

Distribution and Importance of Maize Grey Leaf Spot (*Cercospora Zeaemaydis* Tehon and Daniels) in West Oromia, Ethiopia

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Abstract

Maize (*Zea mays*) is one of the most widely cultivated crops in the world. It occupies an important position in the world economy serving as food, feed, and industrial grain crop. In Ethiopia, a major staple food and an average productivity is about 3.94 t ha⁻¹, which is below the world average of 5.78 tones ha⁻¹. A significant portion of this yield gap is attributable to biotic and abiotic stresses. Diseases play a major role among the biotic constraints. Of these, grey leaf spot (*Cercospora zeaemaydis*) is one of the major foliar diseases threatening maize production in Ethiopia. Also, in Ethiopia the loss caused due to GLS reached 49.5% and more when the pathogen attacked before the flowering stage. Therefore, the objective of this study was to assess the distribution and importance of Grey Leaf Spot. The field assessment was conducted during 2017 main cropping season by sampling 81 maize fields in 9 districts from 3 zones. The survey result showed the highest disease prevalence 62.96 % was recorded in East Wollega zone and the lowest (22.22%) in West-Wollega zone. The highest mean incidence 35.06 % was recorded in East Wollega zone whilst the lowest 9.51% in West-Shewa. The maximum disease Severity index of 31.43% was in East Wollega zone followed by West-Shewa having 11.98% and West-Wollega (10.05%) zones. At a district level, the highest prevalence was recorded in Leka-Dulecha followed by Gobu-Seyo with disease prevalence of 88.9% and 66.7%, respectively, whereas the minimum prevalence was at Ayra-Guliso Gimbi and Bako-Tibe, each with 22.2 % prevalence. The highest mean disease incidence 48.15% was recorded at Gobu-Seyo followed by Leka-Dulecha 47.77%, whereas the lowest was recorded in Gimbi 1.1% district. The highest mean disease severity index was recorded in Leka-Dulecha 46.11% followed by Gobu-Seyo 39.15%, whilst the lowest in Gimbi 1.78%. Thus, there is a need to develop management strategies like crop rotation with non-host, use of tolerance varieties to reduce the impact of GLS on maize production in the study area.

Keywords: *Cercospora zeaemaydis*, Incidence, Severity Index

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Introduction

Maize (*Zea mays*) is one of the most widely cultivated crops in the world. It is one of the three most popular cereal crops next to wheat, and rice in the world (FAOSTAT, 2016). Maize occupies an important position in world economy as a food, feed and an industrial grain crop (Tolesa *et al.*, 1993). It serves as a vital source of proteins, calories and some of the important vitamins and minerals to billions of people worldwide, particularly in Africa, South America and Asia, and has been considered a 'poor man's nutriceal' (Prasanna *et al.* 2001).

Maize is grown worldwide approximately on 226.94 million hectares (ha) annually with the production of 1291.94 million metric tons (FAOSTAT, 2018). In sub-Saharan Africa, maize is produced on an estimated area of about 26 million ha with an average of 460 million metric tons. In East Africa, maize occupies about 17 million of production area and 30.4 million tons of total production and with 1.8 tons per ha (FAOSTAT, 2016).

In Ethiopia, maize is the second largest food security crop after teff, (*Eragrostis teff* (Zucc.) Trotter. It is primarily produced and consumed by the small-scale farmers that comprise about 80% of Ethiopia's population (Alemu *et al.*, 2008).

Currently, about 2.13 million ha of land is covered by maize with an average production of 8.39 million tons, and the average national yield of maize is very low under small-scale farmers, which is 3.94 t/ha in the country (CSA 2018). However, it is very low as compared to the potential of maize (8 – 11 t ha⁻¹) in the high rainfall and irrigated areas and also low as compared to world average productivity 5.78 ton ha⁻¹ (USDA-FAS 2017).

A significant portion of this yield gap is attributable to biotic and abiotic stresses. The major abiotic factors include nutrient deficiency and drought stress, which could be aggravated by land degradation. Among biotic constraints, foliar diseases play a major role in contributing to the reduction of maize production and productivity across the world (Berger *et al.*, 2014; Masuka *et al.*, 2017).

The major diseases include Turicum leaf blight (*Exserohilum turcicum* (Pass) Leonard & Suggs), grey leaf spot (*Cercospora zeaemaydis* Tehon & Daniels), leaf rust (*Puccinia sorghii* Schr.), maize streak virus disease

(Wegary *et al.*, 2001; Tewabech *et al.*, 2012). Foliar diseases, particularly GLS caused by *Cercospora zeaemaydis* (Tehon and Daniels, 1925) is one of the necrotrophic and polycyclic foliar diseases of maize that poses a serious problem to maize production in tropical maize production (Renfro and Ullstrup, 1996). This pathogen causes intense water loss from the plant thereby leading to severe blighting of the leaves and reduced photosynthesis. This eventually leads to undersized ears, low grain yield and premature death of maize plants. Severe blighting of the upper eight or nine leaves that contribute 75 to 90% of the photosynthates for grain fill may lead to stalk weakening or even infectious stalk rot diseases leading to premature stalk death and lodging (Lipps *et al.*, 1996; Ward *et al.*, 1999; Poland *et al.*, 2009).

In Ethiopia, a major epidemic occurred in the early 2000s and made considerable maize grain yield losses 36.9 % and 49.5% and there have been extensively disseminated through severe outbreaks every year, particularly in the warm and humid areas of the country (Tilahun *et al.*, 2012; Negash, 2013).

The potential threat of GLS to maize production was started and identified with a survey carried out during the year 1997-1998 to know the distribution and importance of the disease in most maize growing regions of Ethiopia (Wegary *et al.*, 2001). 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. Currently, GLS, caused by *Cercospora zeaemaydis*, is among the major maize foliar disease in South and Southwest Ethiopia (Nega *et al.*, 2016).

In Ethiopia, Wegary *et al.* (2004) reported that yield loss due to GLS on resistant, moderately resistant and susceptible varieties was between 0-14.9%, 13.7-18.3%, and 20.8-36.9% respectively during 2003/2004 cropping seasons at Bako areas. Similarly, the research carried out at South Ethiopia in the year 2004-2006 showed that the yield loss due to GLS is 29.5% (Tilahun *et al.*, 2012).

The survey study showed that the highest GLS prevalence, incidence and severity were 74%, 71.2% and 45.13% respectively in South and Southwest Ethiopia. Similarly, morphological characterization of GLS isolates were carried out and 10 different isolates were identified (Nega *et al.*, 2016). Therefore, this study showed the importance of the pathogen distribution and diversity of the isolates in the country. Even though Western Oromia is a potential to produce maize crop, importance of the pathogen is not assessed and determined to take a measure.

Studies have been conducted on major foliar diseases of maize since late 1990's in the western part of the country (Wegary *et al.*, 2001). However, it was little indicated specifically for GLS and no updated information on the distribution and disease intensity, on its distribution map in the study area. Therefore, the objective of this study was to assess the distribution and importance of maize Grey leaf spot in West Oromia, Ethiopia.

Survey of Grey Leaf Spot of Maize

Description of the Survey Area

The survey covered the most important maize growing zones of West-Shewa, East Wollega and West-Wollega Zone of Oromia Regional administration which covered 9 districts namely Dano Ilu-Gelan, Bako-Tibe, Gobu-Seyo, Sibul-Sire, Leka-Dulecha, Gimbi, Lalo-Asabi, Ayra-Guliso and a total of 27 PAs each district having 3 PAs (Table 1). Similarly, agro-ecology of the study area was also summarized below in Table 1.

Sampling and Sampling Techniques

Purposive multistage sampling method was used to reach the Peasant Associations (PAs). Potential districts were selected with in collaboration with Zonal experts, whereas particular PAs were selected with experts from each district based on the potential to produce maize crop and accessibility. Maize fields were selected through random sampling technique with frequent stopping at 3-5 km intervals depending on the variability of fields in terms of altitude and cropping systems (Kinyua *et al.*, 2010). The survey route followed major roads and accessible roadside to towns and localities in each zone and district across different altitude. Five representative maize leaf samples with symptoms recognized as those of GLS (principally, pale brown or grey to tan, long narrow streaks that become dark, grayish-brown rectangular lesions as the disease develops) per field were collected along the survey routes. A total of 81 fields were assessed from 27 PAs 3 farms from each PAs and 155 leaf samples were collected from 31 fields those revealed GLS disease symptom.

Samples were air dried and kept in a pressing board after covered with newspaper in the form of the herbarium. Information like Zone, district, PAs, sample code, farm number, name of the collector, date of collection, were written on the label paper and attached to the margin of folded newspaper used to cover the leaves sample (Lyimo *et al.*, 2013). Samples were transported to Jimma University Plant Pathology Laboratory and kept in a refrigerator at 4°C for further isolation and identification.

Disease Assessment

For the assessment of disease incidence and severity, the fields were selected randomly, and the incidence and severity of GLS on maize plants were assessed. A total of 30 plants per field were assessed by visual scale

moving in "W" pattern in the field (Cardwell *et al.*, 1997). Severity of GLS on maize leaf was assessed by using a 1-5 visual disease rating scales in all fields, where: 1 = no symptoms (Very slight to slight infection, one or two to few Scattered lesions on lower leaves); 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 leaves, 4=severe lesion development on all but the uppermost leaves, which may have a few lesions; and 5 = all leaves dead (Maroof *et al.*, 1993).

Data Collection

Disease Incidence

During the field survey, incidences, visual scale of severity, information of the field such as GPS readings (Altitude, Latitude, and Longitude) were recorded. Additionally, farming practices, maize varieties, previous cropping history, like were recorded through visual observation and by interviewing the farmers.

Disease incidence was computed as a percentage of infected maize plants out of total maize plants in the sample plot shown as follow:

$$\text{Disease Incidence (\%)} = \frac{\text{Number of diseased plants}}{\text{Total Number of Plants inspected}} \times 100$$

Disease Severity

During field survey, data on disease severity were recorded by evaluating the field using 1-5 disease recording scale in all assessed fields of the districts.

The numerical rating was converted to percentage severity index (PSI) using the following equation suggested by Wheeler (1969).

$$\text{PSI} = \frac{\text{Sum of all Numerical rating}}{\text{Total Number of rated plants} \times \text{Maximum disease score on scale}} \times 100$$

Disease Prevalence

The prevalence of the disease was measured by using the number of fields affected divided by a total number of fields assessed and expressed in percentage:

$$\text{Disease Prevalence (\%)} = \frac{\text{Number of infected fields}}{\text{Total number of fields assessed}} \times 100$$

Data analysis

The survey data on incidence and severity index of GLS were analyzed using three-stage nested design by nesting districts in Zone, peasant Association (PAs) within districts and farms within PAs with the following model to see their interaction.

$$y_{ijk} = \mu + \tau_i + \beta_{j(i)} + \gamma_{k(ij)} + \varepsilon_{l(ijk)}$$

Where: y_{ijk} is the GLS disease intensity where peasant association k is nested within district J nested within zone i , μ is the overall mean, τ_i is the effect of the i^{th} zone, $\beta_{j(i)}$ is the effect of the j^{th} district within the i^{th} zone, and $\gamma_{k(ij)}$ is the effect of the k^{th} peasant association within the j^{th} district and i^{th} zone, and $\varepsilon_{l(ijk)}$ is the error term.

Analysis of variance (ANOVA) was performed using SAS V 9.3 statistical (SAS 2010). Means were separated using LSD t-test at significance levels of 0.05. The associations of GLS disease incidence and severity with altitude, maize variety, and previous crop were computed using Pearson correlation analysis. In addition, the current extent and the distribution of Grey leaf spot across West Oromia region were mapped by using Arc GIS software 10.1 from the collected GPS coordinates.

RESULTS AND DISCUSSION

Disease Intensity, Distribution of Maize GLS and effect of different variables

Disease Intensity and prevalence of GLS at Zone level

The study revealed that Grey leaf spot disease was found in all assessed zones of Western-Oromia. Statistically, there was highly significant ($p < 0.001$) difference among districts in terms of maize grey leaf spot incidence and severity. Grey Leaf spot of maize was observed with an incidence ranging from 0–76.67% in West-Shewa zone, 0–80% in East Wollega zone, and 0–70% in West-Wollega zone. The highest mean incidence of Grey leaf spot disease was recorded in East Wollega zone (35.06 %) followed by West-Shewa zone (12.09%). The minimum mean incidence was observed in West Wollega zone with 9.51%. Disease Severity index of Grey leaf spot was

observed to be in the range (0-72%) in west Showa zone, whilst (0-79.67%) in East Wollega and (0-74.84%) in West Wollega zone. The highest mean severity index (31.43%) was recorded in East Wollega Zone followed by West Showa zone having 11.98% severity, whereas the minimum severity index was recorded in West Wollega zone with 10.05% (Table 1).

Grey Leaf Spot disease prevalence across Zones showed significant differences with the highest value in East Wollega Zone with 62.96 % followed by West-Shewa Zone with 29.63% disease prevalence while the lowest was recorded in West Wollega Zone with 22.22% of GLS disease prevalence (Table 1).

Table 1. Mean disease Incidence and Severity of GLS of maize across study zones in 2017

Zone	Prevalence (%)	Mean Incidence	Mean Severity
West Showa	29.63	12.09 ^b	11.98 ^b
East Wollega	62.96	35.06 ^a	31.43 ^a
West Wollega	22.22	9.51 ^b	10.05 ^b
LSD		3.41	1.67
CV (%)		75.4	64.39

LSD= Least significance difference Figures followed by the same letter are not significantly different at 0.05.

Disease Prevalence and Intensity at district level

The highest GLS disease prevalence of 88.9% was found in Leka-Dulecha district followed by Gobu-Seyo district with 66.7% prevalence. Also, the medium prevalence were recorded in Dano, Sibiu-Sire, and Lalo-Asabi with 44.44%, 33.33%, and 33.33%, respectively. On the other hand, less GLS prevalence was recorded in Ilu-Gelan, Gimbi, Ayra-Guliso, and Bako-Tibe districts respectively having 22.2%, 22.2%, 22.2%, and 11%. (Table 2). The variation in the disease prevalence among the districts is due to the variation in agro-ecology. For instance, Leka-Dulecha had the highest altitude range which ranges from (2031–2422 m.a.s.l) which associated with high rainfall and also farming practices enhanced the disease. Other things kept constant, the use of specific maize variety had its own effect as disease prevalence is minimum with shone and Limu maize varieties as compared to others.

The prevalence of high incidence of grey leaf spot in cool humid high-altitude areas had also been reported (Lipps 1995; Asea *et al.* 2005). Incidence ranges of GLS in maize fields were varied from 0–50%, 0–60% and 0–76.7% in Dano, Ilu-Gelan, and Bako-Tibe districts of West-Shewa zone, respectively. Similarly, Gobu-Seyo, Sibiu-Sire and Leka-Dulecha districts of East-Wollega zone had shown incidences that range from 0–80%, 0–46.7% and 0–73.3%, respectively. Also, districts of West-Wollega zone namely Gimbi, Lalo-Asabi, and Ayra-Guliso had an incidence ranging from 0–6.7%, 0–40% and 0–70%, respectively (Table 2).

Moreover, the highest mean incidence of GLS in West-Shewa zone was recorded at Ilu-Gelan with 15.2%, followed by Dano (10.74%), whereas the smallest mean incidence was recorded in Bako-Tibe district with 10.37%. In East-Wollega zone, Gobu-Seyo district had the highest mean incidence of 48.15%, followed by Leka-Dulecha district with 47.77%, whereas the minimum mean incidence was recorded in Sibiu-Sire district with 9.26%. Similarly, in West-Wollega, the highest mean incidence of 17.41% was recorded in Ayra-Guliso followed by Lalo-Asabi (10%), but the minimum mean incidence of 1.11 % was found in Gimbi district (Table 2). The difference in disease intensity and prevalence among zones and districts could be due to the differences in environmental factors (altitude, temperature, humidity), and farming practices at the study area.

Those districts with comparatively high disease incidence and severity index were practicing monoculture under high relative humidity. For instance, in Leka Dulecha and Gobu-Seyo the farmers were mainly practicing using BH660 maize variety which is relatively with high disease intensity. On the other hand, in Ilu-Gelan and Bako-Tibe farmers were mainly practicing using Shone and Limu maize varieties. De Nazareno *et al.*, (1993) also reported that when the weather conditions were favorable for the development of the disease, there was a significant positive relationship between the relative humidity and disease severity.

Disease Severity index of Grey leaf spot was observed with a range of 0 – 72% in West-Shewa zone, 0–79.67% in East-Wollega and 0–74.84% in West-Wollega zone. The highest mean severity index was recorded in East-Wollega zone with 31.43% followed by West-Shewa zone having 11.98%, whereas the minimum severity index was recorded in West-Wollega zone with 10.05% (Table 4). The range of disease Severity of Grey Leaf Spot of Maize was varied from 0–65%, 0–57.5%, 0–72.8% in Dano, Ilu-Gelan Bako-Tibe districts of West-Shewa zone, respectively, whereas in Gobu-Seyo, Sibiu-Sire, and Leka-Dulecha of East-Wollega zone it varied from 0–79.7%, 0–48.3%, and 0–74.8%, respectively. Similarly, in West-Wollega zone, Gimbi, Lalo-Asabi, and Ayra-Guliso districts disease severity ranges from 0–8%, 0–48% and 0–74.9%, respectively (Table 2).

The highest mean disease severity of Grey Leaf Spot in West-Shewa zone was recorded at Dano with 16.33% value followed by Ilu-Gelan with 12.00% whereas the smallest mean incidence was recorded in Bako-Tibe district with 7.59%. In East-Wollega zone Leka-Dulecha district the mean GLS disease severity was the

highest with 46.11% followed by Gobu-Seyo with mean severity value of 39.15%, whereas the minimum disease severity was recorded in Sibü-Sire district with 9.37%.

Similarly, the highest mean severity index in West-Wollega zone was recorded in Ayra-Guliso with 16.68% followed by Lalo-Asabi with 11.75% whereas severity the minimum value in Gimbi district with 1.78 % (Table 2). Also percent of disease severity index of the districts were showed on (Figure 1) with their respective level. Accordingly, Leka-Dulecha and Gobu-Seyo districts were grouped under high severity index, whereas Dano, Ilu-Gelan, Lalo-Asabi and Ayra-Guliso were under moderate severity index. On the other hand, Bako-Tibe, Sibü-Sire and Gimbi districts were under lower disease severity index (Figure. 1).

Those districts with maximum disease incidence and severity index had relatively high relative humidity, less crop rotation, and use of susceptible maize varieties as compared to those districts recorded with the minimum. Results from 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 susceptible varieties (Tadesse, 2008). Survey of maize diseases in Western and Northwestern Ethiopia by Tefferi (1999) showed that disease incidence and severity were relatively high. Similarly, 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 (Perkins *et al.*, 1995).

All of the surveyed districts had shown severity ranges from mild to moderately severe grey leaf spot infection indicating the potential of the disease in hindering maize productivity. Agro-ecology of the assessed areas was conducive to the current disease prevalence and intensity. Comparatively warm temperature and high rainfall could give rise to high relative humidity which results in a conducive environment for the pathogen epidemic and enhance disease intensity. Reportedly, warm temperature, well-distributed rainfall, and high relative humidity are weather conditions favoring this disease development (Beckman and Payne 1983).

Table 2. Disease Prevalence, incidence and Severity index of Grey Leaf spot across the study area in 2017

Districts	Altitude Range	Prevalence (%)	D I (%)		SI (%)	
			Range	Mean	Range	Mean
Dano	1630 – 2131	44.44	0-50	10.74 ^{cd}	0-65.0	16.33 ^{cd}
Ilu-Gelan	1685 – 1923	22.22	0-60	15.19 ^{bc}	0-57.5	12.00 ^{cde}
Bako-Tibe	1657 – 1900	11.11	0-76.7	10.37 ^{cd}	0-72.8	7.59 ^e
Gobu-Seyo	1646 – 1959	66.67	0-80	48.15 ^a	0-79.7	39.15 ^b
Sibü-Sire	1668 – 1983	33.33	0-46.7	9.26 ^d	0-48.3	9.37 ^e
Leka-Dulecha	2031 – 2422	88.89	0-73.3	47.77 ^a	0-74.8	46.11 ^a
Gimbi	1846 – 1920	22.22	0-6.7	1.11 ^e	0-8.00	1.78 ^e
Lalo-Asabi	1550 – 1852	33.33	0-40	10.00 ^{cd}	0-48.0	11.70 ^{de}
Ayra-Guliso	1543 – 1631	22.22	0-70	17.41 ^b	0-74.9	16.68 ^c
LSD (0.05)				5.91		4.76
CV				74.43		64.39

LSD=Least significant difference DI=disease incidence SI=severity index CV=coefficient of variance

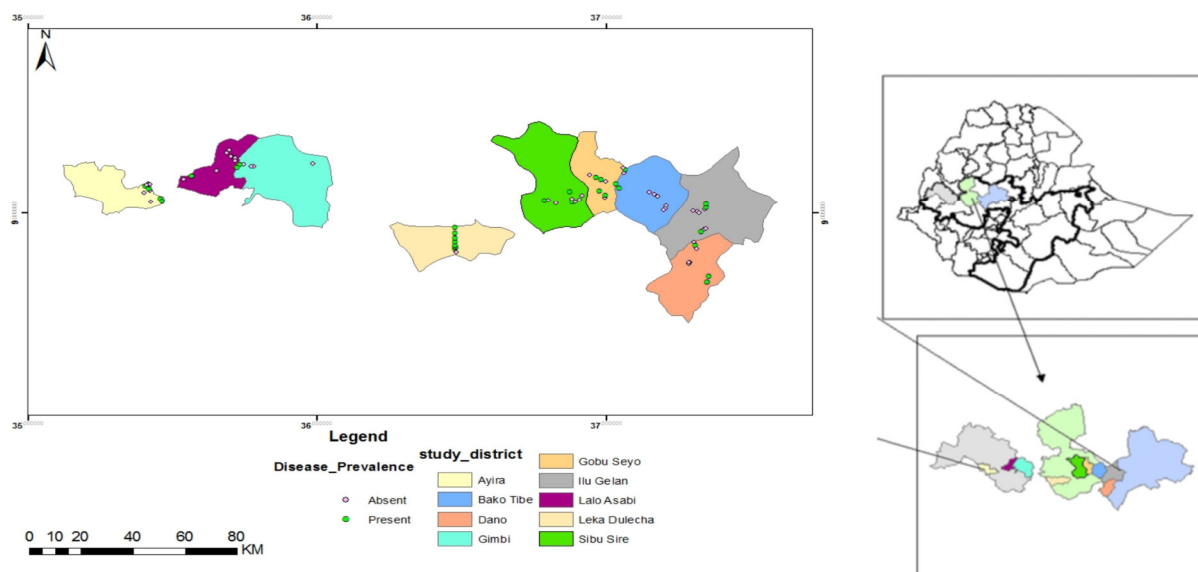


Fig: 1 GLS distribution across districts in zones

Effects of different practices on disease incidence and severity of GLS

Effect of Farming Practices

The highest disease incidence and severity index was recorded on monoculture farming practices with 35.00% and 47.50%, respectively, followed by intercropping having 20.80% and 21.26% respectively. The minimum disease incidence and severity index was recorded in fallow practice with (0.00%) for both (Table 3). The increase in disease intensity on monoculture practice was due to the high inoculums developed in the field year after year whereas the decrease of the disease intensity in the rotation and fallow practices were due to maize is the only host crop this fungus is known to attack. Grey leaf spot of maize is known to be pathogenic only to maize; rotation of the non-host crop for two years can reduce the disease inoculums effectively (Latterell and Rossi, 1983). 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 (Agrios, 2005). Similarly, mixed or intercropping also important in disease intensity because it hinders air circulation inside the crop field which helps to increase relative humidity and favors disease development (Wolf, 2002; Dhama *et al.*, 2015).

Table 3. Mean of disease incidence and severity index across farming practices

Variable	Class	Incidence (%)	Severity Index (%)
Farming Practice	Monoculture	35.00 ^a	47.50 ^a
	Intercrop	20.80 ^{ab}	21.26 ^b
	Rotation	11.33 ^b	12.36 ^b
	fallow	0.00 ^b	0.00 ^b
LSD		22.05	21.76

LSD=Least significant difference Figures followed by the same letter are not significantly different

4.1.3.2. Effect of Maize Varieties

During the assessment, there were about nine hybrids and one local maize variety grown over the surveyed districts. Accordingly, Limu variety had the highest coverage with 35.80% followed by BH661 variety having 30.86% of the total assessed farms. Shone and BH660 with 14.81% and 9.88% had the medium coverage, whereas BH140, BH543, BH545, BH546 and Local maize varieties with 1.23% each, had the minimum coverage under the surveyed districts (Table 4). The highest disease incidence and severity index was recorded on BH545 (70% and 79.67%), BH546 (80% and 68%), BH540 (63.33% and 61.07%), BH140 (76.67% and 73.67%) and local maize varieties with (70 and 74.87%), respectively. On the other, the minimum disease incidence and severity index were recorded on Limu with (2.29% and 2.77%), respectively (Table 4). This result implies that there is a great variation among maize varieties in reaction to the pathogen which could be due to genetic variation within varieties. Increased incidence of GLS has been associated with the continuous cultivation of maize, and use of susceptible maize cultivars (Gevers *et al.*, 1994; De Nazareno *et al.*, 1993; Wegary *et al.*, 2008). The responses of some commercial varieties were showed different resistance and susceptibility level among different maize hybrids (Wegary *et al.*, 2004; Ward *et al.*, 1996). Similarly, according to field survey report, Tefferi (1999) of all released hybrid maize, only BH-660, and PHB-30H83 were found relatively tolerant to grey leaf spot.

Table 4. Mean of DI and DSI of GLS across assessed maize varieties.

Maize Variety	Farm (%) ^a	DI (%)	DSI (%)
Limu	35.80	2.29 ^d	2.77 ^d
BH660	30.86	26.67 ^{cb}	27.52 ^{bc}
Shone	14.81	10.30 ^{cd}	10.12 ^{cd}
BH661	9.88	13.75 ^{cbd}	19.13 ^{cd}
BH540	2.47	63.33 ^a	61.07 ^a
BH543	1.23	33.33 ^b	39.33 ^b
BH545	1.23	70.00 ^a	79.67 ^a
BH546	1.23	80.00 ^a	68.00 ^a
BH140	1.23	76.67 ^a	73.67 ^a
Local	1.23	70.00 ^a	74.87 ^a
LSD (0.05)		19.9	20

DI=disease incidence DSI=severity index BH=Bako Hybrid ^a=of total farms assessed Figures followed by the same letter are not significantly different at 0.05.

Effect of Previous crop history

In surveyed districts majority of the farmers (51.85%) grow maize after maize and 14.81% grow maize after pepper and 12.35% grow maize after teff whereas 4.94% and 3.70% of the farmers grow sorghum and Common bean, respectively. Similarly, Noug and fallow, each had (2.47%) whereas potato and wheat, (4.96% & 2.63%)

in the previous cropping history. The highest disease incidence and severity index was recorded on rotation maize after maize cropping history with (40% and 45.4%) whilst the minimum incidence and severity index were recorded on maize grown after potato, Noug, and fallow each account 0% (Table 5).

The highest result in disease intensity on rotating maize after maize could be due to increase in the amount of inoculum in the field year after year, whereas growing maize after non-host crops to GLS, like Potato, Noug and fallow were showed the lowest disease intensity. On some of the non-host crops like pepper and C. bean GLS incidence and severity were shown high in relation to fallow and Noug. This implies that the pathogen may over winter in maize residue if not properly removed and decomposed. Therefore, it is better to completely remove maize residue and/or deep ploughed to improve the decomposition residue effectively.

Increased incidence of GLS in Africa has been associated with cultural practices such as reduced tillage, continuous cultivation of maize, and use of susceptible maize cultivars (Gevers *et al.*, 1994). Smith, (1989); Ward, (1996) also reported the deficiency of mineral nutrients required by the pathogen may have a potential role in GLS epidemics. Similarly, maize is the only host crop this fungus is known to attack, therefore, rotation with non-host crop Soybean and potato can reduce the disease inoculums effectively (Lipps, 1998; Wolf, 2002; Dhama *et al.*, 2015).

Table 5. Mean of disease incidence and severity index of GLS across assessed previous crop varieties at study area in 2017

Variables	Class	% of Farms	Incidence (%)	Severity index (%)
Previous Crop ^a	Maize	51.85	40.00 ^a	45.00 ^a
	Teff	12.35	16.67 ^{ab}	20.76 ^{ab}
	Pepper	14.81	19.74 ^{ab}	17.19 ^b
	Sorghum	4.94	24.44 ^{ab}	24.93 ^{ab}
	C. bean	3.70	18.00 ^{ab}	22.87 ^{ab}
	Potato	4.92	0.00 ^b	0.00 ^b
	Fallow	2.40	0.00 ^b	0.00 ^b
	Noug	2.40	0.00 ^b	0.00 ^b
	Wheat	2.63	17.62 ^{ab}	18.53 ^{ab}
LSD			27.37	26.96

LSD = Least significance difference ^a = crop sown before the surveyed maize Figures followed by the same letter are not significantly different at 0.05.

Effect of Altitude

The result from the altitude of the survey area revealed that comparatively the highest disease incidence and disease severity index was recorded at high altitude ranges from 2301-2422 m.a.s.l with 40.00% and 46.30%, respectively. The lowest disease incidence and severity index was recorded at the mid-altitude ranges from 1543-2300 m.a.s.l having 12.8% for both respectively (Table 6). This result implies that the pathogen is more severe on the higher altitude might be due to the higher relative humidity associated with a higher altitude than with the mid-latitudes of the study area. The prevalence of high incidence of grey leaf spot in cool humid high-altitude areas has also been reported by Lipps (1995), whereas the results by Lyimo *et al.* (2013) have shown increasing severity of grey leaf spot in low-altitude warmer areas. Therefore, altitude association with other environmental factors like relative humidity and temperature has its own effect in increasing or decreasing disease intensity.

Table 6. Mean disease incidence and severity index of GLS across the agro-ecology in 2017

Variable	Class	Incidence (%)	Severity Index (%)
Altitude	1543-2300	12.85 ^b	12.87 ^b
	2301-2422	40.00 ^a	46.30 ^a
LSD (0.05)		10.36	10.21

LSD= Least significance difference

The Relationship between Altitude, Variety and GLS Intensity

Pearson correlation analysis indicated that there is highly significant ($P < 0.01$) and strong direct relationship between disease incidence and severity index ($r = 0.98$), Altitude ($r = 0.38$) and maize varieties ($r = 0.58$). Similarly, disease severity index with altitude ($r=0.46$) and maize varieties ($r = 0.58$) had a significant positive and strong correlation (Table.7).

This result indicates that some variables like altitude have a strong correlation with disease incidence and severity index this is due to factors associated with altitude like high rainfall could give rise to high relative humidity which results in high disease intensity. Similarly, warm temperature, well-distributed rainfall, and high relative humidity are weather conditions favoring this disease development (Wheeler, 1969).

Table 7. Pearson correlation association between variety, altitude, GLS incidence, and severity

	Severity.	Altitude.	Maize variety
Incidence	0.98**	0.38**	0.58**
Severity		0.46**	0.58**
Altitude			0.06 ^{ns}
Maize Variety			

ns= non-significant, ** highly significant $p < 0.01$

CONCLUSION

Survey result showed that Grey Leaf spot distributed in most of the surveyed Zones and districts, with a significant variation in incidence and severity index from district to district. Accordingly, the highest disease incidence and severity index was recorded in East Wollega zone followed by West Showa zone. The reason for the variation in incidence and severity among zones and districts could be due to the variation in altitude, maize varieties and cropping practices. From the survey result, the farmers at relatively high disease prevalence and intensity area shall better if use those maize varieties with less severity and practicing crop rotation to minimize disease intensity. Besides, there is a need to develop effective, affordable and sustainable management strategies to reduce the effect of GLS on maize production in the study area. Further study would be required in order to see the trend of disease distribution and importance of maize grey leaf spot disease over seasons, as this study only considered one season data.

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