
$p<0.0001$ for both incidence and severity

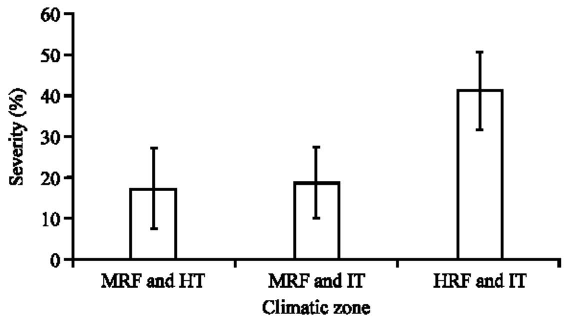

Fig. 3: Anthracnose severity in different climatic zones of Ethiopia. MRF: Moderate rainfall (800-1200 mm), HRF: High rainfall (>1200 mm) IT: Intermediate temperature (16-30°C), HT: High temperature (>30°C)

Table 3: Incidence and severity of sorghum anthracnose in different altitude groups averaged for the two survey years

		Incidence (%)		Severity (%)	
Groups	Elevation (m)	Range	Mean	Range	Mean
I	<1500	0-73	43.4a	0-35	16.8a
II	1500-2000	0-77	31.8a	0-59	19.8a
III	>2000	0-53	15.2b	0-29	7.3b

Means in a column followed by the same letter are not significantly different according to LSD at 5% probability level

followed by Gimbo (53%) and Dedo (45%). Across the survey areas, where the disease was apparent, the lowest average anthracnose incidence (1-3%) was recorded in Gantaafeshum, Gondarzuria, Kiliteawlalo and Medebayzana. The same areas, which are all located in the North, also had the lowest anthracnose severity (ca. 1%).

Incidence and severity of sorghum anthracnose across altitude groups: The survey areas were categorized in to three altitude groups based on their elevation (Table 3). Group I consists of areas, which are located at altitudes below 1500 m and hence considered as lowlands. Group II, areas with altitude ranging between 1500-2000 m, were considered as intermediate altitudes while the Group III areas, with altitude of > 2000 m, were considered as highlands. Both anthracnose incidence and severity were significantly higher ($p<0.0001$ for incidence and $p = 0.0018$ for severity) in the low and intermediate altitudes. Anthracnose severity was up to 35 and 59% while incidence reached up to 73 and 77% for the lowlands and the intermediate altitude areas, respectively. On the other hand, the highlands had a lower level of anthracnose with a maximum of 53 and 29% disease incidence and severity, respectively, indicating that fields with severe anthracnose infection are consistently located in areas below 2000 m.a.s.l.

Severity of sorghum anthracnose in different climatic zones: Complete rainfall and temperature data were available for 20 of the 49 survey districts and hence only these areas could be classified into different climatic zones. Fifty one, 70 and 100 fields were included in zone 1 (areas with moderate rainfall and intermediate temperature), zone 2 (moderate rainfall and high temperature) and zone 3 (high rainfall and intermediate temperature conditions), respectively. None of the survey areas have low rainfall and low temperature and combination of high rainfall and high temperature was also absent among the survey areas. Average results of the two year survey revealed that sorghum anthracnose was less severe in areas with moderate rainfall and intermediate temperature and in areas with moderate rainfall and high temperature (Fig. 3). The disease was severe (41% average severity) in areas with high rainfall and intermediate temperature.

Correlation between geo-climatic factors and anthracnose occurrence: Anthracnose incidence and severity had negative and significant correlation with altitude ($r = -0.35$ and $r = -0.21$, respectively). There was strong positive correlation between 10 year mean rainfall and mean anthracnose incidence and severity ($r = 0.66$ and 0.72, respectively) (Table 4). Rainfall during the actual sorghum production season (April to October) of 2005 and 2007 correlated also strongly and significantly with both anthracnose incidence and severity. On the other hand, temperature had insignificant correlation with both disease incidence and severity. This indicated the strong influence of weather conditions particularly that of rainfall on anthracnose development. A strong positive and highly significant correlation ($r = 0.86$ to 0.92) was also found between disease incidence and severity.

Sorghum is grown over a large area in many parts of Ethiopia. The current survey in different parts of Ethiopia showed great variations in anthracnose ranging from mild to severe infections. About 37% of the surveyed districts had moderate to severe anthracnose infection indicating the potential of the disease in hampering sorghum productivity. Ngugi *et al.* (2002) reported that anthracnose with severities of 20% or more, can impact sorghum yields. Given this prediction, it is possible to assume that anthracnose is likely to cause significant yield loss in 18 (37%) of the 49 surveyed districts unless sorghum plants in these areas are tolerant to the disease or other management practices are undertaken.

Variations in incidence and severity of plant diseases in general can be attributed to differences in cultural practices, which include soil cultivation and removal of

Table 4: Pearson correlation between weather conditions and anthracnose incidence and severity

	Incidence			Severity			Rainfall		
	2005	2007	Mean	2005	2007	Mean	2005	2007	10M
Incidence									
2005	-	0.97****	-	0.87****	-	0.92****	0.56*	-	0.70***
2007	-	-	-	-	0.89****	0.88****	0.45^{NS}	0.49*	0.60**
Mean	-	-	-	0.86****	0.92****	0.91****	0.51*	0.55*	0.66**
Severity									
2005	-	-	-	-	0.90****	-	0.52*	-	0.65**
2007	-	-	-	-	-	-	0.65**	0.68**	0.76***
Mean	-	-	-	-	-	-	0.59**	0.60**	0.72***
Temperature									
2005	-0.30^{NS}	-0.20^{NS}	-0.25^{NS}	-0.25^{NS}	-0.35^{NS}	-0.30^{NS}	-	-	-
2007	-	-0.25^{NS}	-0.29^{NS}	-	-0.36^{NS}	-0.36^{NS}	-	-	-
10M[1]	-0.07^{NS}	-0.02^{NS}	-0.05^{NS}	-0.14^{NS}	-0.18^{NS}	-0.16^{NS}	-	-	-

10M: Mean of 10 year data. Rainfall and temperature conditions for individual year represent the actual weather during sorghum production season (April-October). ^{NS}: Statistically not significant, *Significant at $p<0.05$, **Significant at $p<0.01$, ***Significant at $p<0.001$, ****Significant at $p<0.0001$

crop residues, host genotypes, planting time and the growing environment (Néya and Normand, 1998; Marley, 2004). Cropping systems (mono- vs. inter-cropping and use of variety mixtures) are also known to contribute to disease pressure in positive or negative ways (Agrios, 2005). It was obvious from the present study that farmers in Ethiopia do not apply any specific management practice to combat anthracnose at least consciously. In most of the surveyed areas, sorghum is grown as a sole crop but there were also fields, where it was intercropped with beans and teff (*Eragrotis teff*) in most cases and maize (*Zea mays*) in a very few cases. In our study, we did not observe any pattern between the levels of anthracnose occurrence and growing sorghum either as a sole crop or intercropped with others (data not shown). Most of the intercrops, especially beans and teff, are usually planted late in the season (end of July or later) compared to sorghum, which is usually planted in April or earlier and by that time the initial infection of sorghum by *Colletotrichum sublineolum* might have already occurred (anthracnose can be observed in the field as early as the end of June or beginning of July) as reported by Chala *et al.* (2009). Besides, most of the crops that are intercropped with sorghum are much shorter compared to the tall sorghum plants that can reach as high as 4 m, which are very common in Ethiopia and hence, may not be very effective in preventing further spread of the pathogen from one sorghum plant to the other.

Crop rotation is one important cultural practice that influence disease development through its effect on inoculum survival and carry over (Agrios, 2005). Most of the surveyed fields were continuously planted to sorghum while some were rotated with maize and this might have contributed to the high inoculums build up of *C. sublineoulm* especially in areas with conducive environmental conditions. However, the exact impact of crop rotation under Ethiopian conditions should be investigated in the future by involving different kinds of crops.

Prevailing weather is another important factor that influences the incidence and severity of plant diseases (Kranz and Rotem, 1987). In this study, most of the fields with moderate to severe anthracnose infection are located in the Southwest and South parts of the country, which usually have intermediate to high temperature and high rainfall. Information on the relative humidity of the survey areas was not available for most of the surveyed areas but it is obvious that relatively warm temperature and high rainfall may give rise to high relative humidity. Association of severe sorghum anthracnose infection with low and intermediate altitude areas is most probably attributed to the prevailing weather conditions as most areas with intermediate to high temperature and high rainfall are situated in these altitude groups. These results are in agreement with previous findings that associate a more intense sorghum anthracnose with high temperature and relative humidity (Ali and Warren, 1987; Hess *et al.*, 2002; Thomas, 1992). Exceptions to this trend were observed in three districts, where sorghum fields had low to moderate anthracnose infection despite the environmental conditions being conducive for the disease. This deviation from earlier reports associating anthracnose with warm and humid weather could be linked to the wide distribution of local land races, which might possess certain levels of resistance to the disease. Farmers in these areas have grown sorghum for several decades or even centuries and hence the land races might have developed resistance to the disease. Dogget (1980) also indicated host-pathogen co-evolution as a possible mechanism of establishing an equilibrium that in the end leads to low infection levels.

Ethiopia has 5 climatic zones depending on rainfall and temperature conditions (USDA, 2002). However, it was not possible to categorise all the surveyed areas into these climatic zones due to the lack of weather data for some of the districts included in our survey program. Combining the prevailing temperature and rainfall conditions from 23 of the 49 districts led to the classification of these areas into 3 distinct zones. Variations in anthracnose intensity were noticeable across these zones with the highest disease severity recorded in warmer areas that received higher annual rainfall (>1200 mm). While high anthracnose incidence and severity are always associated with high rainfall, some survey areas with higher temperature had less severe anthracnose and in general the correlation between temperature and anthracnose severity was weak and insignificant (Table 4). In addition, Erpelding and Wang (2007) reported low temperature as conducive for anthracnose development in the field and Chala *et al.* (2009) suggested temperature as having a less important role on anthracnose development compared to rainfall. Given the fact that many of the surveyed areas included in the present study have more or less similar temperature conditions, we believe rainfall was the most important factor behind much of the variations in anthracnose intensity. This was also supported by the strong positive and highly significant correlations that existed between anthracnose incidence and severity and amount of rainfall (Table 4). It was observed that the 10 year average rainfall, which represents the long term and year round climatic conditions of the survey areas, had a stronger correlation with anthracnose incidence and severity compared to the actual rainfall in the growing season of each survey years. This might be because the former has an additional impact on the survival, build up and spread of the inoculum.

This is the first comprehensive study on the geographic distribution, incidence and severity of sorghum anthracnose in Ethiopia. Results of this survey revealed the geographic distribution and intensity of the disease. Occurrence of anthracnose at a severe level in some areas justifies the need for further studies to determine associated yield loss and thereby the economic importance of the disease at least across areas with moderate and high level of infection. Variations in anthracnose intensity among the survey areas indicate not only the effect environmental conditions may have on the disease but also the role local land races may play in managing the disease. Thus, we suggest future studies especially those related to yield loss assessment and disease management should be conducted across areas with different environmental conditions and should give due attention to local land races that may serve as good sources of resistance. Future studies should also give due attention to the impact of cropping practices including cultivar or species mixture on disease development.

We collected sorghum leaves from surveyed areas showing symptoms of anthracnose and the pathogen *Colletotrichum sublineolum* was isolated from the samples. Currently work is underway to characterise the isolates. Besides, field experiments are being conducted to evaluate Ethiopian sorghum germplasm for resistance to anthracnose.

CONCLUSIONS

Sorghum anthracnose was found to prevail in most sorghum growing regions of Ethiopia. However, both disease incidence and severity varied significantly across survey districts, altitude groups and climatic zones. Over all, the Southwest region had the highest anthracnose level and it was followed by the South, Northwest, East, West and North regions of the country. The disease was more severe in areas of intermediate and low altitude than high altitude areas and areas that receive higher annual rainfall had higher anthracnose level as compared to areas with low rainfall. Results of the current survey showed that anthracnose could cause a significant yield reduction in at least 37% of the survey districts and hence, management strategies should be sought to control the disease in an effective, affordable and sustainable manner.

It was found out that anthracnose development in the field is affected by weather and particularly rainfall had a significantly positive impact on the disease. Although, both long term rainfall conditions and actual rainfall during the cropping season affected the incidence and severity of anthracnose in sorghum fields, the former had more pronounced effect and this might be because of its impact on pathogen survival and inoculums build up. Nevertheless, some areas with conducive environment to anthracnose were found to have low anthracnose severity confirming role of host-pathogen co-evolution as one mechanism towards disease resistance. Further research is needed to elucidate the impact of different weather variables on this disease of global importance.

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