Spatio-Temporal Variations in the Incidence and Severity of Maize Streak Disease in the Volta Region of Ghana

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Abstract

The study was conducted to assess the influence of different agro-ecological zones and cropping seasons on the incidence and severity of maize streak disease (MSD) in Ghana. Field surveys were conducted in two districts each of the coastal savannah, forest, and transition agro-ecological zones of the Volta region to assess the incidence and severity of MSD in farmers’ fields, during the 2014 minor and 2015 major cropping seasons. The disease assessment was carried out in 12 fields from each district, and for each field on both maize plants growing under tree shade and in open parts of the field. The plants were scored for disease severity based on a 1-5 visual scale (1=no infection and 5=very severe infection). Percentage total N, available P, exchangeable K, organic matter levels and pH were determined from soil samples collected from each of the fields surveyed. Incidence and severity of MSD on maize plants growing under tree shade and in open parts of the fields were significantly higher (P<0.05) in the transition zone than in the forest and coastal savannah eco-zones during the 2014 and 2015 cropping seasons. Mean incidence and severity of MSD on maize plants growing under tree shade were significantly higher than those in the open part of the fields in both cropping seasons. The levels of MSD incidence and severity recorded in 2014 were significantly higher (P<0.05) than 2015. Low levels of soil total N, available P, exchangeable K and organic carbon were detected across the three agro-ecological zones. Incidence and severity scores of MSD were significantly and negatively correlated with soil total N, available P, exchangeable K and organic matter (P<0.01). In conclusion, MSD incidence and severity vary with the cropping seasons and agro-ecological zones and are partly affected by low soil fertility levels and tree shades.

Keywords: Maize Streak disease; Maize streak virus; Mastrevirus; Disease incidence and severity; Agro-ecological zones; Soil fertility

Introduction

Maize (Zea mays L.) is a principal food and cash crop for over 100 million people in Africa [1]. It is also a major constituent in livestock feed [2]. Maize is mainly produced by small-scale farmers in Ghana for food and income generation and as a source of livelihood.

Despite the economic importance of maize in Ghana, its current average yield of 1.7 metric tonnes per hectare is woefully below its potential yield of 6 metric tonnes per hectare [3]. This large yield gap is attributable to diversity of constraints, notably pests and diseases, low inherent yielding varieties, nitrogen and phosphorus deficiency [4,5] and drought [6] among others. Among the diseases, maize streak disease (MSD) caused by Maize streak virus (MSV; genus Mastrevirus, family Geminiviridae) is the most devastating and destructive disease of maize in Sub-Saharan Africa [7,8] including Ghana [9]. It is obligatorily transmitted by as many as six leafhopper species in the genus Cicadulina, (Homoptera: Cicadellidae) in a persistent manner [1] mainly by C. mbila Naudé and C. storey [10,11]. Incidence of MSD has been reported in several African countries including Ghana [9], Nigeria [12], Cameroon [13], Zimbabwe [14], Uganda [15], Kenya [7], Burundi [16] and South Africa (EPPO [17]) and on the islands of adjacent Indian Ocean (Reunion, Mauritius, Madagascar, Sao Tome and Principe) [17-23].

MSD can infect over 80 other plant species in the family Poaceae [24] including oats, wheat, sorghum, millet, finger millet and sugarcane [1,22]. MSD reportedly causes yield losses that range from a trace to almost 100% [25-27]. MSD is a major threat to cereal crops among smallholder farmers in Sub-Saharan Africa, causing up to 480 million USD losses annually [11].

Effective management of the MSD is required in order to improve yields of maize. Information on the prevalence and severity of MSD in Ghana is an important pre-requisite for developing an effective management strategy. However, such information is limited in the country. The only available work [9] that assessed the prevalence of MSD in Ghana was limited to the minor season reports on the forest and transition zones of Brong-Ahafo, Ashanti, Eastern and Central regions, excluding the Volta region where the crop is a major staple. Soil fertility status has been found to influence the incidence of MSD and its vector Cicadulina spp. in Kenya [7] but such information is not available in Ghana. The aim of this study was to assess the incidence and severity of MSD on maize crops in the various agro-ecological zones of the Volta region and to determine their relationships with soil fertility levels of the maize fields surveyed. The results of this study will be very valuable in developing effective strategies for the management of the MSD.

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Materials and Methods

Field survey/disease assessment

A field survey was conducted in four maize fields from three communities in each of the six-major maize growing districts in the Volta region (3°45’ latitude N and 8°45’ longitude N) during the minor (September-October, 2014) and major (July-August 2015) cropping seasons. Akatsi South and Ketu North districts were selected for the coastal savannah zone, Ho West and Kpandu districts for the forest zone (middle belt) and Krachi-East and Nkwanta South for the Forest-Guinea savannah transition zone (northern sector) Figure 1.

A transect (25 m$^2$) was made at three different points along the diagonal of each field and all plants within the transects were assessed for incidence and severity of MSD. The prevalence of MSD was determined by visually observing and recording the presence or absence of maize plants showing the disease symptoms. Disease incidence per field was estimated as the percentage of plants along the transects showing MSD symptoms [9]. The plants were also scored for disease severity based on a 1-5 visual scale [9,26] with a modification of 0.5 increments; where 1 represents no infection; 2, mild infection; 3, moderate infection; 4, severe infection and 5 very severe infection.

In each field disease assessment was done for maize plants growing under tree shade as well as in the open parts. The survey was undertaken when maize crops were between tasselling and physiological maturity, for the coastal savannah zone (31.7%); with respect to maize plants growing in the open parts of the fields, the transition zone had significantly higher ($P<0.05$) mean incidence (73.5%) than the coastal savannah (69.3%) and forest zones (63.2%). Similarly, the transition zone had significantly higher ($P<0.05$) mean incidence (87.2%) than the coastal savannah (79.3%) and forest zones (79.1%), for maize plants growing under tree shade (Table 1). The ANOVA also showed that the overall mean incidence on maize plants growing under tree shade (81.87%) was significantly higher than those in the open parts of the fields (68.70%) during the minor season ($F=80.81$; $df=125$; $P<0.001$).

Similarly, in the major season, ANOVA indicated highly significant differences in the incidences of MSD in maize plants growing in the open parts of the fields ($F=30.13$; $df=66$; $P<0.001$) and those growing under tree shades ($F=31.03$; $df=65$; $P<0.001$) among the ecological zones (Table 1). Mean disease incidence recorded for the transition zone (31.7%) was not significantly different ($P<0.05$) from that of the forest zone (27.9%) but significantly higher than that of the coastal savannah zone (24.3%), with respect to maize plants growing in the open parts of the fields. Also, among maize plants growing under tree shade, the mean incidence recorded for the transition zone (50.4%) was significantly higher ($P<0.001$) than those in the coastal savannah (42.1%) and forest (43.9%) zones.

Results

Prevalence and severity of maize streak disease in the Volta Region

Mean incidence of MSD in the minor and major seasons: In the minor season, ANOVA indicated highly significant differences in the incidences of MSD in maize plants growing in the open parts of the fields ($F=6.94$; $df=65$; $P=0.002$) and under tree shade ($F=6.46$; $df=65$; $P=0.003$) among the ecological zones (Table 1). In respect of the plants growing in the open parts of the fields, the transition zone had significantly higher ($P<0.05$) mean incidence (73.5%) than the coastal savannah (69.3%) and forest zones (63.2%). Similarly, the transition zone had significantly higher ($P<0.05$) mean incidence (87.2%) than the coastal savannah (79.3%) and forest zones (79.1%), for maize plants growing under tree shade (Table 1). The ANOVA also showed that the overall mean incidence on maize plants growing under tree shade (81.87%) was significantly higher than those in the open parts of the fields (68.70%) during the minor season ($F=80.81$; $df=125$; $P<0.001$).

Data analyses

Data on disease incidence was arcsine transformed in order to homogenise the variance before being subjected to analyses of variance (ANOVA). The other quantitative data (severity scores of MSD, soil fertility status: N, P, K, organic C, pH) were also subjected to ANOVA and the means effect were separated by least significance difference (l.s.d) method at 5% level of probability. Pearson’s correlation coefficients were calculated for the relationships between incidence and severity of MSD and soil total N (%), available P, exchangeable K, pH and organic matter. Comparisons of mean incidence and severity of MSD were made between maize plants growing under tree shades and those in the open parts of the fields across all the three agro-ecological zones using independent sample t-test. All statistical analyses were performed using GenStat Release version 9.2 Rothamsted Research International.
was not significantly different (P>0.05) from that of the forest (44.1%) but significantly higher than that of the coastal savannah (36.3%) zones (Table 1). The ANOVA also revealed that the overall mean incidence on maize plants growing under tree shades (43.6%) was significantly higher (F=46.15; df=125; P<0.001) than those in the open parts of the fields (27.97%) during the major season.

l.s.d. for comparing overall mean incidence difference between open and shade=2.9 at 125 df (minor season). F=80.81; df=125; P<0.001.

l.s.d. for comparing overall mean incidence difference between open and shade=3.788 at 125 df (minor season); F-value=46.15; P<0.001.

Data on disease incidence was arcsine-transformed before ANOVA was done.

Mean severity scores of MSD in the minor and major cropping seasons: The mean severity scores of MSD recorded at the various agro-ecological zones in the minor season differed significantly amongst them for maize plants growing in the open parts of the fields (F=11.46; df=55; P<0.001) and those under tree shades (F=8.32; df=55; P<0.001) as shown in Table 2. For maize plants growing in the open parts of the fields, the transition zone had significantly higher (P<0.05) mean severity score (3.093) than the forest (2.570) and the coastal savannah zones (2.724). Similarly, the transition zone had significantly higher (P<0.05) mean severity score (4.241) than the forest (3.639) and the coastal savannah zones (3.782) among the maize plants growing under tree shades. The overall mean severity score of MSD on maize plants growing under tree shades (3.888) was significantly higher (F=217.76; df=126; P<0.001) than those growing in open parts of the fields (2.796) as indicated in Table 2.

In the major season, ANOVA revealed highly significant differences in the severity of MSD in maize plants growing in the open parts of the fields (F=16.75; df=57; P<0.001) and those growing under tree shades (F=17.96; df=57; P<0.001) among the agro-ecological zones (Table 2). In respect of maize plants growing in the open parts of the fields, the mean severity scores recorded for the transition zone (1.458) was not significantly different from that of the forest zone (1.398) but significantly higher (P<0.05) than the coastal savannah zone (1.134). Among plants growing under tree shades, the transition zone had significantly higher mean severity score (2.199) than the forest (1.816) and coastal savannah zones (1.402) (Table 2).

The overall mean severity score of MSD on maize plants growing under tree shades (1.806) was significantly higher (F=60.55; df=126; P<0.001) than those growing in open parts of the fields (1.330) during the major season (Table 2).

l.s.d. for comparing overall mean severity scores between open and shade=0.1464 at df of 126 (minor season); F-value=217.76; df=126; P<0.001.

l.s.d. for comparing overall mean severity scores between open and shade=0.216 at df of 126 (major season); F=60.55; df=126; P<0.001.

Seasonal comparisons of incidences and severities of MSD: An independent sample t-test analyses revealed that the mean incidence of MSD recorded in the minor season was positively and significantly correlated with mean disease severity score in respect of maize plants growing in the open parts of the fields (r=0.5839; P<0.0001) and those growing under tree shades (r=0.4837; P<0.0001) as shown in Figures 2 and 3, respectively. Similarly, there were positive and significant correlations between mean MSD incidence and mean severity scores recorded in the major season for maize plants growing in the open parts of the fields (r=0.7969; P<0.0001) and those under tree shades (r=0.8468; P<0.0001) as indicated in Figures 4 and 5, respectively.

Influence of soil fertility on the incidence and severity of MSD: Soil pH, total N (%), available P (µ.gg⁻¹) and exchangeable K (cmol kg⁻¹) concentrations in the soils surveyed are shown in Table 4. The percentage total N concentrations in the soils were found to vary significantly among the agro-ecological zones (F=6.28; df=55; P<0.003). The total N concentrations in the transition zone (0.1%) was not significantly different from the forest zone (0.08%) but significantly higher than the coastal savannah zone (0.05%). There were no significant differences

<table>
<thead>
<tr>
<th>Agro-ecological zone</th>
<th>Mean MSD incidence (%) in the minor season</th>
<th>Mean MSD incidence (%) in the major season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open Shade Open Shade</td>
<td>Open Shade Open Shade</td>
</tr>
<tr>
<td>Coastal savannah</td>
<td>69.4 b 79.1 b 24.3 b 36.3 b</td>
<td>69.4 b 79.1 b 24.3 b 36.3 b</td>
</tr>
<tr>
<td>Forest zones</td>
<td>73.8 a 87.2 a 31.7 a 50.4 a</td>
<td>73.8 a 87.2 a 31.7 a 50.4 a</td>
</tr>
<tr>
<td>Transition</td>
<td>68.70b 81.87a 27.97b 43.60a</td>
<td>68.70b 81.87a 27.97b 43.60a</td>
</tr>
<tr>
<td>Mean</td>
<td>68.70b 81.87a 27.97b 43.60a</td>
<td>68.70b 81.87a 27.97b 43.60a</td>
</tr>
<tr>
<td>I.S.D (P&lt;0.05)</td>
<td>5.53 4.96 4.301 6.29</td>
<td>5.53 4.96 4.301 6.29</td>
</tr>
</tbody>
</table>

Means in the same column bearing the same letters are not significantly different from each other (P>0.05). * Mean ± S.D

Table 1: Mean incidence of maize streak disease across the three agro-ecological zones of the Volta region of Ghana during 2014 minor and 2015 major cropping seasons.

<table>
<thead>
<tr>
<th>Agro-ecological zone</th>
<th>Disease severity in the minor season</th>
<th>Disease severity in the major season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open Shade Open Shade</td>
<td>Open Shade Open Shade</td>
</tr>
<tr>
<td>Coastal savannah</td>
<td>2.72a 3.78a 1.34b 1.40b</td>
<td>2.72a 3.78a 1.34b 1.40b</td>
</tr>
<tr>
<td>Forest zones</td>
<td>2.57a 3.63b 1.39b 1.81b</td>
<td>2.57a 3.63b 1.39b 1.81b</td>
</tr>
<tr>
<td>Transition</td>
<td>3.09a 4.24a 1.45b 2.19b</td>
<td>3.09a 4.24a 1.45b 2.19b</td>
</tr>
<tr>
<td>Mean</td>
<td>2.79a 3.88a 1.33b 1.80b</td>
<td>2.79a 3.88a 1.33b 1.80b</td>
</tr>
<tr>
<td>I.S.D (P&lt;0.05)</td>
<td>0.2250 0.3095 0.1131 0.2708</td>
<td>0.2250 0.3095 0.1131 0.2708</td>
</tr>
</tbody>
</table>

Means in the same column bearing the same letters are not significantly different from each other (P>0.05).

Table 2: Mean maize streak disease severity scores recorded at the three ecological zones in the Volta region during 2014 minor and 2015 major cropping seasons.

<table>
<thead>
<tr>
<th>Variables*</th>
<th>df**</th>
<th>t-test</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSD incidence in the open fields between 2014 and 2015</td>
<td>69</td>
<td>27.23</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MSD incidence under tree shade between 2014 and 2015</td>
<td>125</td>
<td>17.84</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MSD severity in the open fields between 2014 and 2015</td>
<td>70</td>
<td>26.67</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MSD severity under tree shade between 2014 and 2015</td>
<td>54</td>
<td>21.24</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Means for comparison are indicated in Tables 1 and; **df=Degree of freedom

Table 3: Independent sample-test comparisons of mean incidence and severity of maize streak disease (MSD) between 2014 (minor crop season) and 2015 (major crop season).
among the agro-ecological zones with respect to available P (F=2.14; df=55; P=1.00) and exchangeable K (F=0.127; df=55; P=0.375) levels in the soils, even though the transition zone had the highest levels and the coastal savannah the lowest. The agro-ecological zones differed significantly in respect of the soil organic matter content (F=6.57; df=55; P=0.03). The mean soil organic matter content of the forest zone (2%) was not significantly different from the transition zone (1.55%) but significantly higher than the coastal savannah (0.99%). Interestingly, the mean soil pH in all the agro-ecological zones was the same (pH 6), indicating slightly acidic soils.

**Correlation between soil fertility status and incidence and severity of maize streak disease:** Incidence of MSD was significantly and negatively correlated with soil exchangeable K (r=-0.841; P<0.001), percentage total N (r=-0.838; P<0.001), available P (r=-0.775; P<0.001), soil organic carbon (r=-0.828; P<0.001) and soil pH (r=-0.997; P<0.001) as shown in Table 5. Similarly, there were significant and negative correlations between mean MSD severity scores and soil exchangeable K (r=-0.790; P<0.001), percentage total N (r=-0.833; P<0.001), available P (r=-0.773; P<0.001), organic carbon (r=-0.822; P<0.001) and soil pH (r=-0.997; P<0.001) indicated in Table 5.

*Data represent MSD incidence and severity scores determined in open parts of the maize fields during the 2014 minor cropping season when the soil sampling was done.*

**Varieties of maize cultivated by the farmers:** In both the minor and major cropping seasons, the maize plants that were surveyed were of both improved and local varieties, with the improved varieties being predominant (Table 6). Comparatively, the transition zone had the highest percentage of improved variety (63.6% to 100%), followed by the forest zone (66.7% to 75%) whereas the coastal savannah had the lowest (50% to 58%).

**Discussion**

The study has revealed high prevalence of MSD across the three agro-ecological zones of the Volta region, with overall mean incidences of 68.70% and 81.87% for maize growing in the open parts of fields and those under tree shades, respectively, in the minor season, and overall mean incidences of 24.3% and 31.7% for maize growing in the open parts of fields and those under tree shades, respectively, in the major season (Table 2). These findings are comparable to that of Rose [19] and Oppong et al. [9]. Mean MSD prevalence of 18.44% was reported by Oppong et al. [9] when they conducted a survey of MSD in maize crops in the forest and transition zones of Brong-Ahafo, Ashanti, Eastern...
The results of the soil analyses indicated that the soils surveyed were slightly acidic (pH 6.0) and had low inherent nutrients content (total N<0.13%; available P<0.20 µg g⁻¹; ECEC<5 c mol kg⁻¹) as reported by Yebboh et al. [41]. The significantly higher organic matter content at the forest and transition zones compared to the coastal savannah zones could be attributable to the high vegetative cover in the forest and transition zones which could add more litter to the soil. Nonetheless, the levels of soil organic matter in all the agro-ecological zones were low. The low soil organic carbon content could be due to rapid decomposition of organic matter promoted by the prevailing high temperatures and high humidity [42], and continuous cropping without the return of crop residues to replenish the soil organic C stock [43]. The slightly low soil pH may be attributed to continuous cropping and leaching of soil basic cations [44].

The high prevalence and severity of MSD observed at various agro-ecological zones could be partly due to low soil fertility status and this is supported by the significantly negative correlation between disease incidence and severity and soil fertility status. It is also reported [33] that generally, MSD incidences are associated with leafhopper density in the rain forest and northern agro-ecological zones. Important differences in the virulence of different MSV-A subtypes in maize have been reported [32]. Subtypes A1, A2 and A5 isolates produce the severest symptoms, subtypes A3 and A6 isolates produce intermediate symptoms, while subtype A4 isolate produce the mildest symptoms. Possibly, the strain of MSV-A infecting maize at the transition zone was more virulent than that of the forest and coastal savannah, hence the more severe symptoms at the transition zone than the forest and coastal savannah zones. It has also been reported [1,32] that virulent MSV isolates cause earlier symptoms with wider and more chlorotic streaks than the mild isolates. This could explain why higher levels of incidence and severity of MSD were recorded at the transition zone than the forest and the coastal savannah zones.

Differences in the climatic conditions prevailing at the different agro-ecological zones could affect the leafhopper populations. Bosque-Perez and Buddenhagen [33] observed that the humid forest locations in the southern part of Nigeria often have consistently low leafhopper populations during most of the year compared to the dry northern locations. It is also reported [33] that generally, MSD incidences are associated with leafhopper density in the rain forest and northern Guinea Savanna zones but not in the southern Guinea Savanna zone of Nigeria.

Incidence and severity of MSD were found to be higher in maize plants growing under tree shade than those in the open parts of maize fields. This finding is consistent with that of Kyetere and Williams [26] who reported that incidence of MSD is greater in the shade than in the open parts of the field due to vector preference for shade. Thus, the higher the vector density under tree shade, the higher the disease incidence [34]. It has therefore been suggested that incidence and severity of MSD could be controlled by cultural practices [7]. Weeding and pruning of trees and planting maize in an open area where there are no trees can reduce vector population and the disease, as *Cicadulina* species prefer shade [35].

In addition to ecological zone and shading effect, incidence of MSD has been found to vary according to planting date and variety [36,37]. In our present study higher levels of incidence and severity of MSD were recorded in the minor rainy season (late planting) than in the major rainy season (early planting) (Table 3). This is consistent with the finding of Fajemisin et al. [38] who reported that late season plantings (July to October) suffer higher disease incidence than early season ones (March to May). This could be due to higher density of leafhoppers in the minor season than in the major rainy season, which may be partly due to an increase in insect mortality due to excessive impact of heavy rain drops in the major season than the minor cropping season [33]. It has also been reported [24] that MSD epidemiology is primarily governed by environmental influences on its vector species, resulting in erratic epidemics every 3-10 years.

Farmers in the region also plant different varieties of maize, both local and improved (Table 6), with varying reactions to MSV. This could also influence the levels of incidence and severity of the MSD reported in the study. Improved maize varieties such as Obatanpa, et al. are reported to be resistant to MSV [39,40] compared to the local varieties.

The table below summarizes the correlation coefficients between mean maize streak disease (MSD) incidence and severity scores and soil fertility status.
influence MSV vector (*Cicadulina* spp.), which correlates positively with MSV disease incidence. Potassium (K) fertilizer is widely reported to decrease insect infestation and disease incidence in many host plants [45], as K promotes the development of thicker outer walls in epidermal cells, thus preventing attack by insect vectors [46]. In his literature review, Perrenoud [47] found that the use of K significantly decreases the incidence of virus diseases by 41%.

Conclusions

There is high prevalence of MSD across the three agro-ecological zones of the Volta region. Incidence and severity of MSD were consistently higher in the transition eco-zone than the forest and coastal savannah eco-zones during both minor and major cropping seasons. The incidence and severity of MSD were higher in the minor season than the major season. The soils of the maize fields surveyed were slightly acidic (pH 6.0) and had low inherent nutrient content (N, P, K, organic C). There were significant negative correlations between disease incidence and severity and soil nutrient content (N, P, K, organic C).

References

34. Reucaud B (1988) Transmission of viruses from the streak, stripe and mosaic of March by their vectors *Cicadulina milba* (Naude) and *Peregrinus maidis* (Ashmead) Biological, genetic and epidemiological approaches to the vector-virus-plant relationship. These, University of Sciences and Techniques of Languedoc, France.
38. Fajemisin JM, Shoyinka SA, Williams LE, Gordon DT, Nault LR (1976)
Maize streak and other maize virus diseases in West Africa. In Proceedings, International maize virus disease colloquium and workshop, USA.


