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Distribution and Importance of Maize Grey Leaf Spot *Cercospora zeae-maydis* (Tehon and Daniels) in South and Southwest Ethiopia

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Abstract

Maize (*Zea mays* L.) is one of the most important cereal crops used in the human diet in large parts of the world as well as in Ethiopia and its production are limited by diseases such as grey leaf spot caused by a fungus *Cercospora zeae-maydis*. Currently grey leaf spot has become the most important threat to maize production in maize belt areas of Ethiopia causing significant yield loss. The objective of this study was therefore, to assess the distribution and importance of maize grey leaf spot in south and southwest Ethiopia. The field assessments were conducted during the year of 2014 cropping seasons by sampling 110 farmer fields in 11 districts selected from two zones of Oromia region and two zones of Southern Nation, Nationalities and People region (SNNPR). The result revealed that the disease occurs in the entire assessed districts having different agro-ecological zones. Maize grey leaf spot was prevalent in all surveyed farms of south and southwest Ethiopia, 74% of maize fields were infected by grey leaf spot. However, the mean incidence and severity of grey leaf spot on maize was significantly varied from district to district. The highest grey leaf spot incidence (71.2%) and severity (46.2%) was recorded in Boricha district, while Damote Gale had the lowest mean incidence (51.8) and severity (33.5%). Among the surveyed four zones in two regions, the highest incidence was found in Sidama (65.6%) and Illubabore (63.1%) followed by Jimma (62.5%) and Wolaita (57.6%). The highest mean severity of maize grey leaf spot was observed in Sidama (44.5%) followed by Illubabore (43.7%) and Jimma (42.63%) while the lowest severity was recorded in Wolaita (36.4%) zone. The disease was more severe in intermediate/humid areas with intermediate annual rainfall. The current study revealed maize grey leaf spot pressure in maize farms of south and southwest Ethiopia and the need to design an efficient, inexpensive and sustainable management approaches against the pests.

Keywords: *Cercospora zeae-maydis*; Grey leaf spot; Incidence; Prevalence; Severity; Zea mays

Introduction

Maize (*Zea mays* L.) is one of the most essential cereal crops used in the human diet in most parts of the world and it is an imperative feed constituent for domestic animals. Among cereal crops, maize has the highest average yield per hectares and remains third after wheat and rice in total area and production in the world [1]. The estimated area under maize production in the world is about 144 million hectares, and has an annual production of about 700 million tons [2], with about 60% produced in the developed countries, mainly by the United States, produces nearly one half of the total world production. The next largest maize producing countries are China and Brazil [2]. About 70% of the world maize production area is found in developing countries. However, these countries contribute to only 49% of the world's maize production [1]. In sub-Saharan Africa maize is produced in an estimated area of about 26 million hectares with an average yield of 460 million tons. In east Africa, maize occupies about 11 million hectares production area with an average yield of 16 million tons [2].

Maize is one of the most important cereal crops cultivated in Ethiopia ranking second after teff in area coverage and first in total production. The recent post-harvest crop production survey of 2011/12 indicated that total land areas of about 12 million ha are covered by grain crops. Out of the total grain crop areas, 79.34% (about 9 million ha) is under cereals. Of this, maize covered 17% (about 2 million ha) and gave about 6.1 million tons of grain yields [3]. The major maize producing regions of Ethiopia are southern, western and southwestern and in some northern, northwestern and eastern parts where over 90% of the maize produced are used as food among the low income groups [4].

Despite the large area under maize, the national average yield of maize is about 2.95 tons/ha [3]. This is by far below the world's average yield, which is about 5.21 tons/ha [2]. The low productivity of maize is attributed among other, to frequent occurrence of drought [5], declining of soil fertility, poor agronomic practice, limited use of input, lack of credit facilities, poor seed quality [6], diseases [7,8], insect pests and weed [9].

Among these constraints diseases play a major role and a foliar disease particularly grey leaf spot (GLS) is among the important constraints limiting tropical maize production [10]. Grey leaf spot has been reported as one of the major yield-limiting diseases of maize in sub-Saharan Africa [11]. It also poses a serious threat to maize production in central, eastern, southern, and western Africa. Grey leaf spot is apparent on plants as small spots first on lower leaves of plants at tassel initiation. The disease moves upwards and spots change into long characteristics lesions within a month turning plants into a diseased field. The disease is significant since it rapidly destroys foliage when the plant is near at grain maturity. This disease is most rigorous and injurious when comprehensive periods of high relative humidity occur, resulting from slow-drying dews and prolonged late-season fogs [12]. Increased incidence of grey leaf spot in Africa has been associated with cultural practices such as reduced tillage, continuous cultivation of maize, and use of susceptible maize cultivars [13]. Conservation

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tillage leaves infested residue from previous crop on the soil surface that increases initial inoculums of the disease.

Documented yield losses of maize attributed to grey leaf spot vary from 11 to 69% [11], with estimated losses as high as 100% when severe epidemics contributed to loss of photosynthetic area, severe lodging also can adversely affect mechanical harvesting and results in further grain loss due to a reduction in harvestable grain yield [14]. The yield losses caused by the disease were estimated to reach 50% for moderately resistant and 65% for susceptible hybrid maize in South Africa [11].

Grey leaf spot was first reported in Ethiopia in 1997 in the border of west Wellega and Ilubabor zones, of western Ethiopia [15,16]. The survey report of [15] showed increased prevalence of grey leaf spot in the major maize producing regions of Western, Southern and Northwestern parts of Ethiopia. According to the report, grey leaf spot has become the principal maize disease since 1998 in Ethiopia. In Ethiopia, [17] reported that yield losses due to grey leaf spot on resistant, moderately resistant, and susceptible varieties were between 0-14.9%, 13.7-18.3% and 20.8-36.9%, respectively during 2003/2004 cropping seasons in Bako and its nearby areas. The severity of grey leaf spot was high in the warm humid maize belt areas of the country which adversely affecting farmers who live with limited resources. The disease has been observed spreading over the years in the maize belt areas of the country. Despite the observed high grey leaf spot incidence and severity in the farmers' fields, little empirical information is available regarding the distribution and importance of grey leaf spot (GLS) in maize growing areas of south and southwest Ethiopia. Therefore, the objective of this study was to assess the distribution and importance of maize grey leaf spot in four major maize growing zones in south and southwest Ethiopia.

Materials and Methods

Survey area

The survey was conducted in different agro-ecological Zones of Oromia Regional States (Jimma and Illubabore) and SNNPR (Wolaita and Sidama) during the 2014 cropping season (Table 1). The survey route followed major roads to towns and localities in each regional state. A total of 110 farmers' fields in 11 districts of 4 administrative zones within 2 regional states were assessed for the occurrence and intensity of maize grey leaf spot (Figure 1).

Assessment of grey leaf spot prevalence, incidence and severity

The survey programs covered the most important maize growing zones in southern and southwestern Ethiopia with frequent stopping at different intervals depending on the variability of fields in terms of altitude and cropping systems. Size of the survey site and availability and accessibility of maize field was given due consideration in deciding where to stop on survey routes. Disease prevalence was assessed by determining the number of fields where grey leaf spot was recorded in relation to the number of fields sampled in different origins of south and southwest Ethiopia. Disease assessment was made in 30 randomly selected spots in each field. Grey leaf spot incidence was assessed as:

$$\text{Disease incidence} = \frac{\text{Number of diseased plants}}{\text{Total number of plants inspected}} \times 100$$

Disease severity: Grey leaf spot severity was rated according to Maroof [18], using 1-5 scales: 1 = no symptoms; 2 = moderate lesion development below the leaf subtending the ear; 3 = heavy lesion development on and below the leaf subtending the ear with a few lesions above it; 4 = severe lesion development on all but the uppermost leaves, which may have a few lesions; and 5 = all leaves dead. The survey was conducted at tasseling and physiological maturity stage to assess the average leaf area of maize covered by grey leaf spot symptom for 30 randomly selected diseased plants per field. The numerical rating was converted to percentage severity index (PSI) using the following equation suggested by Wheeler [11]:

$$\text{PSI} = \frac{\text{Sum of all numerical ratings} \times 100}{\text{Total number of rated} \times \text{Maximum disease score on scale}}$$

Data analysis

Data was first checked for various ANOVA assumptions. The mean incidence and severity data were calculated for each district. The field survey data for maize grey leaf spot (incidence and severity) was analyzed using three stage nested design. Mean grey leaf spot incidence and severity of each zone were used to make comparison between the surveyed zones within two regions. The same process was followed to determine grey leaf spot incidence and severity for the different agro-climatic districts within zones. All the statistical analyses were carried out using SASV 9.2 and the Least Significant Difference (LSD) test was used for mean comparison.

Result and Discussion

Distribution and importance of grey leaf spot

Maize grey leaf spot was prevalent in all maize producing districts of south and southwest Ethiopia included in this survey. The disease prevalence of maize gray leaf spot ranged from (54%-98%) (Figure 2). This indicated the disease was the most destructive diseases during the season. The highest prevalence of gray leaf spot (98%) was recorded in Boricha district followed by Urumu, Bedele and Seka chekorsa which had 95%, 82% and 76% gray leaf spot prevalence, respectively, while the lowest prevalence of grey leaf spot (54%) was recorded in Damote Gale district (Table 2). In general, grey leaf spot was (74%) prevalent in all 110 surveyed farms of the different eleven districts of south and southwest Ethiopia in 2014. The widely distribution and the high prevalence of grey leaf spot during the survey season in all assessed district could be attributed to the favorable environmental conditions coupled with cultivation of susceptible maize cultivars worsened the problem to maximum. A grey leaf spot epidemic is favored by high rainfall and relative humidity, warm temperatures, and the presence of large amounts of inoculums. The most possible reason could be due to the inconsistency in environmental condition, production systems and practices and the variety grown. As a result, producers can have an impact on the prevalence and intensity of this disease by deciding from a number of management strategies including host plant resistance, cultural practices (adjusting planting date, crop rotation, tillage practices) and careful use of foliar-applied fungicides [19]. The previous study of Dagne et al. [15] reported that increased prevalence of gray leaf spot in the major maize producing regions of Western, Southern and Northwestern parts of Ethiopia. According to the report, GLS has become the principal maize disease since 1998 in Ethiopia.

Sr.No.	Regional States	No of Zones	No of District	No of Farms surveyed	Total
I	Oromia	Jimma Illubabore	2 3	10 10	20 30
II	SNNPR	Wolaita Sidama	3 3	10 10	30 30
Sub Total	2	4	11	40	110

Table 1: Description of surveyed areas and number of farms surveyed in 2014.

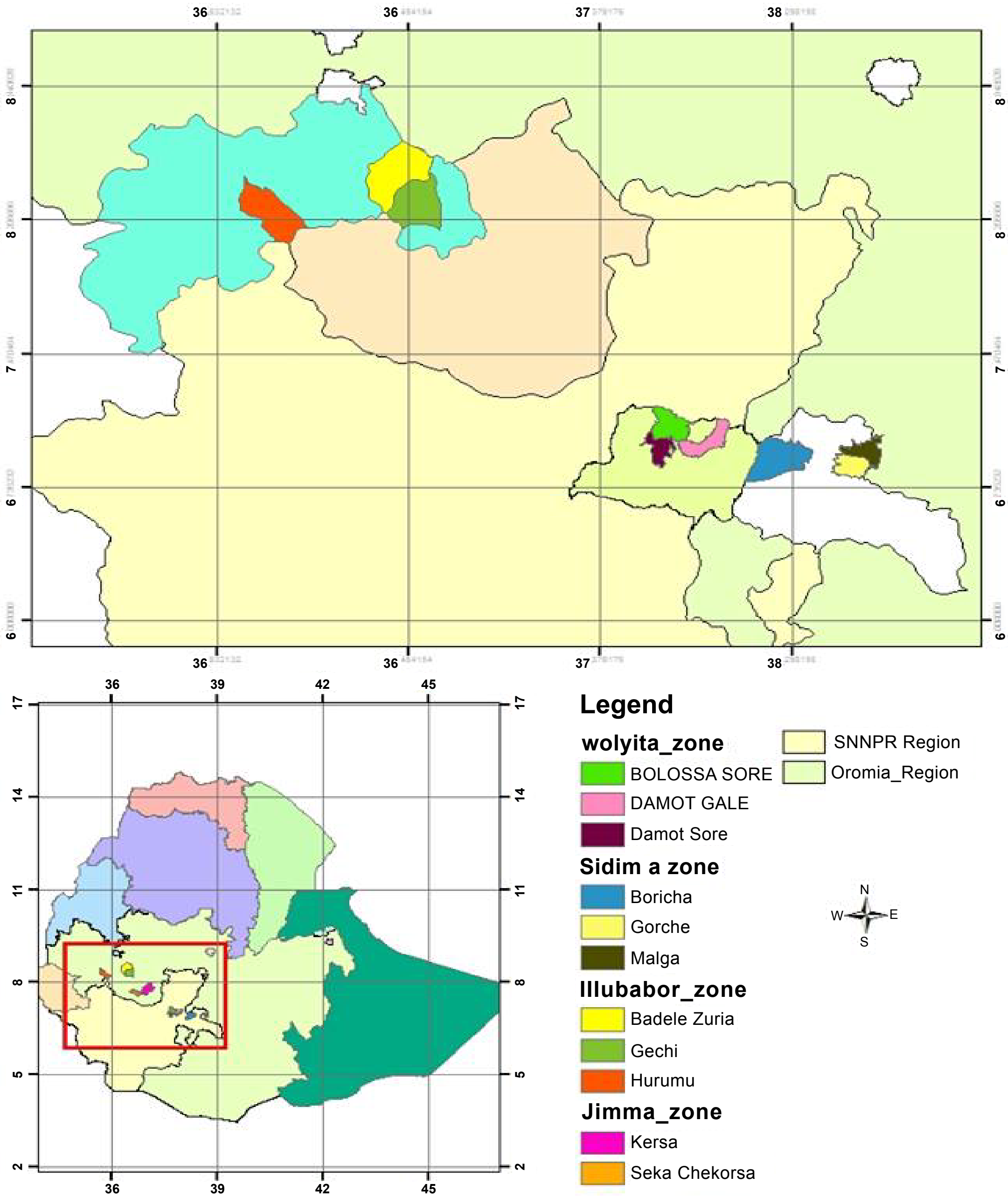

Figure 1: Map of Ethiopia showing study areas included in the survey program.

Incidence and Severity of grey leaf spot across zone within regions

A total of four zones (Sidama, Wolaita, Jimma and Illubabore) were included in the survey program and maize grey leaf spot was prevalent in the entire surveyed zone/areas but with varying intensity. The mean incidence and severity of maize grey leaf spot was significantly varied from zone to zone (Tables 3 and 4). The mean incidence of maize grey leaf spot in the different zones ranged from (57.6-65.6%) (Table 3). There was a statistically significant ($p<0.001$) difference among zones in terms of maize grey leaf spot incidence within two regions. We found higher incidence of maize grey leaf spot in Sidama (65.6%) and Illubabore (63.1%) followed by Jimma (62.5%) and Wolaita (57.6%). The widely distribution and the high incidence of grey leaf spot in Sidama and Illubabore followed by Jimma and Wolaita could be attributed to intermediate rainfall occurrence, variation in altitude and germplasm planted by farmers and lack of crop rotation in the zone that are favorable for stimulating the growth of the fungus [13]. Showed that increased incidence of grey leaf spot in Africa has been associated with cultural practices such as reduced tillage, continuous cultivation of maize, and use of susceptible maize cultivars. Conservation tillage leaves infested residue from previous crop on the soil surface that increases initial inoculums of the disease. Moreover, increasing crop residue on the soil proportionally increases the amount of primary inoculums. Although Anderson [12] reported that the beneficial effects of stubble tillage on soil and water conservation are widely recognized, these benefits are frequently offset by the increased crop damage by

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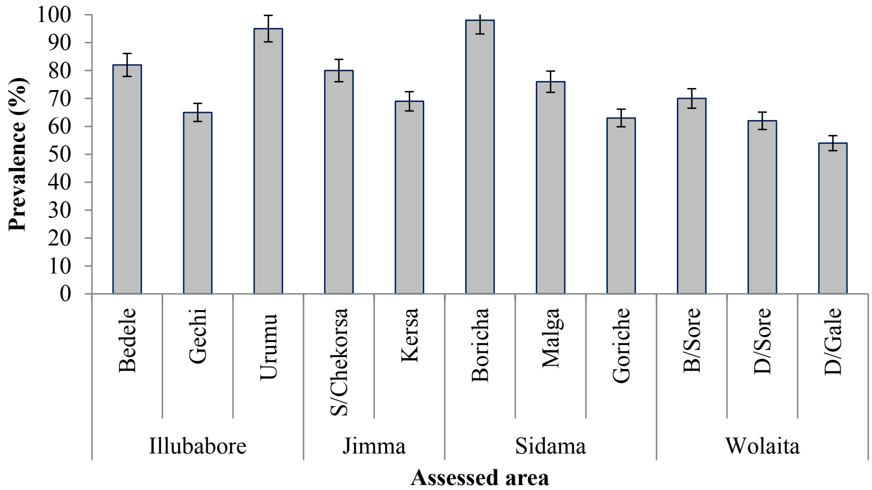

Figure 2: Percentage prevalence of grey leaf spot of maize in south and southwest Ethiopia in 2014.

Region	Zone	District	Location	Altitude (m.a.s.l.)	Annual rainfall (mm)	Mean Temp. (ºC)	
						Max	Min
SNNPR	Sidama	Boricha	06º56'30.8" N and 03º825'07.4" E	1866	1317	27.9	14.5
		Goriche	06º51'00.3" N and 038º18'04.6" E	1950	1319	28	14.3
		Malga	7º4'N and 38º 31'E	1073	1700	26.3	14.1
	Wolaita	D/Gale	077º03'06'' N and 036º16'30''E	1612-2964	900-1400	24	12
		B/Sore	7º04'N-37º42'E	1830	101.3-158.1	26.2	11.4
		D/Sore	37º20'80''N	1900-2010	850-1200	25	20
Oromia	Jimma	Kersa	7º35'-8º 00'N and 36º 46'-37º 14'E	1600-2400	1587	15	10
		Seka Chekorsa	7º17'-7º 44' N and 17'-36º 52' E	1580-2560	1800-2300	25	15
	Illubabore	Hurumu	8º33'N 35º67' E	1780	1015	27	18
		Bedele	8º46'-8º56' N and 36º01'-36º15' E	1500-2300	144-173	21.9	18.5
		Gechi	8º 8'58" N - 8º 24' 30" N and 36º17' 30" E - 36º31'45"E	1300 -2270	2214-2300	18	9

Table 2: Location and the climatic characteristics of the study area in 2014.

Level of Zone		Number of farms surveyed	Disease Incidence	
			Mean	SD
Sidama	SNNPR	30	65.60[a]	±5.30
Wolaita	SNNPR	30	57.60[c]	±6.28
Jimma	Oromia	20	62.50[b]	±3.44
Illubabore	Oromia	30	63.10[b]	±3.63
LSD(0.05)	2.06			
CV (%)	6.12			

Mean within a column followed by the same letters are not significantly different according to LSD at 5% probability level. SD = Standard Deviation, LSD = Least Significant Difference, CV = Coefficient of Variation.

Table 3: Incidence of maize grey leaf spot in different Zones of South and Southwest Ethiopia in 2014.

Level of Zone		Number of farms surveyed	Disease Severity	
			Mean	SD
Sidama	SNNPR	30	44.50[a]	±2.05
Wolaita	SNNPR	30	36.41[c]	±4.38
Jimma	Oromia	20	42.63[b]	±3.20
Illubabore	Oromia	30	43.70[ab]	±2.81
LSD(0.05)	1.60			
CV (%)	7.08			

Mean within a column followed by the same letters are not significantly different according to LSD at 5% probability level. SD = Standard Deviation, LSD = Least Significant Difference, CV = Coefficient of Variation.

Table 4: Severity of maize grey leaf spot in different Zones of South and Southwest Ethiopia in 2014.

fungal pathogens that survived in the previous season's debris. This indicated that variations in grey leaf spot severity within a zone may be due to differences in weather and maize variety during the survey year. Reportedly, in the U.S.A. (Iowa) the outbreak of grey leaf spot based on empirical observations, moderate to high temperatures and prolonged periods of high relative humidity generally are accepted as being favorable for the development of this disease [11].

Statistically there was also significant (p<0.001) difference in severity of maize grey leaf spot in the surveyed zones of maize belt areas of South and Southwest Ethiopia. The mean severity of grey leaf spot in the different zone ranged from (35.4 - 44.5%) (Table 5). Severity of maize grey leaf spot could also be higher in the Sidama (44.5%) and Illubabore (43.7%) followed by Jimma (42.63%) whereas the lowest severity was recorded in Wolaita (36.41%), south and southwest Ethiopia in 2014. Our result revealed that high variation in disease incidence and severity were recorded in Sidama and Illubabore followed by Jimma and Wolaita (Table 4). This suggests that variation in existing weather condition, cultural practices, lack of crop rotation and difference in genetic background of maize genotype planted by farmers in the zone encourage the development of the fungus. Therefore, farmers can have a contact on the variation in incidence and severity of grey leaf spot by choosing from a number of management techniques including cultural practices, which include crop rotations, soil cultivation and removal of crop residues, resistant host genotypes, use of short-season maize varieties, regulating planting time and use of fungicides [14,20].

Incidence and severity of grey leaf spot across districts within zones

The survey result on the distribution and importance of grey leaf spot in maize growing districts of separate zone of South and Southwest Ethiopia are presented in Table 5 and 6. Maize grey leaf spot was prevalent in the all assessed areas of south and southwest Ethiopia, both incidence and severity of the disease varied significantly across the districts with in four zones of different agro-ecological condition (Tables 5 and 6). The mean incidence of maize grey leaf spot in the different districts ranged from (51.8%-71.2%). Statistically there was highly significant (p<0.001) difference among districts in terms of maize grey leaf spot incidence and severity (Tables 5 and 6). The highest grey leaf spot incidence (71.2%) was recorded in Boricha district followed by Urumu, Gechi and Seka chekorsa which had 65.7%, 64.1% and 62.8% grey leaf spot incidence, respectively, while the lowest (51.8%) was recorded in Damote Gale district (Table 6). The mean severity values of maize grey leaf spot in the different districts of farmer field ranged from (33.5 - 46.2%) (Table 6). The severity of maize grey leaf spot was highest in Boricha (46.2%) followed by Urumu, Kersa and Goriche (45.13%, 44.06% and 43.2%), respectively. Although the lowest disease severity (33.5%) was recorded in Damote Gale district (Table 7). The seriousness of grey leaf spot was elucidated by the damage (severity) demonstrated on the plant. Generally, the overall severity of the disease was 41.64% (Table 6). As a result, farmers are frustrated by the nature and epidemic of the grey leaf spot disease during the season. In view of the fact that, all of the surveyed areas, maize grey leaf spot was recorded in all districts, thus grey leaf spot was present in all areas of the assessed districts. Earlier results of various surveys conducted in most maize growing regions of Ethiopia indicated that the disease has a wide distribution and significant impact on maize yield reduction on both local and improved varieties [21]. According to field visit report [22] of all released hybrid maize, only BH-660 and PHB-30H83 were found relatively tolerant to grey leaf spot. The disease has also been observed in maize seed multiplication sites at East Shewa and Sidama in most released maize varieties. Reportedly, in the U.S.A. (Iowa) the epidemic of grey leaf spot is severe under monoculture maize with no rotation practices and minimum tillage practices [23]. It was apparent that maize is grown over a large area of south and southwest Ethiopia. The current survey in different parts of south and southwest Ethiopia showed great variations in grey leaf spot ranging from mild to severe infections. All of the surveyed districts had moderate to severe grey leaf spot infection indicating the potential of the disease in hindering maize productivity.

Level of District	Level of Zones	No of farms surveyed	Disease Incidence	
			Mean	SD
Bedele	Illubabore	10	62.10^{cd}	±3.47
Gechi	Illubabore	10	64.10^{bc}	±3.07
Urumu	Illubabore	10	65.70^{b}	±3.49
S/Chekorsa	Jimma	10	62.80^{bc}	±3.79
Kersa	Jimma	10	62.10^{cd}	±3.21
Boricha	Sidama	10	71.20^{a}	±4.16
Malga	Sidama	10	61.40^{cd}	±2.55
Goriche	Sidama	10	61.50^{cd}	±2.67
B/Sore	Wolaita	10	59.40^{d}	±4.78
D/Sore	Wolaita	10	61.50^{cd}	±6.46
D/Gale	Wolaita	10	51.80^{e}	±2.17
LSD(0.05)	3.37			
CV (%)	6.12			

Mean in a column followed by the same letters are not significantly different according to LSD at 5% probability level. SD = Standard Deviation, LSD = Least Significant Difference, CV = Coefficient of Variation.

Table 5: Incidence of maize grey leaf spot in different district of South and Southwest Ethiopia in 2014.

Level of District	Level of Zones	No of farms surveyed	Disease Severity	
			Mean	SD
Bedele	Illubabore	10	42.90^{b}	±2.88
Gechi	Illubabore	10	43.06^{b}	±3.02
Urumu	Illubabore	10	45.13^{ab}	±2.13
S/Chekorsa	Jimma	10	42.56^{b}	±3.32
Kersa	Jimma	10	44.06^{ab}	±2.04
Boricha	Sidama	10	46.20^{a}	±1.69
Malga	Sidama	10	42.70^{b}	±3.36
Goriche	Sidama	10	42.20^{b}	±1.12
B/Sore	Wolaita	10	39.06^{c}	±4.35
D/Sore	Wolaita	10	36.70^{c}	±3.57
D/Gale	Wolaita	10	33.50^{d}	±3.55
LSD(0.05)	2.64			
CV (%)	7.08			

Mean within a column followed by the same letters are not significantly different according to LSD at 5% probability level. SD = Standard Deviation, LSD = Least Significant Difference, CV = Coefficient of Variation.

Table 6: Severity of maize grey leaf spot in different district of South and Southwest Ethiopia in 2014.

Variables	Incidence	Severity	Altitude	Rainfall
Incidence	1.00			
Severity	0.76**	1.00		
Altitude	0.02	-0.06	1.00	
Rainfall	0.22	0.41	-0.10	1.00
Temperature	0.17	-0.21	-0.23	-0.39

Altitude, Rainfall and Temperature represent the actual weather of each location. Significant level: NS = Non-significant, * p ≤ 0.1, ** p ≤0.01 and *** p ≤0.001

Table 7: Pearson correlation between weather condition and grey leaf spot incidence and severity.

Relationship between weather variables, grey leaf spot incidence and severity

The relationship between disease development and weather variables was established using correlation analysis to look for the effect of individual variable on disease development. Correlations between weather variables and grey leaf spot (GLS) incidence and severity were determined in Table 7. The result revealed that grey leaf spot incidence and severity had negative and insignificant correlation with altitude (r = 0.02 and r = -0.06, respectively). There was strong positive correlation between rain fall and mean grey leaf spot incidence and severity (r = 0.22 and r = 0.41, respectively). Rainfall during the actual maize production season of each surveyed area of 2014 correlated also strongly and insignificantly with both grey leaf spot incidence and severity. On the other hand temperature had insignificant correlation with both disease incidence and severity. This indicated the strong influence of weather condition particularly that of rain rainfall on grey leaf spot development. A strong positive and highly significant correlation (r = 0.76) was also found between disease incidence and severity.

It was evident that maize is grown over a large area in many parts of the country, particularly in southern and southwestern Ethiopia. In a current survey conducted in southern and southwestern parts of Ethiopia showed great variation in grey leaf spot intensity ranging from mild to severe infections. In this study, all of the surveyed areas with moderate to severe grey leaf spot infection, which usually have, humid or warm temperature and high rainfall. Information on the relative humidity of the assessed areas was not on hand for all of the assessed areas but it is understandable that comparatively warm temperature and high rainfall could give rise to high relative humidity. Reportedly, warm temperature, well distributed rainfall and high relative humidity are weather conditions favoring this disease development [11].

Cropping methods such as mono or inter-cropping and use of cultivar mixture are also recognized to supply to disease pressure in positive or negative ways [19]. It was observable from the present study that farmers in surveyed maize belt areas of Ethiopia do not apply any specific management practice to contest grey leaf spot at least intentionally. Furthermore, crop rotations are another means of reducing initial inoculums and even a single year of crop rotation will significantly reduce the initial level of *C. zeae-maydis* inoculums. However, it normally takes several years of rotation to reduce the inoculums to levels achieved by deep ploughing [24]. Most of the surveyed fields were continuously planted to maize while some were rotated with bean/sorghum/teff and this might have contributed to the high inoculums buildup of *Cercospora zeae-maydis* especially in areas with conducive environmental conditions.

Conclusion

Our results revealed that gray leaf spot of maize was widely distributed in all surveyed areas. Gray leaf spot incidence and severity varies from location to location within two regional states of South and Southwest Ethiopia. Maize grey leaf spot was prevalent in all maize producing zones and districts of south and southwest Ethiopia included in this survey. Grey leaf spot incidence and severity showed a noticeable variation between zones. Sidama zone had the highest grey leaf spot level and it was followed by the Illubabore, Jimma and Wolaita zones of south and southwest Ethiopia. Variations in grey leaf spot incidence and severity within a zones and districts may be due to differences in weather and maize variety planted by farmers during the survey year. The current study revealed that maize farms surveyed in south and southwest Ethiopia are under maize grey leaf spot pressure and consequently, management should be required to control the disease in an effective, affordable and sustainable approach. Furthermore, in order to get full depiction of the distribution and importance of maize grey leaf spot disease and to design appropriate control technique, it is worthwhile to conduct similar assessments in different maize belt areas of the country.

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