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Incidence and severity of maize streak disease: The influence of tillage, fertilizer application and maize variety

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Maize streak disease (MSD) is one of the most destructive diseases of maize (*Zea mays* L.) estimated to cause a yield loss of about 20% in Ghana. Field experiment was conducted at Nkwanta in the Volta Region of Ghana during the cropping seasons of 2015 to assess the effects of tillage practices, fertilizer application and maize variety on the incidence and severity of MSD. The MSD severity was assessed using 1 to 5 visual scale (1=no symptom and 5= very severe symptom). The relationship between total N, available P and exchangeable K contents of soils and maize leaves sampled at silking stage and MSD incidence and severity were elucidated with Pearson correlation coefficients. Although symptoms were observed in both fertilized and non-fertilized plants, fertilizer addition effectively reduced the MSD impact on growth and yield. Incidence and severity of MSD under no-tillage system were significantly lower than under conventional tillage. Severe MSD, particularly, of plants on the plots with no added nutrients led to stunted growth and reduced grain yield. The severity of MSD correlated positively with maize leaf N content, while increasing leaf K content resulted in reduced MSD severity. It can therefore be concluded that tillage and plant nutrition affect the severity of MSD in tropical soil.

Key words: *Zea mays*, grain yield, inorganic fertilizer, maize streak disease, maize varieties, tillage.

INTRODUCTION

Maize (*Zea mays* L.) is a major food security and cash crop for over 100 million people in Africa (Bosque-Perez, 2000) and also a major constituent in livestock feed (Romney et al., 2003). It accounts for 50 to 60% of total cereal production in Ghana (MiDA, 2010; Agyare et al., 2013). Diseases and pests, unpredictable rainfall and declining soil fertility are very critical biophysicalfactors contributing to decline in maize yields across sub-Saharan Africa including Ghana (Magenya et al., 2008; Obeng-Bio, 2010; MoFA, 2013). Maize streak disease

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(MSD) is one of the most destructive diseases of maize in terms of growth and yield loss in Africa (Magenya et al 2008; Karavina, 2014). The disease is caused by maize streak virus (MSV; genus *Mastrevirus*, family Geminiviridae) which is transmitted by various species of leafhoppers of the genus *Cicadulina* (Cicadilidae: Homoptera) in a persistent manner but the most important vector is *Cicadulina mbila (*Karavina, 2014*).* MSV has a wide host range, infecting over 80 other plant species in the family Poaceae (Shepherd et al., 2010). MSD is identified as yield declining factor of maize in Ghana with an estimated yield loss of about 20% (Oppong, 2013). Yield losses due to MSD reported elsewhere range from trace to almost 100% (Kyetere et al., 1999; Alegbejo et al., 2002).

One major challenge of MSD is its sporadic and unpredictable nature that makes it difficult to decide on how to apply any strategy to control it (Martin and Shepherd, 2009). In view of this, several methods, including the use of insecticides against the leaf hoppers (vector), plan planting to avoid the peak period of the vector infestation and the use of resistant varieties are employed to manage the disease (Magenya et al., 2008). These interventions however have not been very successful (Magenya et al., 2008).

Therefore, there is need to find alternative measures to control this disease in cost-effective and environmentally friendly manner to increase yield and to improve grain quality. Magenya et al. (2009) proposed that soil nutrient management provides a potential alternative measure to widening the scope of MSD management. The ability of a crop plant to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and mainly biological properties of soils as well as soil management (Altieri and Nicholls, 2003). Soil nutrients are reported to affect the development of a disease by affecting plant physiology, the pathogen or both (Ownley et al., 2003). Again, modification of the soil environment through tillage practices can influence plant nutrient availability and hence plant growth, disease tolerance and yield (Dordas, 2009). The study was conducted to examine the effectiveness of different rates of inorganic nitrogen (N), phosphorus (P) and potassium (K) fertilizers on incidence and severity of MSD of two maize varieties (*Obatanpa* and *Domabin*) under no-tillage and conventional tillage systems.

MATERIALS AND METHODS

Study area

The field experiment was conducted at Nkwanta in the Volta Region of Ghana, which lies between latitudes 7° 30' and 8° 45'N and longitude 0° 10' and 0° 45'E. Nkwanta is found in the Forest-Guinea Savannah transition zone of Ghana. The average annual rainfall of the area ranges from 922 to 1,874 mm and the mean temperature is about 26.5°C (GSS, 2014). The dominant soil type was Acriosol (WRB, 2015). The field experiments were conducted under rain-fed conditions in both the major (June-September, 2015) and minor (September-December, 2015) cropping seasons. The monthly rainfall distribution of the experimental year is as shown in Figure 1.

Experimental design

The study was conducted using the split-split plot design with four replications, with tillage as the main plot, maize variety as sub-plots and fertilizer rates as sub-sub plots, respectively. The main treatments involved were: (1) Two tillage practices, No-tillage (T1) and Conventional tillage (T2); (2) Two local maize varieties; *Obatanpa* (V1) and *Domabin* (V2); and (3) Seven fertilizer application rates (N, P and K kg ha^{-1}), 0:0:0 (F1), 100:30:60 (F2), 100:80:60 (F3), 100:60:60 (F4), 100:60:30 (F5), 100:60:80(F6) and 60:60:60 (F7). These together make a total of 112 sub-sub plots.

On the no-tillage plots, the vegetation was first slashed and then followed by Glyphosate herbicide application at a rate of 1 L ha^{-1}. Three seeds were sown per hill at a spacing of 80 cm between rows and 40 cm within rows up to a depth of 5 cm. After emergence, the seedlings were thinned to two per hill.

The split fertilizer application method was adopted. In order to attain the different fertilizer application rates, NPK (15:15:15) was used for the basal application and supplemented with Urea (46% N), Triple Super Phosphate (TSP) (46% P_2O_5) and Muriate of Potash (MOP) (60% K_2O). The first fertilizer split was done 10 days after planting in a band about 5 cm away from the hills to a depth of 5 cm while the top-up application was done six weeks after planting, where necessary.

Data collection

Data collections were done in both major and minor cropping seasons. On each plot, 12 plants from middle rows were randomly selected and tagged for growth, disease and yield assessments. The plant height and disease incidence and severity were measured on 9th week after planting and yield data was collected at physiological maturity. Plant height was measured from the soil level to the tassel height using a meter rule. Grain yield was determined by measuring the total weight of maize per plot at 13% moisture content with a balance and expressed in tons per hectare. The incidence of MSD was determined by visually observing and recording the number of maize plants showing the disease symptoms and the percentage incidence was calculated as follows:

$$\text{Incidence (\%)} = \frac{Number\ of\ infected\ plants}{Number\ of\ plants\ assessed} \times 100$$

The plants were also scored for disease severity based on a scale of 1 to 5 adopted from Bosque-Perez and Alam (1992) with a modification by Oppong et al. (2014a, b) (Table 1).

In the study, soil sampling was done at two different periods. The initial soil sampling was done at the beginning of the study to characterize soils at the study site before treatments were applied whilst the second soil samples were taken at maize silking stage to determine the soil nutrient status after the period of maximum uptake by the maize. A composite sample for each plot was obtained by thoroughly mixing soil samples collected at a depth of 01 to 20 cm at six randomly selected points within each plot with an, using Auger. Leaf samples were collected from four plants in each plot at maize silking stage to determine the leaf nutrient content uptake by the maize. On each plant, leaves opposite and just below the uppermost ear (the second most fully expanded leaf) were sampled using a knife (Arnon, 1975). Maize grains were also sampled from each plot at the physiological maturity stage harvest

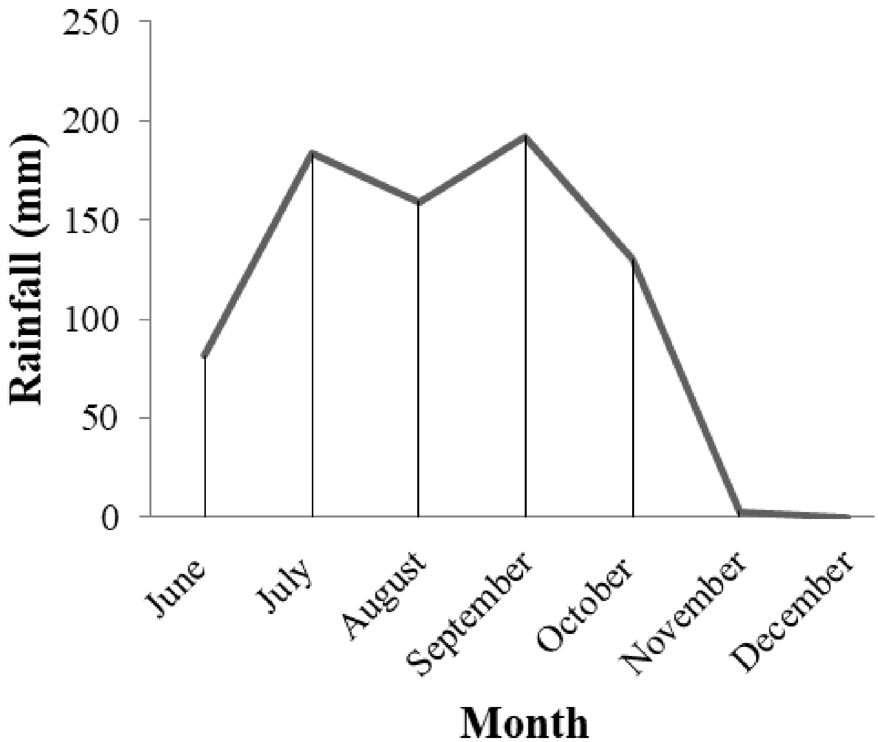

Figure 1. Mean monthly rainfall distribution during the 2015 cropping seasons at Nkwanta, Ghana.

Table 1. Visual rating scale for maize streak disease (MSD) severity.

Rating scale	Description	Expression in terms of severity
1	No symptoms	No infection
2	Very few streaks on leaves, light streaking on old leaves gradually decreasing on young leaves	Mild infection
3	Moderate streaking on old and young leaves, slight stunting	Moderate infection
4	Severe streaking on about 60-75% of leaf area, plants stunted	Severe infection
5	Severe streaking on more than 75% leafarea, plants severely stunted or dead	Very severe infection

Source: Bosque-Perez et al. (1992) and Oppong et al. (2014a, b).

for crude protein determination).

Soil and maize grain analyses

Soils of the experimental fields were characterized by the determination of the textural class, pH, bulk density, organic matter content, total nitrogen, available phosphorus, exchangeable bases ($Ca^{2+,}$ $Mg^{2+,}$ K^+, Na^+) and exchangeable acidity (H^+ and Al^{3+}). The soil samples collected at maize silking stage were analysed for total N, available P and exchangeable K contents. Soil pH was measured in a 1:2.5 soil-water ratio using a glass electrode pH meter (Rowel, 1994). The particle size distribution of the soil was determined using the pipette sampling technique described by Rowel (1994). The organic carbon (C) content of the soil was determined using the Walkley-Black method and the organic matter content of the soil was estimated from the organic C content (FAO, 2008). The total N in the soil samples were determined by the Micro-Kjeldahl method as described by Rowel (1994), with a slight modification. The exchangeable cations were also determined using techniques described by Rowel (1994).

The grain N content was determined using protocol obtained from IITA (1985). The grain crude protein was then estimated by multiplying the percentage N by 6.25 (Galicia et al., 2009).

Data analyses

All data were analysed using GenStat Discovery Version 4 (VSN International). Data in percentages were normalized using angular transformation. Relationships between disease data (MSD incidence and severity scores) and plant height, grain yield, and soil total N, available P and exchangeable K were established by calculating Pearson's correlation coefficients. Analysis of variance

(ANOVA) was performed to test the treatments and their interaction effects for significance at 5% level of probability. The least significant difference (l.s.d) was used for means comparison.

RESULTS

Physicochemical properties of soils of the study area

The physicochemical properties of soils used for the field experiments are shown in Table 2. The soil had low pH and organic matter content as well as low total nitrogen, available phosphorus, exchangeable potassium and exchangeable calcium contents.

MSD incidence and severity

During the major season, the incidence and severity of MSD were both significantly greater ($P < 0.05$) in the conventionally tilled plots than in the no-till plot (Table 3). In the minor season, incidence did not differ among the tillage systems, but the severity was higher in the conventionally tilled plots than in the no-till plots.

In the major season, MSD incidence and severity were not significantly ($P>0.05$) different between the two maize varieties. In the minor season, MSD severity was significantly ($P < 0.05$) higher on *Domabin* as compared to *Obatanpa,* but the disease incidences were not significantly different ($P>0.05$).

The fertilizer treatments did not significantly ($P>0.05$) affect the overall MSD incidence and severity in the major season. However, in the minor season, the MSD severity in the control was significantly higher ($P<0.05$) than in the fertilizer amended plots, which did not differ significantly among themselves.

Plant height (cm), grain yield (kg ha^{-1}) and grain crude protein content (%)

The plant height and grain yield of the two maize varieties under different tillage operations and fertilizer treatments are shown in Table 4. The maize plants under conventional tillage generally had significantly higher heights than under no-tillage. The overall mean plant height for *Obatanpa* was not significantly different ($P>0.05$) from that of *Domabin*. Maize from the fertilized plots showed significantly higher plant heights than from the control but, the plant heights were not significantly different among the different fertilizer treatments.

Pooling all the data, conventional tillage resulted in significantly higher ($P<0.05$) grain yield than no-till. Also, *Obatanpa* had a significantly ($P> 0.05$) higher grain yield than *Domabin*. The mean grain yields recorded for the fertilized plots were not significantly different ($P>0.05$) among themselves but they were significantly higher than the control.

Table 2. Physicochemical properties of the soil used in the study.

Soil parameter	Value
Bulk density (g cm^{-3})	1.6
Soil pH	6.6
Organic matter (%)	1.20
Total N (%)	0.01
Available P (µg g^{-1})	8.20
Exchangeable bases ($cmol_c$ kg^{-1})	
Ca^{2+}	1.84
Mg^{2+}	3.08
K^{+}	0.12
Na^{+}	0.17
Exchangeable acidity($cmol_c$ kg^{-1})	3.80
ECEC ($cmol_c$ kg^{-1})	6.08
Sand (%)	62.30
Silt (%)	24.80
Clay (%)	13.00
Textural class	Sandy loam

The results indicated a significantly positive interaction between tillage and fertilizer application on mean grain yield.

Soil total N, available P and exchangeable K status at maize silking stage

The nitrogen, phosphorus and potassium contents of soil under the different treatments at silking stage are shown in Table 5. Soil total N content at maize silking stage under conventional tillage was not significantly different ($P > 0.05$) from under no-tillage but available P and exchangeable K contents under no-tillage system were significantly higher ($P \leq 0.05$) than under the conventional tillage system

Fertilizer application did not significantly ($P > 0.05$) affect soil N content. Maize plots, which received fertilizer at a rate of 100:60:80 (F6) had both the highest available P and the highest exchangeable K contents. The total N and exchangeable P contents of soils were not significantly ($P > 0.05$) affected by interactions among the different treatment variables. However, but soil exchangeable K content was significantly affected ($P<0.05$) by both the tillage × fertilizer and variety × fertilizer interactions.

Maize leaves N, P and K contents at maize silking stage

The results indicated that plants under conventional tillage had significantly ($P\leq 0.05$) higher nitrogen (N) content in their leaves than those under no-tillage (Table 6). The two maize varieties did not differ significantly

Table 3. Mean MSD incidences and severity as affected by tillage systems, maize varieties and N, P, K fertilizer application rates.

Parameter	Major season		Minor season	
	Incidence (%)	Severity	Incidence (%)	Severity
Tillage system				
T1 (No- tillage)	17.9	1.21	88.80	2.58
T2 (Conventional tillage)	41.6	1.67	90.00	2.72
l.s.d	6.86*	0.215*	NS	0.1236*
Maize variety				
V1(Obatanpa)	29.8	1.42	89.40	2.62
V2(Domabin)	29.7	1.47	89.40	2.68
l.s.d	NS	NS	NS	0.0543*
Fertilizer rates (NPK kg ha^{-1})				
F1	33.2	1.61	88.95	2.86
F2	28.2	1.39	88.95	2.59
F3	28.2	1.40	88.95	2.62
F4	30.9	1.44	90.00	2.57
F5	33.1	1.46	88.95	2.66
F6	27.6	1.40	90.00	2.62
F7	26.9	1.40	90.00	2.64
l.s.d	NS	NS	NS	0.1208*
Mean	29.7	1.44	89.4	2.65
Treatment interactions				
T×V (P)	0.633	0.597	1.00	0.410
T×F (P)	0.479	0.342	0.826	0.317
V×F (P)	0.237	0.331	0.368	0.633
T×V×F (P)	0.237	0.526	0.368	0.860

*Significance at P ≤ 0.05, NS: Not significant, T: tillage, V: maize variety and F: fertilizer application.

(P>0.05) in terms of their leaf N contents. Fertilizer application significantly (P≤ 0.05) affected the N contents in the leaves of maize plants. Plot amended with fertilizer rate of 100:30:60 (F2) had the highest leaf N content whilst the unfertilized plot, F1 (0:0:0) had the lowest. Both tillage systems and maize varieties did not have significant influence (P>0.05) on mean leaf P content but tillage system × fertilizer rates and variety × fertilizer rates interaction effects were significant (P<0.005) (Table 6). Fertilizer application rates did not have significant influence on the mean leaf P contents.

The mean leaf K content recorded for no-tillage system was significantly higher (P<0.05) than that of conventional tillage. The improved maize variety *Obatanpa* had significantly higher mean K content than the local variety *Domabin* (Table 6).

Tillage and varietal interaction did not significantly (P>0.05) affect N and P but significantly (P≤ 0.05) affected K contents of maize leaves. Tillage and fertilizer application interactively affected leaf P and K but not leaf N content. Interaction between maize varieties and fertilizer application did not have a significant (P> 0.05) effect on the leaf N content but significantly (P≤ 0.05) affected leaf P and K contents.

Relationship between MSD incidence and severity and plant height, grain yield, N, P, K contents in the soil and leaves at silking

MSD incidence significantly correlated positively with plant height (r =0.595; P≤0.05) and grain yield (r =0.403; P≤ 0.05) as shown in Table 7a. MSD severity also significantly correlated positively with plant height (r =0.461; P<0.05) and grain yield (r=0.295; P≤ 0.05) (Table 7a).

Table 7b shows the correlation between the soil nutrient (NPK) content at maize silking stage and MSD incidence and severity. The soil total N content weakly correlated positively with MSD incidence (r = 0.041; P>0.05) and severity (r = 0.077; P>0.05) whiles soil available P weakly correlated negatively with MSD incidence (r = -0.233; P>0.05) and severity (r = -0.045; P>0.05) (Table 7b). Conversely, soil exchangeable K

Table 4. Plant heights and grain yields of maize as influenced by tillage, variety and fertilizer application.

Treatment	Plant height (cm)	Grain yield (kg ha^{-1})
Tillage		
T1 (No- tillage)	143.5	3127
T2 (Conventional tillage)	203.1	3941
l.s.d	12.87*	453.0*
Varieties		
V1(Obatanpa)	176.9	3759
V2(Domabin)	169.8	3309
l.s.d	NS	434.6*
Fertilizer rates (NPK kg ha^{-1})		
F1	150.6	2757
F2	178.5	3801
F3	171.8	3539
F4	171.3	3588
F5	180.7	3758
F6	177.4	3673
F7	182.9	3624
l.s.d	16.96*	653.2*
Mean	173.3	3534
Treatment interactions		
T×V (P)	0.460	0.658
T×F (P)	0.169	0.018*
V×F (P)	0.517	0.636
T×V×F (P)	0.760	0.032*

*Significance at $P \leq 0.05$, NS: Not significant, T: tillage, V: maize variety and F: fertilizer application.

content significantly and negatively correlated with both MSD incidence (r = -0.439; P≤ 0.05) and severity (r = -0.319; P≤ 0.05).

Correlations between maize leaf N, P and K contents and MSD incidence and severity are shown in Table 7c. Correlations between leaf N content and MSD incidence (r=-0.057; P>0.05) and severity (r = -0.57; P>0.05) were not significant. Similarly, correlations between P content in the maize leaves and MSD incidence (r=-0.017; P>0.05) and severity (r= -0.20; P>0.05) were not significant. There was however positive and strong correlation between leaf P content and leaf K content (r = 0.501: P<0.05). There was a significant negative correlation (-0.296; P ≤ 0.05) between leaf K content and MSD severity.

DISCUSSION

Laboratory analyses of the soil at the experimental site (Table 2) revealed that the soil had a high bulk density, which is characteristic of sandy soils (Arthur, 2014). The soil pH was 6.6, which is slightly acidic and considered as good for plant growth (Yeboah et al., 2012). The organic matter content of soil was low (Table 2). Moreover, the soil was low in nitrogen, phosphorus, potassium and calcium, but had adequate magnesium content (Yeboah et al., 2012).

The significantly lower MSD incidence recorded under no-tillage than conventional tillage corroborated with the findings of Bowden (2015) who also reported lower incidence of barley yellow dwarf of wheat under no-tillage plots. Bowden (2015) attributed the situation to vector behaviour and explained that the aphids that carried barley yellow dwarf virus preferred tilled fields to fields with abundant crop residue on the soil surface. The finding of the present study suggests that no tillage can be a suitable method for managing MSD especially by resource-poor smallholder farmers. The result however contradicts the findings of Krupinsky and Tanaka (2001) who observed a higher incidence of leaf spot disease and Gilbert (2005) who also observed more severe net blotch of barley under no-till plots than conventional tillage.

The two maize varieties (*Obatanpa* and *Domabin*) differed significantly in terms of MSD severity when the disease pressure was high in the minor season. Similarly,

Table 5. Soil total N, available P and exchangeable K status at maize silking stage as affected by tillage systems, maize varieties and N,P, K fertilizer application rates.

Treatment	Total N (%)	Available P (μg g^{-1})	Exchangeable K ($cmol_c$ kg^{-1})
Tillage			
T1 (No- tillage)	0.036	45.4	0.489
T2 (Conventional tillage)	0.039	33.1	0.345
l.s.d	NS	6.73*	0.0564*
Maize variety			
V1(*Obatanpa*)	0.039	27.5	0.343
V2(*Domabin*)	0.041	38.1	0.395
l.s.d	NS	NS	NS
Fertilizer rates (NPK kg ha^{-1})			
F1	0.041	13.7	0.390
F2	0.043	25.0	0.430
F3	0.033	46.4	0.333
F4	0.037	37.6	0.402
F5	0.057	40.6	0.334
F6	0.029	77.0	0.637
F7	0.022	34.5	0.391
l.s.d	NS	28.42*	0.1144*
Treatment interactions			
T×V (P)	0.734	0.8I5	0.655
T×F (P)	0.117	0.877	0.004*
V×F (P)	0.406	0.209	0.018*
T×V×F (P)	0.878	0.586	0.103

*Significance at P ≤ 0.05, NS: Not significant, T: tillage, V: maize variety and F: fertilizer application.

Table 6. N, P and K contents of maize leaves at silking stage as affected by treatments.

Treatment	Leaf N	Leaf P	Leaf K
Tillage system			
T1 (No- tillage)	1.280	0.281	1.418
T2 (Conventional tillage)	1.637	0.285	1.294
l.s.d	0.2921*	NS	0.0442*
Maize variety			
V1 (Obatanpa)	1.403	0.287	1.394
V2 (Domabin)	1.515	0.280	1.219
l.s.d	NS	NS	0.0579*
Mean	1.459	0.283	1.356
Treatment interaction			
T× V (P)	0.673	0.619	0.023
T× F (P)	0.887	<0.001*	<0.001*
V×F (P)	0.920	<0.001*	<0.017*
T × V× F (P)	0.931	0.441	0.113

*Significance at P ≤ 0.05, NS: Not significant, T: tillage, V: maize variety and F: fertilizer application.

Bua et al. (2010) working with three maize varieties realized that MSD severity significantly varied among them. These differences in the degree of MSD severities among the maize varieties could be due to the differences in the genetic makeup of maize genotypes as reported by Aziz et al. (2008) when screening tomato germplasm for resistance to tomato yellow leaf curl virus. *Obatanpa* is an improved variety reported to be high yielding and tolerant to MSV infection (Twumasi-Afriyie et al., 1992) compared to *Domabin* which is a local cultivar (Asare-Bediako et al., 2017). The findings of the present study confirm the observations made by previous authors.

The disease incidence was not affected by fertilizer application. This could be attributed to the fact that fertilizer application does not necessarily affect MSD occurrence, especially as the virus could have infected the plants before the first fertilizer was applied (10 days after planting). The result does not agree with Magenya et al. (2009) who reported that the types and concentrations of nutrient elements in host plant tissues indirectly influence the population dynamics of leafhoppers and may therefore affect transmission of MSV. The impact of fertilizer application on MSD was realized only in the minor season. Though MSD incidence was not reduced, severity was significantly affected by NPK application. This result is in agreement with the findings of Huber et al. (2007) which state that take all disease of wheat is reduced when balanced nutrient is applied. The results thus suggest that fertilizer application may not necessarily affect MSD occurrence, but it can have significant impact on the ability of plant to limit penetration and development of the invading virus (Huber et al., 2007). Also, the fertilized plants obtained sufficient nutrients and hence grew stronger and healthier and so they compensated for any viral damage that would have occurred. The ability of the MSD affected plant to maintain its own growth in the presence of sufficient amounts of plant nutrients in spite of the MSV infection, possibly explains why MSD severity was reduced by fertilizer application.

The high MSD incidence and severity recorded in the control further supports this suggestion. The study has demonstrated that fertilizer application has beneficial effect against MSD severity. The results indicate that maize from fertilized plots potentially obtained sufficient nutrients and grew stronger and healthier. The capacity to grow faster enabled the fertilized plants to with stand any viral damage that would have occurred if their growth were slower.

In agreement with Bosque-Perez and Alam (1992), MSD incidence and severity were higher during the minor cropping season than during the major cropping season. Martin and Shepherd (2009) observed that droughts or irregular rains around the time that maize is planted tend to be associated with severe MSD. They argued that the number of viruliferous leaf hoppers is low in the major rainy season but increase in the minor season when the rainfall intensity reduces.

The low grain yields under no-tillage treatment can be attributed to slow early crop establishment which resulted in relatively shorter plant heights as compared to those under conventional tillage. The amounts of available P in the 0 to 20 cm layer indicate that there was probably less P fixation and uptake by plants under no-tillage. As the surface-applied nutrients often remain largely in the surface soil layer of soils under no-tillage (Arnon, 1975), they may not be readily accessible to the crop. This was evident in comparatively higher plant height and grain yield under conventional tillage than under no-tillage system.

Fertilized plots, gave 24.8% more grains than the unfertilized plots. Phosphorus application at 30 kg ha^{-1} yielded 6 and 7% more grains than at the 60 kg P, which is the recommended rate for the study site (Yeboah et al., 2012) and also at 80 kg P ha^{-1} respectively. Fosu-Mensah and Mensah (2016) also obtained a maximum yield of 4953 kg ha^{-1} at 120 kg ha^{-1} N and 30 kg P ha^{-1}. They explained that at soil available P levels beyond 30 kg ha^{-1}, plant growth and grain yield were adversely affected as excessive soil P induced deficiency of micronutrients such as Zn (Olusegun, 2015). Also, Kogbe et al. (2003) reported that P application rates beyond 40 kg ha^{-1} depressed plant yields, leading to low economic returns. In this study the yield response of *Obatanpa* was greater than that of *Domabin*, possibly due to the genotypic superiority of the former in terms of nutrient use efficiency and hence grain yield. This agrees with widely accepted assertion that plant genotypes differ in their responses to changing soil fertility and environmental conditions (Faisal et al., 2013).

The significant negative correlation between the soil exchangeable K concentration with both MSD incidence (r = -0.4393) and severity (r = -0.3189) agreed with the findings of Wang et al. (2013). They reported that increased K fertilizer application significantly reduced the incidence of stem rot disease and aggregate sheath spot of rice. Magenya et al. (2009) also observed a significant negative correlation between soil K concentration and number of *C. mbila* (vector of MSV) and noted that fields that exhibited low K contents had the highest numbers of *C. mbila*.

The MSD incidence and severity had positive correlation with the maize height and the grain yield (Table 6). The low mean MSD incidence and severity of 29.7% and 1.4, respectively in the major cropping season implied that although the disease incidence occurred, the plants were able to maintain their own growth and yield in spite of infection as reported by Dordas (2009). The findings however disagreed with that of Bosque-Perez et al. (1998) who reported a significant negative correlation of MSD incidence with plant height and grain weight. The disease also has been reported by Bua et al. (2010) to significantly reduce maize growth and yield. The lack of significant correlation between the MSD incidence and severity with grain crude protein content imply that the quality of maize grains is not affected by the MSD occurrence.

Table 7. Correlation matrices among MSD incidence and severity and **a**. plant height and grain yield **b**. soil N, P and K contents and **c**. leaf N, P and K contents**.**

Parameter	MSD incidence (%)	MSD severity	Plant height (cm)	
a				
MSD severity	0.905*	-	-	-
Plant height (cm)	0.595*	0.461*	-	-
Grain yield (kg ha^{-1})	0.403*	0.295*	0.507*	-
b	**Soil N**	**Soil P**	**Soil K**	**MSD incidence**
Soil P	- 0.041	-	-	-
Soil K	-0.177	0.5548*	-	-
MSD incidence	0.157	-0.233	-0.439*	-
MSD severity	0.077	-0.145	-0.319*	0.908*
c	**Leaf N**	**Leaf P**	**Leaf K**	**MSD Incidence (%)**
Leaf P	0.133	-	-	-
Leaf K	-0.173	0.501*	-	-
MSD Incidence (%)	-0.057	0.017	-0.110	-
MSD Severity	0.025	-0.020	-0.296*	0.141

*Significant at $p<0.05$.

The results showed that higher maize leaf N content was associated with higher MSD severity. MSD severity in the minor season was significantly higher on conventional tillage system (Table 7). Also, *Domabin* which was less tolerant to MSD showed higher leaf nitrogen content. Similar results were obtained by Zafar and Athar (2010) in their investigation to reduce disease incidence of cotton leaf curl virus (CLCUV) in cotton (*Gossypium hirsutum* L.) by potassium supplementation. A comparison of two cotton varieties showed that diseased leaves of susceptible variety had significantly greater concentration of N than the healthier leaves of both susceptible and resistant varieties.

A significantly higher K content in the leaf of *Obatanpa* than *Domabin* reflected in a significantly lower MSD severity and greater plant heights recorded for *Obatanpa* variety compared to the higher MSD severity and lower plant heights of the *Domabin* variety, especially during the minor season. Increased disease resistance in *Obatanpa* could be related to its ability to absorb greater amounts of the applied K. According to Wang et al. (2013), the presence of adequate plant K content decreases internal competition by pathogens for nutrient resources, and increases phenol concentrations which play a critical role in plant resistance. The significant negative correlation observed between leaf K content and MSD severity confirms this suggestion and was also evident in the higher grain yield produced by *Obatanpa.*

Conclusions

The study showed that no-tillage and fertilizer application, particularly K addition, are effective in minimizing the occurrence and severity of MSD. Furthermore, it was concluded that the use of improved varieties such as *Obatanpa* can reduce incidence and severity of MSD as compared to local varieties such as *Domabin*.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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