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Participatory Evaluation of Maize Varieties for the Management of Maize Gray Leaf Spot Disease (*Cercospora zeae maydis*) at Gondar Zuria District, in Northwestern Ethiopia

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Abstract

Gray leaf spot is one of the major constraints of maize production in Ethiopia where warm humid environmental condition is prevailing. A field experiment was conducted in Gondar zuria district of western Ethiopia during 2016/17 and 2017/18 cropping season with the aim to evaluate effective maize varieties for the management of maize gray leaf spot disease. The experiment was laid out in Randomized Complete Block Design (RCBD) in three replications. Nine improved varieties i.e., *SBRH*, *Gibie 2*, *Gibie 3*, *Gibie 3*, *Jibat*, *BH-546*, *SPRH*, *Wonji*, *AMR-852* and one local maize(check) were tested for GLS resistance. The varieties significantly varied and there were showed significant differences at p<0.05 in the overall mean of GLS disease incidence, severity, AUDPC%-day, yield and yield component parameter. Data were analyzed using SAS system version 9.2. The result indicated that the maximum disease incidence and AUDPC%-day value, 58.8% and 214.83%-day, respectively were recorded from local maize, followed by *AMR-852* variety which result of 56.27% and 211.06%-day while the minimum incidence and AUDPC%-day value, 22.7% and 150.49%-day, respectively were recorded from *Gibie 2* variety, followed by *Jibat* variety which result of 24.17% and 152.64%-day. The maximum grain yield of 8611.7 kg/ha was recorded from *Gibie 2* variety while the minimum grain yield of 4542.3 kg/ha was recorded from local maize, followed by *AMR-852* variety which result of 4763.3 kg/ha. The study suggested that variety of *Gibie 2* and *Jibat* were showed minimum grain yield loss which result of negligible and 1.47%, losses, respectively and showed significant reduction of maize GLS incidence, with a corresponding increased grain yield of maize.

Keywords: *Zea mays; Cercospora zeae maydis;* Maize varieties; Area under disease progress curve; Disease incidence; Disease progress rate

Introduction

Maize (*Zea mays L*) is one of the world's most widely cultivated crops, providing food and animal feed as well as being a source of biofuel. In Ethiopia it is grown in the lowlands, the mid altitudes and the highland regions. It is an important field crop in terms of area coverage, production and utilization for food and feed purposes. However, maize varieties mostly grown in the highlands of Ethiopia are local cultivars. They are low yielding, vulnerable to biotic and biotic constraints [1]. Currently the average national yield of maize is very low under small scale farmers of Ethiopia 3.7 t/ha [2]. Foliar diseases of maze are the number one factors in contributing in the reduction of maize production and productivity across the world [1]. Gray leaf spot caused by *Cercospora zeae maydis* has become one of the major yield-limiting diseases of maize in eastern Africa including Ethiopia [3]. This disease is most severe and damaging when periods of high relative humidity extended occur, resulting from slow-drying dews and prolonged late-season fogs [4]. Increased incidence of gray leaf spot in Ethiopia has been associated with cultural practices such as reduced tillage, continuous cultivation of maize, and use of susceptible maize cultivars [5,6]. Documented yield losses of maize attributed to gray leaf spot vary from 11% to 69% [7], with estimated losses as high as 100% when severe epidemics contributed to loss of photosynthetic area, increased stalk lodging, and premature plant death [8]. The yield losses caused by the disease were estimated to reach 50% for moderately resistant and 65% for susceptible hybrid maize in South Africa [9,10]. In Ethiopia, reported that yield losses due to gray leaf spot on resistant, moderately resistant, and susceptible varieties were between 0%-14.9%, 13.7%-18.3% and 20.8-49.5%, respectively in Bako and its surrounding areas [4,9]. Gray leaf spot was first reported in Ethiopia in 1997 in the border of west Wellega and Ilubabor zones, of western Ethiopia [11]. The survey report showed increased prevalence of gray leaf spot in the major maize producing regions of Western, Southern and Northwestern parts of Ethiopia [9,11]. According to the report, gray leaf spot has become the principal maize disease since 1998 in Ethiopia. In Ethiopia, however no commercial cultivars have been found to be resistant to gray leaf spot, but have identified high yielding hybrids that are less susceptible to the disease [3]. However, presently gray leaf spot is becoming one of the major constraints of maize production in Ethiopia, genetic resistance is the most economic and effective means of reducing yield losses caused by this disease [3,12]. In view of its expansion, seriousness, and potential destructiveness of this disease, it is necessary to develop resistant genotypes for resource poor farmers. Therefore, the main objective of this study was to evaluate the effective maize varieties resistance against maize gray leaf spot disease.

Materials and Methods

Description of the study area

The experiment was conducted at Gondar zuria district, in central Gondar Zone, Amhara National Regional State, Ethiopia during the main cropping season (May to November) for two consecutive years in 2016/17 and 2017/18. The experimental site located in the geographical location of between longitude 37°- 48° E to W and latitudes 12°-24° N to S. The experimental site lies at an altitude of about 2380 m.a.s.l and

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the mean annual rainfall is 992.5 mm. The soil type of the study area is black vertisoil according to FAO/UNESCO soil classification, and characterized with 5.5 pH. The soil is deep-weathered, well drained and slightly acidic in reaction. The average annual maximum and minimum temperature are 28.5°C and 13.5°C respectively [13].

Treatment and experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The size of the experimental plot was 4.5 m × 2.5 m (11.25 m^2) with six rows in which four central rows were used for data collection. The path between plots and blocks

Variety	Incidence (%)	Severity (1-5 scale)	AUDPC (%-day)	Disease progress rate
Local	58.80^{a}	2.47 (49.4)^{a}	214.83^{a}	0.0862
AMR-852	56.27^{a}	2.41 (48.2)^{a}	211.06^{a}	0.0844
Agrene	50.23^{b}	2.28 (45.6)^{b}	184.09^{b}	0.0715
Gibie 3	47.70^{b}	2.27 (45.4)^{b}	181.52^{b}	0.0701
SPRH	43.50^{c}	2.03 (40.6)^{c}	167.73^{c}	0.0655
Wonji	39.77^{d}	2.02 (40.4)^{c}	175.85^{d}	0.0689
Hora	35.47^{e}	1.72 (34.4)^{e}	162.49^{e}	0.0368
SBRH	32.90^{e}	1.68 (33.6)^{e}	166.76^{c}	0.0625
BH-546	25.57^{f}	1.66 (33.2)^{e}	154.52^{f}	0.0368
Jibat	24.17^{f}	1.06 (21.2)^{f}	152.64^{f}	0.0349
Gibie 2	22.70^{f}	1.02 (20.4)^{f}	150.49^{f}	0.0315
LSD (5%)	2.956	0.164	4.231	NS
CV (%)	7.39	8.15	7.43	3.67

LSD=Least Significant Difference; CV=Coefficient of Variation; NS=Non-Significant; AUDPC=Area Under Disease Progress Curve.
Means followed by the same letter didn't show significant different at p<0.05 according to least significant difference.

Table 1: Main effect of maize varieties on gray leaf spot incidence, severity, and area under disease progress curve (AUDPC) and gray leaf spot disease progress rate.

Variety	Ear length (cm)	Ear diameter (cm)	Stand count (N)
Local	16.62^{a}	15.65^{a}	76.67
AMR-852	18.35^{b}	16.92^{abc}	77.33
Agrene	18.44^{b}	16.45^{ab}	78.33
Gibie 3	19.94^{cd}	18.18^{c}	74.00
SPRH	19.95^{cd}	16.42^{ab}	77.33
Wonji	20.65^{d}	20.95^{d}	75.67
Hora	18.95^{bc}	19.67^{d}	76.33
SBRH	20.59^{d}	17.11^{bc}	77.33
BH-546	23.89^{e}	24.38^{e}	78.33
Jibat	24.59^{ef}	24.82^{e}	81.33
Gibie 2	25.28^{f}	26.48^{f}	80.67
LSD (5%)	1.007	1.438	NS
CV (%)	8.63	8.02	4.52

LSD=Least Significant Difference; CV=Coefficient of Variation; NS=Non-significant.
Means followed by the same letter didn't show significant different at p<0.05 according to least significant difference.

Table 2: Main effects of maize varieties on ear length, ear diameter and stand count at harvest.

Variety	Grain yield (Kg/ha)	Relative grain yield loss (%)	Thousand kernel weight (g)	Relative thousand kernel weight loss (%)
Local	4542.30^{a}	47.25	245.64^{a}	42.96
AMR-852	4763.30^{a}	44.69	251.74^{a}	41.54
Agrene	5753.00^{b}	33.19	389.10^{b}	9.64
Gibie 3	5859.00b^{c}	31.96	391.32^{bc}	9.12
SPRH	7045.00^{d}	18.19	397.11^{cd}	7.78
Wonji	6086.00^{c}	29.33	403.52^{de}	6.29
Hora	7358.30^{e}	14.55	406.04^{e}	5.71
SBRH	7207.00^{de}	16.31	410.87^{e}	4.58
BH-546	8120.70^{f}	5.70	422.27^{f}	1.94
Jibat	8485.00^{g}	1.47	425.42f^{g}	1.21
Gibie 2	8611.70^{g}	0.00	430.61^{g}	0.00
LSD (5%)	231.201		7.801	
CV (%)	7.85		9.34	

LSD=Least significant difference; C=Coefficient of variation.
Means followed by the same letter didn't show significant different at p<0.05 according to least significant difference.

Table 3: Main effect of maize varieties on grain yield, thousand kernel weight and their corresponding grain yield losses and thousand kernel weight losses due to maize grey leaf spot.

were 1m and 1.5m, respectively. The seeds were planted at spacing of 25 cm between plant and 75 cm between rows. Nine improved maize varieties, i.e., *SBRH, Gibie 2, Gibie 3, Argene, Jibat, BH-546, SPRH, Wonji, AMR-852* and one local variety (check) were obtained from the Ethiopian National Maize Research Co-ordination Center, Bako and International Maize and Wheat Improvement Centre (CIMMYT) and used for this study to develop gray leaf spot resistant: Date of plating was the same for all trials. Planting was made at same seed rate. 100 kg/ha DAP were applied at planting time. Weeding and other agronomic practices were carried out as per recommendations.

Disease development

Appearance of the natural occurrence disease in the experimental plots was inspected 10 times every 7 days. Initial scoring for disease incidence was done when lesions were visible on the three to five basal leaves of the plants. Numbers of plants infected in the four middle rows were recorded and their means were converted into percentage as the total plant observation.

Disease incidence on each plot was calculated on the following way:

$$DI\ (\%) = \frac{\text{Number of plant that appear symptoms}}{\text{Both number of disease infected and healthy plants}} \times 100$$

Disease severity was recorded on ten randomly tagged plants per plot. It was assessed as the percentage of the total leaf surface covered with gray leaf spot lesions on each expanded leaflet separately at regular intervals using a 1-5 standard disease scoring scale recommended by Roane [14]. Where 1=No lesions; 2=Lesions on some plants, usually not visible; 3=A few scattered lesions, usually seen only after careful examination; 4=Lesions and defoliation on some plants, not damaging and 5=Abundant lesion on all leaves with most of leave tissue being necrotic. Area under progress curve (AUDPC) was calculated for each treatment from the assessment of disease incidence using the formula:

$$AUDPC = \sum_{i-1}^{n-1} 0.5(xi+1+xi)(ti+1-ti)$$

Where, xi is the cumulative disease severity expressed as a proportion at the ith observation, ti is the time (days after sowing) at the i^{th} observation and n is total number of observations. AUDPC values were expressed in %- days [15]. AUDPC values were used in analysis of variance to compare amount of disease among plots with different treatments. Relative yield losses were calculated separately for each of the treatments with different levels of disease using the formula of Madden [15]

$$\%\ RYL = \frac{Y1-Y2}{Y2} \times 100$$

Where, RYL=Relative yield loss (reduction of the yield and yield component), Y1=the yields which was obtained from plots with maximum protection) and Y2=the yields which was obtained from plots with minimum protection).

Statistical data analysis

Data on maize gray leaf spot incidence, severity, AUDPC and the various agronomic data collected were subjected to analysis of variance (ANOVA) according to the Duncan Multiple Range Test (DMRT) as suggested by Gomez [16] using SAS software programs and least significance difference (LSD) was used for the mean comparison at 5% probability level.

Results and Discussion

The two consecutive cropping seasons data were analyzed separately, but there were no significant difference among two season outputs in the experiments, so that, the two season data was combined and analyzed together.

Incidence of maize gray leaf spot

The analysis of variance was showed to be significant differences at $p<0.05$ with reaction to gray leaf spot incidence among the main effects of maize varieties. The highest incidence of 58.8% and 56.27% were recorded from local (check) and *AMR-852* improved maize variety, respectively while the lowest incidence of 22.7%, 24.17% and 25.57% were recorded from *Gibie 2*, *Jibat* and *BH-546* maize varieties, respectively (Table 1). The hybrid varieties used in this experiment reacted differently with regards to the onset of gray leaf spot epidemics. The result agrees with the work of Bakeko [3] in which differential response of these varieties to gray leaf spot was reported.

Severity of maize gray leaf spot

The analysis of variance on gray leaf spot severity was showed significant difference at $p<0.05$ among the main effects of maize varieties. The highest gray leaf spot severity were recorded from local maize (check) and *AMR-852* hybrid variety which result of 2.47 (49.4%) and 2.41 (48.2%), respectively that were not showed significant different whereas the lowest gray leaf spot severity were recorded from *Gibie 2* and *Jibat* varieties which result of 1.02 (20.4%) and 1.06 (21.2%), respectively and that were not showed significant different (Table 1).

Area under Disease Progress Curve (AUDPC)

Area under the disease progress curve (AUDPC) showed significant difference at $p < 0.05$ among the main effects of maize hybrid varieties. The analysis of variance revealed that the highest AUDPC%-days of 214.83%-days and 211.06%-days were calculated from local maize (check) and *AMR-852* hybrid variety, respectively and that were not showed significant different (Table 1) whereas the lowest AUDPC%-days of 150.49%-days was calculated from *Gibie 2* variety, followed by *Jibat* and *BH-546* varieties which result of 152.64%-days and 154.52-days, respectively and that were not showed significant different (Table 1). Previous works at Bako indicated genotypes considered as susceptible variety had AUDPC values more than resistant genotypes [12]. There was gray leaf spot pressure on the susceptible local maize and high inoculum pressure had major influence on disease development and reproduction in conformity with the findings of Madden [15].

Gray leaf spot disease progress rate

Disease progress rates were calculated from the data taken seven days after gray leaf spot disease symptom development and did not exhibited significant difference at $p<0.05$ among the main effects of maize varieties. The faster gray leaf spot disease infection rate progressed rapidly on the susceptible local maize and *AMR-852* variety varied from 0.0862 to 0.0844 units-day, respectively while slowest infection rate of 0.0315 units-day was recorded from *Gibie 2*, followed by *Jibat* and *BH-546* maize varieties which result of 0.0349 and 0.0368 units-day, respectively (Table 1). Disease progress rates of the resistant varieties, namely *Gibie 2*, *Jibat*, *BH-546* and *Hora* showed little increase in rate starting from the time of disease onset onwards, whereas the susceptible varieties local maize (check) and *AMR-852* showed variability in disease progress rates from time to time, i.e. progress rate increased over time. The use of genetically resistant maize varieties is the preferred means of controlling gray leaf spot [12] (Table 1).

Maize ear length, ear diameter and stand count

The analysis of variance for ear length and ear diameter showed significant difference at $p < 0.05$ among the main effect of maize varieties. The longest ear length (25.28 cm) was recorded in *Gibie 2*, which is not significantly different from *Jibat* variety but the shortest ear length (16.62 cm) was recorded in local maize (check), followed by *AMR-852* and *Argene* maize varieties (Table 2). On the other hand the thicker ear diameter (26.48 cm) was recorded in *Gibie 2* while the thinner (15.65 cm) ear diameter was recorded in local maize, which is not significantly different from *AMR-852* and *Argene* maize varieties. The result of analysis of variance indicated that there was no-significant difference among the treatments on the stand count of maize due to main effect of maize varieties. The stand count at harvest across the treatments ranged from 80.67 to 76.67 plants of maize per plot. This is because gray leaf spot did not predispose to stalk rots, resulting in no lodging (Table 2).

Grain yield and thousand-kernel weight of maize

The analysis of variance for grain yield and thousand-kernel weight showed significant difference at $p<0.05$ among the main effect of maize varieties. The variation in mean grain yield between the tested varieties was attributed to their genetic potential for yield and disease resistance. Accordingly, the maximum grain yield of 8611.7 kg/ha was obtained from *Gibie 2* hybrid variety, followed by *Jibat* which resulted in grain yield of 8485.0 kg/ha while the minimum grain yields of 4542.3 kg/ha and 4763.3 kg/ha were recorded from local maize and ARM-852 variety, respectively (Table 3). On the other hand analysis of variance also showed that thousand-kernel weight was significantly affected by maize varieties at $p<0.05$. Among the main effect the maximum thousand-kernel weight of 430.61g was obtained from *Gibie 2* maize variety, followed by *Jibat* which resulted of 425.42 g. Whereas the minimum thousand-kernel weight of 245.64 g was recorded from local maize. However, it was not significantly different with *AMR-852* maize variety which result of 245.64 g (Table 3).

Losses in grain yield and thousand-kernel weight of maize

In all maize varieties grown under the same condition the highest grain yield losses of 47.25% was recorded in local maize (check), followed by *AMR-852* maize variety which resulted in grain yield losses of 44.69% while the lowest grain yield losses was obtained from *Gibie 2* which result of negligible losses, followed by *Jibat* and *BH-546* maize varieties which results of 1.4% and 5.7%, respectively (Table 3). This result agrees with the finding of Stromberg [17] who reported reduction in grain yield due to increased disease pressure that was associated principally with increased blighting and premature death of photosynthetic tissues prior to grain filling. A loss in thousand-kernel weight was highest for local maize (check) and *AMR-852* maize variety which results of 42.96% and 41.54%, respectively while the lowest thousand-kernel weight losses were obtained from *Gibie 2*, *Jibat*, *BH-546* and *SBRH* maize varieties which result of insignificant losses, 1.21%, 1.94% and 4.58%, respectively (Table 3). This result also agrees with the findings of Tilahun [3,12,18] who reported that the premature death of the tissues seriously restricted the accumulation of photosynthesis in the developing maize kernels.

Conclusion

The present study suggested that application of resistance varieties results in reduced gray leaf spot disease incidence, and loss of grain yield and thousand kernels weigh, with a correspondingly increased total grain yield and thousand kernel weigh. Based on the findings of this study, gray leaf spot is an important disease that calls for better attention in maize producing area in terms of economic management with resistant varieties. Based on collected data analysis varieties *Gibie 2*, *Jibat* and *BH-546* showed best performance resistance to maize gray leaf spot disease incidence and gave better grain yield.

Conflict of Interests

The authors have not declared any conflict of interests.

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