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 planting 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 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) (Dowsell 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 (Assela 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 (Assefa 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).

GLS disease epidemics have been managed conventionally through deep tillage to bury 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...
more damaging levels than in the fields where infected resi-
dues are either absent or greatly reduced (De Nazareno et al. 1992; Ward et al. 1998).

GLS epidemics have been frequently reported from dif-
ferent 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; Tewa-
bech et al. 2011). In view of the expansion, seriousness and po-
tential destructiveness of the disease, a number of re-
search activities that could contribute towards the manage-
ment 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 crop-
ing 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 loca-
tions 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 (S1), 27
March (S2), 7 April (S3), 17 April (S4) and 27 April (S5) at Areka
and similarly 8 April (S1), 18 April (S2), 28 April (S3), 8 May (S4)
and 18 May (S5) 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 rectangu-
lar 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 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 cultiva-
tion and hand weeding) for each location. 46 kg P₂O₅ and 54 kg N
eters 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 regu-
larly 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 differ-
ce between mean yields of protected (sprayed) and unpro-
tected (with similar managements to protected except with no
application of the fungicide benomyl) plots. It was computed using
the formula (Miller 1965):

\[
YL(\%) = \frac{YP - YI}{YP} \times 100
\]

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 sig-
ficantly 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 recor-
ded from early planting (S1) 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 re-
corded from late planting (S5) 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
shrivelled 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 plant-
ing. 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 (Sag-
hai Maroof et al. 1993; Gever et al. 1994; Saghai Maroof

| Table 1 |

<table>
<thead>
<tr>
<th>Planting Dates</th>
<th>Ear Length (cm)</th>
<th>Grain Yield (t ha⁻¹)</th>
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<td>S2</td>
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<td>8.09</td>
</tr>
<tr>
<td>S5</td>
<td>11.23</td>
<td>6.32</td>
</tr>
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Effect of planting dates for control of maize gray leaf spot in Ethiopia. Solomon et al.

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.

<table>
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<th>Planting date</th>
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<th>EAS***</th>
<th>CHA***</th>
<th>CDI**</th>
<th>ELE*</th>
<th>EDIA*</th>
<th>Y***</th>
<th>TKW**</th>
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<td>15.78</td>
<td>4.45</td>
<td>8.06</td>
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<td>2.29</td>
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<td>14.95</td>
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<td>8.04</td>
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<td>6.65</td>
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<td>5.11</td>
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<td>69.17</td>
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<td>14.41</td>
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<td>27.07</td>
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<td>4.81</td>
<td>2.38</td>
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<td>14.99</td>
<td>4.39</td>
<td>7.48</td>
<td>436.63</td>
</tr>
</tbody>
</table>

SEV = severity, ULINF = upper 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), 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.

<table>
<thead>
<tr>
<th>Planting date</th>
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<th>EAS***</th>
<th>CHA***</th>
<th>CDI**</th>
<th>ELE*</th>
<th>EDIA*</th>
<th>Y***</th>
<th>TKW**</th>
</tr>
</thead>
<tbody>
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<td>4.19</td>
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<td>96.25</td>
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<td>3.99</td>
<td>9.09</td>
<td>434.75</td>
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<td>99.88</td>
<td>9.67</td>
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<td>8.75</td>
<td>430.96</td>
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<tr>
<td>4</td>
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<td>6.37</td>
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<td>R2</td>
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<td>0.65</td>
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<td>0.90</td>
<td>0.75</td>
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<tr>
<td>CV</td>
<td>12.46</td>
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<td>37.70</td>
<td>7.00</td>
<td>7.53</td>
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<td>MSE</td>
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<td>0.79</td>
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<td>8.23</td>
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<td>2.72</td>
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</table>

SEV = severity, ULINF = upper leaf infestation, CHA = number of cobs harvested, CDI = number 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 inoculum 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.
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 \( (0.39) \) while it had a significantly negative correlation with ear diameter \( (-0.29) \) and 1000-kernel weight \( (-0.24) \) \( \). Grain yield had a significantly positive correlation with number of cobs harvested \( (0.46) \), 1000-kernel weight \( (0.39) \) while it had a significantly negative correlation with ear diameter \( (-0.29) \) and 1000-kernel weight \( (-0.24) \) \( \). Grain yield had a significantly positive correlation with number of cobs harvested \( (0.46) \), 1000-kernel weight \( (0.39) \) while it had a significantly negative correlation with ear diameter \( (-0.29) \) and 1000-kernel weight \( (-0.24) \) \( \).

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.

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.

<table>
<thead>
<tr>
<th>SEV***</th>
<th>ULINF***</th>
<th>LTYP***</th>
<th>STHA</th>
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<th>CHA</th>
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<th>ELE</th>
<th>EDIA*</th>
<th>Y***</th>
<th>TKW***</th>
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<td>92.47</td>
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Table 4 Correlation among GLS disease severity and agronomic parameters for maize.

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