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Assessment of Yield Loss and Determination of Optimum Planting Date for the Control of Gray Leaf Spot on Maize (*Zea mays* L.) in South Ethiopia

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ABSTRACT

Maize (*Zea mays* L.) is one of the most important strategic crops selected for food security mainly due to its high productivity and wider adaptability in Ethiopia. In recent years, gray leaf spot (GLS) has become a serious disease in different parts of the country. However, no research activity has been carried out to determine the role of planting date on the control of GLS. Therefore, the objectives of this study were to assess the damage and yield loss due to GLS and to identify and determine the optimum plating date of maize for the control of GLS. The experiment was carried out at Areka and Billito, Southern Ethiopia which are GLS hotspots during the 2004-2006 main cropping seasons. Fungicide treatment as the main plot and planting dates as the subplot treatment were arranged in a split plot design and replicated four times. The result of this experiment shows that there were significant differences among planting dates, fungicide spray, years and locations. Analysis of variance carried out across years at Areka and Billito indicated that there were statistically significant differences among planting dates for severity, upper ear leaf infestation, number of cobs harvested, number of diseased cobs, ear length, ear diameter, grain yield and 1000-kernel weight. The highest grain yield (8.12 and 9.09 t ha^{-1}) was recorded from plantings on March 17 and April 18 at Areka and Billito, respectively. Planting on March 27 and April 18 increased yield by 55.5 and 43.0% more than maize planted on April 17 and May 18 at Areka and Billito, respectively. The highest grain yield (8.61 t ha^{-1}) was recorded in plots sprayed with fungicide at Billito while the least was recorded in unsprayed plots (6.3 t ha^{-1}) at Areka. The yield loss due to late planting was 29.5% more than early planting.

Keywords: Areka, Billito, GLS, planting date, severity

INTRODUCTION

Maize is the second most important cereal crop after *teff* (*Eragrostis teff*: annual grass crop harvested for grain in Ethiopia) in terms of area coverage. In 2010, it was produced on 2.0 million ha of land which covers about 20% of all the land allotted to cereal production in the main season (CSA 2010). Even though improved maize cultivars have been included in the national extension package, the national average yield of maize is only 2.5 ton ha^{-1} (CSA 2010), which is far below the world average (3.8 ton ha^{-1}) (Dowswell *et al.* 1996). The low yield is attributed to a combination of several constraints among which diseases play a major role. Maize disease surveys have been carried out in different parts of Ethiopia (Assefa and Tewabech 1993; Tewabech *et al*. 2001) and the major diseases identified were gray leaf spot (GLS), Turcicum leaf blight (TLB), common leaf rust (CR) and *Maize streak virus* (MSV).

GLS caused by *Cercospora zeae maydis* Tehon and Daniels (1925) has been recognized as one of the most yield-limiting diseases of maize worldwide. Ward (1996) and Lipps *et al*. (1996) reported that GLS poses a serious threat to maize in the major production areas of the USA and Africa. This disease, which causes severe lesions leading to defoliation and drying up of leaves, has the tendency to spread over a wide distance within a short time unless closely monitored. Ward *et al*. (1999) estimated the rate of spread to be 80-160 km $year^{-1}$.

GLS, which has a recent history of occurrence in Ethiopia, has become the most important threat to maize production (Asefa and Tewabech 1993; Dagne *et al*. 2001; Tewabech *et al*. 2001). Results of various surveys conducted in most maize-growing regions of the country indicated that the disease is widely distributed and is considered to have a significant impact in reducing maize yield of both local and improved varieties (Tewabech *et al*. 2001).

The extent of damage is dependent on hybrid and on environmental conditions (Ward *et al*. 1999; Dagne *et al*. 2001). Increased incidence of GLS in Africa has been associated with continuous cultivation of maize, and use of susceptible maize cultivars (De Nazareno *et al*. 1993; Gevers *et al*. 1994). A study conducted in Ethiopia for three years on three commercial varieties, BH-660, BH-140 and PHB-3253, indicated that grain yield loss ranged from 0 to 36.9% depending on the time of disease onset, disease severity and on maize hybrid's susceptibility and yield potential. This indicates that GLS could be severe in some favorable seasons causing significant yield losses, even on resistant varieties (Dagne *et al*. 2004).

GLS disease epidemics have been managed conventionally through deep tillage to burry previous maize residue, fungicide application, and field hygiene (Ward *et al*. 1997). However, these measures have not been efficient in the management of GLS (Bigirwa *et al*. 2001). High levels of maize residue, moist conditions in the crop canopy, and susceptible hybrids are all factors that can contribute to yield loss caused by this disease. Fungicide application is costly and not practical in most operations for resource-poor farmers. When maize is planted into no-till fields with infested maize residues remaining on the soil surface and environmental conditions are favorable for GLS development, GLS epidemics usually progress faster and reaches

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more damaging levels than in the fields where infected residues are either absent or greatly reduced (De Nazareno *et al.* 1992; Ward *et al.* 1998).

GLS epidemics have been frequently reported from different parts of Ethiopia (Jimma, Illubabor, West Wellega, North Omo and the Sidam zone) in recent years (Dagne *et al.* 2001; Tewabech *et al.* 2001; Dagne *et al.* 2004; Tewabech *et al.* 2011). In view of the expansion, seriousness and potential destructiveness of the disease, a number of research activities that could contribute towards the management of GLS have been initiated. However, no research activity was carried out on planting date for the control of GLS. Therefore, the objectives of this study were to assess the damage and yield loss due to GLS and identify and determine optimum planting date of maize for the control of GLS in southern Ethiopia.

METHODOLOGY

The experiment was carried out at two GLS hotspots of southern Ethiopia, Areka and Billito, during 2004-2006 in the main cropping season. A split plot design with four replications was used in which fungicide spray type was used as the main plot and planting dates as the sub-plot.

Planting dates

Five planting dates with 10-day intervals were set for both locations and years based on the onset of rainfall at each location. Planting dates were fixed based on the recommended planting time for each location (March for Areka and April for Billito). The planting dates in 2004, 2005 and 2006 were 17 March (S_1), 27 March (S_2), 7 April (S_3), 17 April (S_4) and 27 April (S_5) at Areka and similarly 8 April (S_1), 18 April (S_2), 28 April (S_3), 8 May (S_4) and 18 May (S_5) at Billito.

Fungicide application

A systemic fungicide Benlate 50% WP (50% benomyl at a rate of 1000 g active ingredient (a.i) in 200 L of water] was applied to one hectare using a manual knapsack sprayer of 15 L capacity. The fungicide was sprayed 6 times at 10-day intervals starting from the time when GLS symptom was first observed (when mature GLS lesions are readily distinguished from those of other foliar diseases of maize; they are gray to tan in color and are distinctly rectangular in shape, with dimensions ranging from 5 to 70 mm long by 2 to 4 mm wide).

Planting and field management

Moderately GLS tolerant maize variety, 'BH-540', was used for this study at both locations. Each plot had six rows 4.5 m long with a spacing of 75 cm between rows and 30 cm (for Areka) and 25 cm (for Billito) between plants. Two seeds were planted per hill and then thinned to one plant $hill^{-1}$ to have a final plant density of 44,444 and 53,333 plants ha^{-1} for Areka and Billito, respectively. Data were recorded from the four central rows of each plot. Other management practices (frequency of cultivation, weeding) were performed as per research recommendations (three times cultivation and hand weeding) for each location. 46 kg P_2O_5 and 54 kg N was used for Areka while 24 kg P_2O_5 and 44 kg N was used for Billito. All P and one third of the recommended rate of N fertilizers were applied at planting while the remaining two thirds of N were applied as a side dress at 25-35 days after emergence (V5-V8 growth stages) of the crop.

Disease assessment

GLS severity, upper ear leaf infection (number of leaves infested with GLS above the upper most ear) and lesion type were recorded at the late milk stage (90-100 days after planting) of the crop. GLS severity was recorded on a plot basis using a 1-5 scale where 1 = slight infection and 5 = very heavy infected, as described by Roan *et al.* (1974).

Yield and yield component assessments

Grain yield and yield components were recorded for three years 2004-2006. Grain yield and 1000-kernel weight were recorded at 12.5% moisture while ear length and diameter were recorded as the average of 10 randomly selected ears from each experimental unit. Ear aspect was recorded from each plot using a 1-5 scale where 1 = best, i.e., uniform, disease and insect-free ears and regularly arranged kernels in rows while 5 = worst, i.e., non-uniform, highly infested with diseases and insects and irregularly arranged rows on ear. The number of cobs harvested and diseased was a total count of the number of cobs harvested and diseased from each experimental unit, respectively.

Data analysis

The locations where the experiment conducted had different soil type, altitude and mean annual rainfall and were considered to be individual environments. Analysis of variance (ANOVA) for each environment and year was assessed for grain yield and other traits using SAS version 9 computer program (SAS Institute 2002). Bartlett's test was used to assess homogeneity of error variances prior to combine analysis over locations.

Yield loss due to GLS was estimated as the proportion of the difference between mean yields of protected (sprayed) and unprotected (with similar managements to protected except with no application of the fungicide benomyl) plots. It was computed using the formula (Miller 1965):

$$YL(\%) = \frac{YP - YI}{YP} X100$$

where YL = yield loss, YP = yield of protected plot and YI = yield of unprotected plot. Simple Pearson's correlation analysis was applied to study the relationships among yield, yield components and disease parameters.

RESULTS AND DISCUSSION

Continuous production of maize in the same field significantly increases the incidence and severity of GLS. It has been suggested that the increasing incidence of GLS damage, especially in maize belts of the southern region of Ethiopia, is due to the more frequent growth of maize in monoculture systems.

Planting dates

A significant difference was observed among planting dates for disease severity, upper ear leaf infestation, ear aspect, number of cobs harvested, number of diseased cobs, ear length, ear diameter, grain yield and 1000-kernel weights. The highest grain yield (8.60 t ha^{-1}) and ear length (15.78 cm) were recorded from the second planting date (**Table 1**) whereas the lowest grain yield (6.06 t ha^{-1}) was recorded from plots planted late followed by the fourth and the third planting dates (**Table 1**).

The fewest diseased cobs (7.45) and longest ears (15.78 cm) and highest 1000-kernel weight (466.30 g) were recorded from early planting (S_1) while the highest number of diseased cobs harvested (10.83), the shortest ears (14.41 cm) and the lowest 1000-kernel weight (403.09 g) were recorded from late planting (S_5) at both locations (**Table 1**). Plots planted early were less predisposed to ear rot than those planted late. Besides, the plots planted early had well-filled and heavier kernels than those planted late, which had shriveled kernels. This indicates that early planting on March 17 at Areka and April 8 at Billito improve grain yield and quality more than when planted late at both locations. The loss in yield caused by GLS due to late planting of maize was 29.5% higher than values observed in early planting. These values coincide with those of several previous reports from the USA, South Africa and Ethiopia in which yield losses of 10-50% have commonly been reported (Saghai Maroof *et al.* 1993; Gevers *et al.* 1994; Saghai Maroof *et al.* 1996; Ward *et al.* 1997; Dagne *et al.* 2001).

Table 1 Effect of planting date on gray leaf spot severity, yield and yield components of maize at Areka and Billito during 2004-2006 cropping seasons.

Planting date	SEV***	ULINF***	EAS***	CHA***	CDI**	ELE*	EDIA**	Y**	TKW**
1	2.36	4.39	2.04	78.35	7.45	15.78	4.45	8.06	466.30
2	2.48	4.50	2.13	79.33	7.58	15.17	4.28	8.60	465.61
3	2.77	5.02	2.29	81.04	9.40	14.95	4.37	8.04	437.33
4	2.78	5.04	2.63	76.52	10.24	14.67	4.53	6.65	410.83
5	2.85	5.11	2.79	69.17	10.83	14.41	4.33	6.06	403.09
R2	0.90	0.67	0.57	0.77	0.69	0.65	0.69	0.82	0.78
CV	11.93	23.52	27.07	19.06	42.52	14.82	25.37	13.72	15.33
MSE	0.32	1.13	0.64	14.66	3.87	2.22	1.11	1.03	66.94
MEAN	2.65	4.81	2.38	76.88	9.10	14.99	4.39	7.48	436.63

SEV = severity, ULINF = upper ear leaf infestation, EAS = ear aspect, CHA = number of cobs harvested, CDI = number diseased cobs, ELE = ear length (cm), EDIA = ear diameter (cm), Y = gain yield (t ha^{-1}) and TKW = 1000 kernel weight (g).
*, **, *** significant at $P < 0.05$, 0.01 and 0.001, respectively according to DMRT (Duncan Multiple Range Test)

Table 2 Effect of planting date on gray leaf spot severity, yield and yield components of maize at Areka and Billito, Ethiopia during 2004-2006 cropping seasons.

Planting	Billito								Areka							
date	SEV ***	ULINF ***	CHA ***	CDI **	ELE **	EDIA **	Y **	TKW **	SEVE **	ULINF	CHA ***	CDI ***	ELE ***	EDIA	Y ***	TKW ***
1	2.40	4.33	96.42	9.96	15.65	4.19	8.83	439.04	2.29	4.42	70.63	4.46	15.83	4.12	7.38	520
2	2.48	4.50	96.25	9.33	15.79	3.99	9.09	434.75	2.60	4.58	72.50	5.42	16.68	4.02	8.12	523
3	2.58	5.04	99.83	9.67	15.20	4.08	8.75	430.96	2.83	4.83	72.29	8.58	15.67	3.98	7.23	480
4	2.75	5.38	99.13	11.33	15.02	4.28	8.10	390.33	2.92	4.88	63.33	8.63	15.36	3.90	5.22	460
5	2.85	5.46	85.50	13.04	14.05	4.10	6.37	376.75	2.96	4.96	62.88	8.17	15.77	3.97	5.75	458
R2	0.92	0.72	0.83	0.64	0.72	0.63	0.85	0.83	0.90	0.75	0.83	0.73	0.82	0.67	0.85	0.74
CV	12.46	23.49	8.88	37.27	7.00	7.53	9.60	8.07	12.03	20.94	11.86	48.15	6.94	8.04	15.78	6.98
MSE	0.33	1.17	8.48	3.98	1.06	0.32	0.79	33.46	0.33	0.99	8.10	3.39	1.10	0.32	1.06	34.08
MEAN	2.61	4.94	95.43	10.67	15.14	4.13	8.23	414.37	2.72	4.73	68.33	7.05	15.86	4.00	6.74	488.18

SEV = severity, ULINF = upper ear leaf infestation, CHA = number of cobs harvested, CDI = number of diseased cobs, ELE = ear length (cm), EDIA = ear diameter (cm), Y = gain yield (t ha^{-1}), TKW = 1000-kernel weight (g).
*, **, *** significant at $P < 0.05$, 0.01 and 0.001, respectively according to DMRT (Duncan's multiple range test)

ANOVA for each location in **Table 2** shows that there was a significant difference among planting dates for severity of GLS, upper ear leaf infestation by GLS, number of cobs harvested, number of diseased cobs, ear length, ear diameter, grain yield and 1000-kernel weights both at Billito and Areka. At Billito, the highest grain yield (9.09 t ha^{-1}) was recorded from the second planting date (18 April) while the lowest yield (6.37 t ha^{-1}) was recorded from the fifth planting date (18 May). The highest GLS severity of 2.85 and 2.75 and upper ear leaf infestation by GLS 5.56 and 5.38 were recorded at Billito from 18 May and 8 May plantings, respectively. Similarly the highest grain yield (8.12 t ha^{-1}), 1000-kernel weight (523 g) and ear length (16.68 cm) were recorded from early planting (March 17 and 27) while the least grain yield (5.75 t ha^{-1}) and ear length (15.36 cm) were recorded from the late planting (April 17) at Areka (**Table 2**).

Planting on March 27 had 55.5% higher yield than planting on April 17 at Areka while planting on April 18 had 43.0% higher yield than planting on May 18 at Billito (**Table 2**). These results demonstrate the potential for GLS to substantially reduce yield when disease pressure (disease severity) is very high.

An effective GLS disease control program involves the integration of a number of cultural practices, including the selection of optimal planting dates. Growers should consider planting different crops in rotation with maize in their farming system. A one- or two-year rotation away from maize would help reduce the level of *C. zeae maydis* inoculum. Crop rotation is a very powerful disease-control tool. Many common pathogens, including GLS, require the presence of a living host crop for growth and reproduction. Rotating to non-host crops (e.g., soybeans, alfalfa, clovers, and canola) "starves out" these pathogens resulting in a reduction in inoculum levels and the severity of disease. In Ohio, a 3-year rotation of corn, soybean, and wheat is recommended in order to reduce the build-up of surface residue, and consequently, primary inoculum of fungal foliar pathogens such as *C. zeae maydis*, which overwinters best in crop residue left on the soil surface (Donahue *et al.* 1991; Latterrel and Rossi 1983; Ward *et al.* 1999), leading to earlier GLS onset and greater disease intensity in no-till fields than in tilled fields (Payne *et al.* 1987; Meseret and Temam 2008).

The effect of fungicide on GLS

A significant difference was observed between sprayed and unsprayed plots in terms of GLS severity, upper ear leaf infestation, ear length, ear diameter, grain yield and 1000-kernel weights at Billito. The highest grain yield (8.61 t ha^{-1}), 1000-kernel weight (432.87 g), ear diameter (4.21 cm), ear length (15.35 cm) was recorded from plots sprayed with fungicide while the lowest values were observed in unsprayed plots (**Table 3**). The highest disease severity (3.18) and upper ear leaf infestation (5.80) was recorded from unsprayed plots.

Similarly, at Areka, the highest grain yield (7.20 t ha^{-1}), 1000-kernel weight (499.27 g) and number of cobs harvested (70.33) and the least disease severity and upper ear leaf infestation were recorded from the sprayed plot (**Table 3**). This indicates that fungicide spray was able to control GLS infection for crops planted at different dates. The economic benefit of controlling GLS with fungicides in grain-producing fields is still marginal except in high risk areas with significant yield losses each year (Lipps *et al.* 1996). Accurately determining economic thresholds for plant diseases is very difficult because of lack of a reliable relationship between yield reduction and disease severity at a particular time or growth stage and the likelihood of multiple stresses in a given field contributing to yield loss. The probability of yield increase with a fungicide application is higher when more risk-factors (susceptibility of the hybrid, history of disease, and favorable weather conditions) for GLS development are applicable, especially with an expected yield greater than 200 bushels and a high maize price (Rees and Jackson 2008). Late planting dates increase the risk of greater GLS-related problems due to increased fungal inocula available at earlier stages of plant maturity. Therefore, planting dates should be adjusted to the least GLS inoculum load and less infection time combined with a GLS-resistant variety.

Table 3 Effect of fungicide on gray leaf spot severity, yield and yield components of maize planted at Areka and Billito, Ethiopia during 2004-2006 main growing seasons.

		SEV***	ULINF***	LTYP***	STHA	EAS	CHA	CDI	ELE*	EDIA**	Y***	TKW***
Billito	Sprayed	2.04	4.08	2.10	93.00	2.38	96.18	11.07	15.35	4.21	8.61	432.87
	Unsprayed	3.18	5.80	2.60	92.47	2.37	94.67	10.27	14.93	4.05	7.85	395.87
	CV	12.46	23.49	17.57	6.67	27.07	8.88	37.27	7.00	7.53	9.60	8.07
	MEAN	2.61	4.94	2.35	92.73	2.38	95.43	10.67	15.14	4.13	8.23	414.37
Areka	Sprayed	2.11	3.83	2.10	67.65	1.99	70.33	6.87	16.03	4.01	7.20	499.27
	Unsprayed	3.33	5.63	2.62	67.30	2.12	66.32	7.23	15.70	3.98	6.28	477.08
	CV	12.03	20.94	21.09	10.33	19.52	11.86	48.15	6.94	8.04	15.78	6.98
	MEAN	2.72	4.73	2.36	67.48	2.05	68.33	7.05	15.86	4.00	6.74	488.18
Years	2004	2.30	4.73	2.20	93.50	2.63	104.03	13.90	14.58	4.16	8.14	430.80
	2005	2.99	5.35	2.55	94.95	1.95	101.33	9.30	15.76	3.98	8.35	375.00
	2006	2.55	4.75	2.30	89.75	2.55	80.93	8.80	15.08	4.25	8.20	437.30
	CV	12.46	23.49	17.57	6.67	27.07	8.88	37.27	7.00	7.53	9.60	8.07
	MEAN	2.61	4.94	2.38	92.73	2.38	95.43	10.67	15.14	4.13	8.23	414.37

SEV = severity, ULINF = upper ear leaf infestation, LTYP = lesion type, STHA = stand count at harvest, EAS = ear aspect, CHA = number of cobs harvested, CDI = number of diseased cobs, ELE = ear length (cm), EDIA = ear diameter (cm), Y = gain yield (t ha^{-1}), TKW = 1000-kernel weight (g).
*, **, *** significant at *P* < 0.05, 0.01 and 0.001, respectively according to DMRT (Duncan's multiple range test)

Table 4 Correlation among GLS disease severity and agronomic parameters for maize.

	SEV	ULINF	EAS	CHA	CDI	ELE	EDIA	Y	TKW
SEV	1	0.78***	-0.15	0.01	-0.08	0.05	-0.29**	-0.12	-0.39***
ULINF		1	-0.16	0.10	-0.05	-0.04	-0.30***	-0.05	-0.24**
EAS			1	-0.02	0.41***	-0.35***	0.14	-0.22	-0.05
CHA				1	0.23**	0.08	-0.03	0.46***	0.01
CDI					1	-0.25*	0.08	-0.29**	-0.21*
ELE						1	-0.03	0.31***	0.06
EDIA							1	-0.01	0.13
Y								1	0.50***
TKW									1

SEV = severity, ULINF = upper ear leaf infestation, EAS = ear aspect, CHA = number of cobs harvested, CDI = number of diseased cobs, ELE = ear length (cm), EDIA = ear diameter (cm), Y = grain yield (t ha^{-1}), TKW = 1000 kernel weight (g)
*, **, *** significant at *P* < 0.05, 0.01 and 0.001, respectively according to DMRT (Duncan's multiple range test)

Correlation among some agronomic parameters and GLS disease severity

There was a significant positive correlation between disease severity and number of upper leaf infestation (r = 0.78) while a significantly negative correlation with ear diameter (r = -0.29) and 1000-kernel weight (r = 0.39) (**Table 4**). This indicates that as the severity of GLS increases, the weight of the kernels harvested and diameter of the ears decreases. The plumpness of the grain is positively correlated with grain yield. A perusal of the data presented in **Tables 1-3** reveals that sowing date and fungicide treatments were significantly different from one another showing the influence of different times of planting and fungicide application on 1000-kernel weight. **Table 4** also shows that upper leaf infestation had a significantly negative correlation with ear diameter (-0.30) and 1000-kernel weight (-0.24). Grain yield had a significantly positive correlation with number of cobs harvested (0.46), 1000-kernel weight (0.50) and ear length (0.31) while it had a significantly negative correlation with number of diseased cobs (-0.29) (**Table 4**).

CONCLUSIONS

From the results of our study, adjusting the planting date of a maize crop at both study locations has paramount importance by increasing the production and quality of maize grain. Planting maize early on 27 March at Areka and on 18 April at Billito can profoundly increase the yield of maize and decrease the inoculum load at an early stage of crop growth. Since GLS disease management involves an integrated approach, combining a resistant variety (like BH-660) with early planting of maize will be an economical and acceptable method for farmers to decrease the negative impact of GLS on maize production.

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