UNIVERSITY OF CAPE COAST

INFLUENCE OF FERTILIZER APPLICATION, MAIZE VARIETY AND TILLAGE SYSTEM ON THE INCIDENCE AND SEVERITY OF MAIZE STREAK DISEASE AND GRAIN YIELD

BY

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature…………………………. Date…………………….

Name: Dorcas Blankson

Supervisor's Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

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ABSTRACT

Maize streak disease (MSD), one of the most destructive maize diseases causes an estimated yield loss of about 20 % in Ghana. A baseline survey was conducted from July to August, 2015 across three agro-ecological zones within the Volta Region to assess the level of MSD incidence and severity in the zones. In addition, field experiments were conducted at Nkwanta during the cropping seasons of 2015 to assess the effects of tillage practices, maize variety and fertilizer application on the incidence and severity of MSD.The split-split plot design with four replications was used, with tillage as the main plot, maize variety as the sub-plots and fertilizer application as the sub-sub plots. The MSD severity was assessed using 1-5 visual scale. The study revealed that soils across the Volta Region were low in major nutrients, especially nitrogen and phosphorus, but adequate in potassium. Mean MSD incidence as high as 84.5% was recorded in the region and varied among the agro-ecological zones. No relationship was detected among soil N, P and K contents and MSD prevalence in the region. Fertilizer application effectively reduced the MSD impact on growth and yield. Incidence and severity of MSD under no-tillage system was significantly lower than under conventional tillage. Plants on the plots with no added nutrients exhibited severe MSD symptoms, including stunted growth and reduced grain yield. However, MSD incidence and severity did not correlate significantly with the content of grain crude protein. The severity of MSD positively correlated with maize leaf N content, while increasing leaf K content resulted in reduced MSD severity. It can therefore be concluded that tillage and fertilizer application affect the severity of MSD in low nutrients soils.

KEY WORDS

Agro-ecological zones

Grain nutrient content

Inorganic fertilizer

Maize streak disease

Maize varieties

Tillage systems

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DEDICATION

To Mr Albert Bruce Acquah

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LIST OF ACRONYMS

EDTA	Ethylene diaminetetra acetic acid
ECEC	Effective cation exchange capacity
FAO	Food and Agriculture Organization
GSS	Ghana Statistical Service
IITA	International Institute of Tropical Agriculture
MSD	Maize streak disease
MiDA	Millennium Development Authority
MoFA	Ministry of Food and Agriculture
MSV	Maize streak virus
MOP	Muriate of Potash
SRID	Statistics, Research and Information Directorate
TSP	Triple Super Phosphate

CHAPTER ONE

INTRODUCTION

Background to the Study

Inorganic fertilizer exerts strong influence on plant growth, development and yield (Stefano, Dris & Rapparini, 2004). Plant nutrition, although frequently unrecognized, contributes significantly to disease control and the ability of plants to express their genetic potential for disease resistance (Agrios, 2005).

Maize (*Zea mays* L.) is Ghana's most important cereal crop in terms of area planted and accounts for 50-60% of total cereal production (Agyare, 2013; Millennium Development Authority [MiDA], 2010). It is the largest staple crop in Ghana, which contributes significantly to consumer diets and is also one of the most important crops for food security (Ministry of Food and Agriculture [MoFA], 2013). It is also an important component of poultry and livestock feeds as well as a raw material for the brewing industry (Angelucci, 2012). In Ghana, maize yields of up to 6.0 t ha^{-1} can be obtained but the average yield is about 1.7 t ha^{-1} (Voto Mobile Org, 2015) resulting in inadequate supply of maize for its numerous uses. The vast majority of maize is produced by smallholder farmers under rain fed conditions, leading to wide annual variations in yield (MiDA, 2010).

Most soils in Ghana are of low inherent fertility coupled with higher rates of soil nutrient depletion, especially of nitrogen and phosphorus (MoFA, 2015). The maize streak disease (MSD) caused by maize streak virus (of the genus Mastrevirus) is one of the most serious biotic factors affecting maize production in Ghana. Serious epidemics have been reported in at least 20 African countries including Ghana (Karavina, 2014). In situations of severe disease incidence, the disease can result in up to 100% yield loss (Danson, Laget, Ininda & Kimani, 2006). Therefore, MSD is a major contributor to shortages of maize in endemic regions. In this regard, there is the need to investigate how inorganic fertilizer application or change in the soil environment influences soil nutrient availability to possibly control MSD.

Statement of the Problem

Soil fertility decline has been recognized as the major biophysical constraint affecting maize yield in small-holder farming systems in Ghana (MoFA, 2013). The MSD has also been identified as a yield declining factor in maize production in Ghana (Oppong, 2013). There has been a current upsurge of the disease in the Volta Region affecting significantly the yield and production of maize. MSD has made the production of maize in the Volta Region less remunerative and highly risk-prone. The losses in yield due to the disease are not easy to quantify and may range from 0-100% (Alegbejo, Olojede, Kashina, & Abo, 2002).

Attempts so far have involved the release of resistant maize varieties and with adoption of agronomic practices suitable for endemic regions (Oppong, 2013). The methods used in MSD management such as the use of MSD resistance maize varieties, chemical, biological, and cultural controls have given conflicting results. Another problem with the disease is that its occurrence is sporadic and unpredictable, thus makes it very difficult to decide which, where and when to apply a particular control strategy (Martin & Shepherd, 2009). Soil nutrient management provides a potential method of widening the scope of MSD management (Magenya, 2009). This work sought to find out the best land preparation method and most effective inorganic fertilizer (NPK) application rates that will reduce stress posed by the disease, and increase grain yield of maize in the Volta Region.

Justification

Several methods that have been employed to manage MSD, including the use of insecticides against leaf hoppers, planting to avoid the peak period of pest attack and the use of resistant varieties focus only on the elimination of yield losses associated with the disease without any attempt to increase yield. Yet, almost all these existing techniques have not been very successful (Magenya, Mueke & Omwega, 2008). Therefore, there is the need to find alternative measures to control this disease which do not harm the environment and at the same time, increase maize yield and improve grain quality. In this view, the study focuses on the effectiveness of soil fertility enhancement strategies to minimize the incidence and severity of MSD.

Major nutrients such as N, P and K supply are important for growth and development of plants and microorganisms, as they are also important factors in disease control (Dordas, 2009). Research has made it clear that the severity of most diseases and the control of disease pathogens can be reduced by proper nutrition (Spectrum Analytic Inc., 2000). Nutrients can influence the development of a disease by affecting plant physiology and biochemistry (Dordas, 2009). Host plant nutrition also affects disease severity by either affecting the vector, the virus, or both (Dordas, 2009). Inorganic fertilizer application produces a more direct means of using nutrients to reduce the severity of many diseases (Oborn et al., 2003). The soil nutrient contents have been reported to influence the variability of spatial distribution and abundance of leafhopper which is the vector of MSV (Orians & Jones, 2001).

Huber and Graham (1991) suggested that apart from nutrient addition through fertilizers, the soil environment can also be changed to influence nutrient availability through practices such as tillage (as cited in Dordas, 2009). Tillage affects the occurrence of plant disease, for instance, no-tillage results in greater soil-residue contact, which may allow soil microbes to compete better against pathogens residing in the straw (Bowden, 2015). Conventional tillage reduces crop debris that serves as a refuge for many pathogens and also destroys volunteer plants that serve as a reservoir for pathogens such as viruses that require a living host. Tillage can alter the soil environment and these changes can result in an increase, decrease or no change in disease incidence or severity, depending on the tillage practice, cropping system and disease (Dordas, 2009).

There is the need for development of proper fertilizer programmes based on soil tests, plant analysis, and disease monitoring and from that, elucidate the most effective inorganic (NPK) fertilizer rate together with the tillage system that would either reduce stress posed by disease pathogen and or economically increase the grain yield of maize in the Volta Region of Ghana.

Research Objectives and Hypotheses

General objectives

The project sought to determine the effect of different rates of N, P and K fertilizer application, maize variety and tillage system on incidence and severity of MSD as well as maize grain yield and protein content.

Specific objectives

1. To assess the relationship between soil chemical characteristics under different agro-ecological zones and incidence as well as the severity of MSD in the Volta Region.
2. To determine the influence of different fertilizer (N, P and K) application rates, maize varieties and tillage systems on the incidence and severity of MSD.
3. To determine the effect of different fertilizer (N, P and K) application rates and maize varieties on the growth and grain yield of maize under conventional and no-tillage systems.
4. To measure the crude protein, P and K content of maize grains as affected by different rates of N, P and K application.
5. To assess the relationships among maize leaves N, P and K content determined at silking time and MSD incidence and severity.

Hypotheses

The hypotheses underlying this study are presented below:

1. Prevalence of maize streak disease across the Volta Region is not related to the inherent macro nutrient (N, P and K) contents of soils of the region.
2. The impact of the incidence and severity of MSD on growth and yield of maize is not affected by fertilizer (N, P and K) application, maize variety and tillage.
3. The MSD incidence and severity is unaffected by increased maize leaf nutrients (N, P and K) content that result from fertilizer application.

Significance of the Study

The findings from this research will inform researchers about the soil nutrients content and prevalence of MSD in the agro-ecological zones involved in the study. Findings from this research will also help to establish the optimal NPK application rate, appropriate maize variety and tillage system that will minimize the impact of MSD and improve maize yields in the Volta Region.

CHAPTER TWO

LITERATURE REVIEW

This chapter reviews existing literature concerning the research topic: "Influence of Inorganic Fertilizer Application, Maize Variety and Tillage System on the Incidence and Severity of Maize Streak Disease and on Maize Yield". The review covers the production, constraints, fertility status of soils and interventions to boost maize production in Ghana. The review also covers the epidemiology, economic importance and the existing interventions for the control of MSD. This chapter further provides information regarding the use of inorganic fertilizer as an option for MSD control and the relationship between soil properties and soil nutrients on vectors and viral diseases. This review again covers the effects of tillage on plant diseases and yield, as well as effects of inorganic fertilizer application on maize grain nutrients content.

Maize Production in Ghana

Maize (*Zea mays* L.) is the most important cereal crop in Sub-Saharan Africa (Food and Agriculture Organizations [FAO], 2005). Maize has been cultivated in Ghana since it was introduced in the late 16th century and attracted the attention of commercial farmers. However, it never achieved the economic importance attained by traditional plantation crops, such as oil palm and cocoa (Morris et al., 1999). Over time, the eroding profitability of many plantation crops served to strengthen interest in commercial food crops, including maize (Morris et al.). Currently, maize is Ghana's most important cereal crop, accounting for 55% of grain output (maize, rice, sorghum and millet) (Agyare et al., 2013). Additionally, maize is the second largest commodity crop in the country after cocoa. It is one of the most important crops for Ghana's agricultural sector and for food security (MiDA, 2010).

In Ghana, maize is often cultivated in association with other crops, particularly in the coastal savanna and forest zones, so planting densities are generally low. Average grain yield of maize is less than 2 t ha^{-1}. According to a report by the Statistics, Research and Information Directorate (SRID) of the Ministry of Food and Agriculture (MoFA), maize production volume increased by 38% from 2007 to 2011, but this was mainly due to the 30% increase in area harvested. Over the same period, the average yield of maize was around 1.7 t ha^{-1} (Agyare et al., 2013).

Maize accounts for the largest planted area of all food crops in Ghana (Hill, 2014). Marketing of the crop represent an important source of income for many households, even households that cultivate maize primarily to satisfy their own consumption requirements (Hill, 2014). Maize grain is used as food, feed and industrial raw material in the manufacturing industry. The bulk of maize produced in Ghana is processed into indigenous dishes and consumed directly by humans (Sallah, Obeng-Bio, Amoako-Ando & Ewoo, 2002). It serves as an important source of infant nutrition, without any protein supplement such as egg, milk or beans (Morris et al., 1999). It is also an important component of poultry feed and to a lesser extent the livestock feed sector, as well as an ingredient for the brewing industry (FAO, 2012).

Constraints to Maize Production in Ghana

According to MiDA (2010), the average yield of maize in Ghana is 1.7 t ha^{-1} as against achievable yields of approximately 6 t ha^{-1} (Hill, 2014). In the Volta Region of Ghana, the average yield recorded in 2010 was 1.8 t ha^{-1}

(MoFA, 2010). This yield gap can be traced to many factors which may be either biotic or abiotic. In Sub-Saharan Africa, the major abiotic yield diminishing factors are unpredictable rainfall and low levels of soil fertility. Biotic factors that reduce maize yields in Africa include stem borers, the parasitic weed *striga*, and maize streak virus (MSV) (Magenya et al., 2008; Obeng-Bio, 2010).

Other researchers have attributed yield decline in maize to other factors, for example, in a survey across the forest-transition zones of Ghana, farmers ranked limited source of finance, lack of physical assets, climate change, and pests and diseases as constraints to production (Oppong et al., 2014). Also, Agyare et al. (2013) pointed out that lack of credit for farming activities is a key constraint inhibiting farmers' ability to produce maize in the Ashanti and Brong-Ahafo regions of Ghana.

With regard to yield loss on the field, farmers may fail to pinpoint the exact causes. Even after the major cause has been established, there is the likelihood of failing to quantify the losses associated with it. According to Martin and Shepherd (2009), there is lack of accurate account of annual impact of diseases, including MSD, on maize production in African countries. In order to improve maize yields in Ghana, there is a need to recognize nutrient depletion and MSD equally as threats and emerging threats to maize production and therefore initiate the earliest intervention.

Soil degradation, including decline in soil fertility, is one of the major factors underlying low crop yields in Ghana. Soil fertility decline is attributed to disappearing fallows, continuous cropping without fertilization, agricultural intensification and deforestation (Agyare, 2012). It has been observed that small-scale farmers often remove large quantities of nutrients from soils without replenishment (Magenya, Mueke & Omwege, 2009). Also, most soils in Ghana are developed on highly weathered parent material for which the organic matter content is generally low, and is therefore of low fertility (MoFA, 2015). Further, soil erosion, low vegetative cover, as well as cultural practices which include burning, crop and residue removal have further exacerbated the low fertility problem (MoFA, 2015). Significant soil multi-nutrient (NPK) deficiencies have been found in all the agro-ecological zones of Ghana with nitrogen and phosphorus being the most deficient. Generally, Ghana is estimated to have annual nutrient losses of around 60 kg NPK ha^{-1} (Hill, 2014).

The least predicted and most destructive disease of maize in Africa is maize streak virus disease. The disease causes yield losses that range from a trace to almost 100% (Alegbejo et al., 2002). Like many virus-induced diseases, maize streak disease is naturally erratic, varying from insignificant in some years to epidemic proportions in others. Yield losses vary with the time of infection and varietal resistance (Bosque-Perez et al., 1998). Field trials relying on natural infection in East Africa detected yield losses of between 33 and 56% (Guthrie, 1989), whereas losses of 100% were reported in many countries in West Africa by Fajemisin and Shoyinka (1976). Fajemisin et al. (1986) reported a yield reduction of 71 to 93% in maize due to MSV (as cited in Lemma, Michael & Tsegay, 2015). Magenya et al. (2009) also reported yield losses which ranged from 25% to 46% in Kenya in 2005 and 2006. Alegbebo et al. (2002) and Martin and Shepherd (2009) estimated yield losses due to MSD from 0 to 100%. They added that the extent of yield was dependent on the maize cultivar and time of infection (cited in Karavina, 2014). Ininda et al. (2006) also reported that food security in the small-holder sector of Kenya was greatly affected because up to one million metric tons of maize grain is lost annually to MSD (cited in Karavina, 2014). In Ghana, farmers lose about 20% of their produce to MSD (Oppong, 2013).

Interventions to Improve Maize Production in Nutrient Deficient Soils

Deep, permeable well-drained and fertile soils rich in organic matter, and well supplied with available nutrients are ideal for maize production (Department of Agriculture, 2003). To improve maize yields in Ghana, great attention ought to be given to soil nutrient replacement. MoFA (2015) advised that the improvement of crop yields in Ghana soils is dependent on careful management of the soils with the objective of preventing and controlling erosion, using organic fertilizer to increase soil organic matter content, and replacing plant nutrients lost through erosion and crop uptake.

On small-holder farms, the use of organic inputs has great potential for improving soil productivity and crop yield, but their bulkiness, low nutrient content and slow nutrient release make their use less convenient (Quansah, 2010). At high levels of maize grain yield, organic inputs are likely to be insufficient and must be supplemented with inorganic fertilizers (Quansah, 2010). Therefore, the use of inorganic fertilizer is necessary for improved maize yield. Inorganic fertilizers have advantage for yield increase because the nutrients present in them are easily absorbed by the plants (Jaliya, Falaki, Mahmud & Sani, 2008). Additionally, maize has a strong nutrient depleting effect on the soil, so when it is continuously cropped without fertilizer application, it often leads to poor grain yield (Jaliya et al., 2008). Therefore, the use of mineral fertilizers becomes the most effective and more convenient way to improve maize yields.

Among the plant nutrients, nitrogen, phosphorus and potassium play crucial roles in determining the growth and yield of maize (Adeniyan, 2014). Most researchers have affirmed that fertilizer application significantly affects crop yield. Maize responds favourably to fertilizer application especially where soils are low in fertility; however, better growth and higher yield are usually obtained with the optimum fertilizer application (Jaliya et al., 2008).

Nitrogen is taken up in large amounts by maize, as it has many functions including the promotion of rapid growth, increasing leaf area and forms integral parts of many important components including amino acids (Kow et al., 2015). Nitrogen influences the rate of crop growth and quality and also increases the plumpness of maize grains as well as the protein content of seeds (Kow et al.). Most Ghanaian soils have been reported to be deficient in nutrients particularly nitrogen (MoFA, 2015). For the importance of nitrogen on growth and overall maize production to be fully realized, external input of fertilizer is required.

Regardless of the soil type, N application has been reported in a number of studies to increase maize yields as well as quality. For example, maximum number of grain per cob, grain weight, grain yield and harvest index were all observed to increase in plots receiving 250 kg N ha^{-1} in an experiment by Hammad et al. (2010) (as cited in Mensah, 2014). Similarly, Bashir et al. (2012) also reported the highest maize grain yield on plots fertilized with 175 kg urea ha^{-1}. Also, maize grain yield of 7.4 t ha^{-1} was realized on plots treated with 225 kg N ha^{-1} (Sharifi et al., 2016).

Phosphorus (P) is another limiting nutrient in crop production in Ghana (MoFA, 2015). An adequate supply of easily available phosphorus is of great importance during plant growth, especially at the early stages of growth, because it is needed for root development, stalk and stem strength, flower and seed formation and crop maturity (Mensah, 2014). Maize demand for phosphorus is high and it is also sensitive to a low phosphorus supply. In a field trial by Iqbal and Chauhan (2003) with a basal dose of 150 kg N ha^{-1} and different rates of P application, the number of cob-bearing plants which has a direct effect on the final grain yield was highest in plots that received 75 kg P ha$^{-1.}$ However, in the same trial the highest grain yield was attained on a plot which received 150 kg of P ha^{-1}, though not significantly different from the rest that received 75 and 100 kg P ha^{-1}, but far higher than the control plots on which no P was applied. Conversely, a rather conflicting result was reported by Mazengia (2011) that phosphorus fertilizer rates had no significant effect on grain yield. The application of P fertilizer was negatively correlated with grain yield and, thus, a unit increase in P fertilizer rate decreased grain yield by 6.1units. It was further realised that the relationship between the applied P rates and grain yield showed decreasing trend of yield beyond application of 23 kg P ha^{-1}, and the plots where no P fertilizer was applied gave higher yield compared to application of 69 and 92 kg P ha^{-1}. That is the yield obtained from no application was 10.6% greater than the highest P application rate, 92 kg P ha^{-1} (Mazengia, 2011).

Potassium plays an essential role in plant physiological processes such as photosynthesis and respiration; it thereby directly determines the rate of growth and yields (Arnon, 1975; Kow et al., 2015). In Ghana, a number of studies have reported that there is usually lack of response to K fertilizers on most soils, especially on those from the fallow state (Yawson, Kwakye, Armah & Frimpong, 2011). However, given the state of these same soils as a result of intensive cropping without nutrient replacement, K fertilizer application becomes mandatory for sustained crop production (Yawson et al., 2011). Maize grain yield of 4265 and 6156 kg ha^{-1} were attained on plots fertilized with 0 and 100 kg of K ha^{-1}, respectively, when the same level of 200 and 150 kg ha^{-1} of N and P respectively was applied (Radulov, 2012). Similarly, grain yields from K and no-K treatments were significantly different, comparing NPK treatments with the control and NP treatment, respectively; average increases in grain yield ranged between 17.3 and 23.2% with 112.5 kg K ha^{-1}, and 20.1 to 26.2% with 225 kg K ha^{-1} (Lei et al., 2000). On the contrary, Bruns and Ebelhar (2006) did not find K fertilization to improve grain yield, although they reported increased K tissue concentrations as a result of K fertilization (as cited in Radulov, 2012).

Different rates of N, P, and K fertilizers significantly affect maize yield, but the effect may vary considerably between, soils, maize varieties and seasons, and therefore, it will be very difficult to establish the optimal fertilizer rates and fertilizer combinations for high yields in a particular region (Arthur, 2014). A highest grain yield of 6.29 t ha^{-1} was recorded with 250 kg ha^{-1} fertilizer application and was not significantly different from that produced in the 350 kg ha^{-1} (5556 kg ha^{-1}); but both were significantly higher than those on plot fertilized with 150 and 0 kg ha^{-1} fertilizer in the major cropping season as reported by Arthur (2014). Maize yield of 7.95 t ha^{-1} was obtained on a plot that was fertilized with 400 kg N ha^{-1} (NPK 15:15:15) and the lowest yield was recorded on the plot where no fertilizer was applied (Law-Agbomo et al., 2009). Similar result was reported by Tahiru et al. (2015) in an experiment to determine fertilizer and genotype effects on two soils in the Northern Region of Ghana. In both soils, the plot on which NPK 90:60:60 kg ha^{-1} was applied recorded grain yield of 2361 kg ha^{-1} which was higher than the yield of the recommended fertilizer rate of 60:40:40 kg ha^{-1} with a yield as low as 213 kg ha^{-1} was recorded on plot where no fertilizer was applied.

Maize yields in Ghana have continued to rise slowly at long-term trend growth rates, and show no obvious jump, even after the fertilizer subsidy had been introduced (MoFA, 2015). Studies have shown that crop response to inorganic fertilizer on farmers' field is still low (MoFA, 2015) despite higher responses that had been achieved in field trials that mimicked farmer growing conditions. This is an issue of concern that need to be addressed.

Epidemiology of Maize Streak Disease

Maize streak virus (MSV) was initially named as 'mealie variegation', but renamed 'maize streak virus' in 1925 (Magenya et al., 2008). It is the most economically significant member of the genus *Mastrevirus* of the family Geminiviridae (Magenya et al., 2008). Maize streak virus is a causative agent for maize streak disease (MSD) which is indigenous to African grasses; and it prevalent from sea level to 2000 m above sea level (Karavina, 2014). The MSV is obligatorily transmitted by various species of leafhoppers of the genus

Cicadulina (Cicadilidae: Homoptera); the most important vector is *Cicadulina mbila* which has a wider geographical range and greater capacity to transmit the virus than any other leafhopper species (Karavina, 2014). *Cicadulina mbila*, which is known to move to different plant tissues when feeding, inoculates MSV into maize by injecting phloem tissues (Magenya et al., 2009).

The maize plant is susceptible to MSD from emergence to tasselling. Symptoms of MSD consist of broken to almost continuous, narrow, white chlorotic stripes which develop over and along the vein on most of the leaf surface (Bosque-Perez & Alam, 1992). They first manifest as minute pale circular spots in the lowest exposed parts of the leaf, and later develop into discontinuous pale yellow streaks along the blades parallel to the veins (Pioneer Hi-Bred International [PHI], 2010). The chlorosis is caused by the failure of chloroplasts to develop in the tissues surrounding the vascular bundles and thus results in reduced photosynthesis and increased respiration leading to reduction in leaf length and reduced growth. The affected maize plants become shorter and produce smaller grains and cobs (Karavina, 2014; Magenya et al., 2008). The MSD outbreak occurs under particular environmental conditions such as drought followed by irregular rains around the time when maize is being planted. Certain farming practices such as multiple cropping, crop rotations and so on, are also strongly associated with increased MSD incidence (Martin et al., 2009).

Management and Existing Interventions for the Control of MSD

In countries where farmers are fully aware of MSD and researchers have done a bit of impact assessment of the disease on their economy, numerous strategies have been recommended for the management of the disease. The availability, feasibility and cost-effectiveness of each method differ with the production system, that is either commercial or subsistence system (Karavina, 2014).

The use of natural enemies (predators and parasitoids) for the control the leaf hoppers has been demonstrated in some areas. However, no exhaustive attempts have been made to identify and utilize biological control agents of leafhoppers in Africa (Magenya et al., 2008). There is the need to explore and identify indigenous natural enemies of *Cicadulina spp.* present in Africa.

The use of resistant cultivars is by far the most effective, economically viable and environmentally friendly method for MSD management (Magenya et al., 2008). Resistant cultivars are produced through either conventional breeding or genetic engineering with transgenic MSV-resistant maize cultivars. Genetically modified crops cannot be used in the country because in Ghana like in most African countries, the use of such crops is banned (Karavina, 2014).

In Ghana since 1979, all breeding efforts have placed emphasis on developing MSV-resistant varieties which led to the release of cultivars such *Abeleehi* and *Okomasa*, a follow up was made in 1992 with the release of *Obatanpa* (Oppong, 2013). In spite of all these efforts at breeding of varieties against MSV disease, sporadic outbreaks of MSV have continued to occur in Africa, with significant yield losses. According to a report by Bosque-Pérez (2000), even some maize varieties known to be resistant to MSV in one ecological zone, would show susceptibility to the disease in another (as cited in Magenya et al., 2008).

Chemical control is another common method employed by farmers in all parts of Africa in tackling numerous diseases, including MSD. The application of pesticides is aimed at either controlling the vectors or killing grasses that may serve as alternative hosts for the leafhopper (Martin et al., 2009). However, studies have never mentioned the incidence of virus diseases and, thus failed to clarify whether the increase in yield was due to reduced direct feeding damage or due to low virus incidence (Magenya et al., 2008). In addition, reports show that there has been several ill health cases associated with the application of pesticides in maize-based systems in Africa (Magenya et al., 2008).

Various cultural practices are also employed in the management of MSD. Crop rotation or intercropping with broad leafed crops minimize invasion by viruliferous leafhoppers since MSD does not infect such plants. However, small-holder farmers prioritize the growing of staple cereal crops over MSD management since they usually own small land sizes (Karavina, 2014). Also, Owor (2008) noted that these methods have no discernable impact on MSD incidence, and do not detectably improve yields (cited in Martin et al., 2009). Some researchers recommend the practice of disease avoidance by adjusting planting dates to avoid migrating leafhoppers landing on young plants. However, given the unreliable and erratic rainfall, it is not feasible to recommend planting of maize, before the onset of rains, or even late planting (Magenya et al., 2008). Even though control of MSD using appropriate cultural strategies is cheapest and most accessible to most small-holder farmers, it is difficult to realize its full potential due to the inherent unpredictability of MSD (Martin et al., 2009).

Use of Inorganic Fertilizer as an Option for MSD Management

For the control and management of MSD to be widely applicable and effective in Africa, Magenya et al. (2008) suggested that better use of basic agricultural tools such as fertilizer can have a substantial impact on MSD and other maize diseases, simply because stronger, healthier plants are better able to resist pathogens (Martin et al., 2009). Plants require nutrients for growth and development and also disease control (Agrios, 2005). Essential plant nutrients affect resistance or tolerance (Dordas, 2009). Chaboussou (2004) noted that K increases plant growth, and reduces viral concentration. Similarly, Orians and Jones (2001) noted that the spatial distribution and abundance of leafhoppers and MSV pathogens were influenced by the levels of soil nutrients. Martin et al. (2009) also observed that leafhoppers are attracted to yellowing leaves and so healthy plants are likely be less appealing to leafhoppers, and should therefore get infected less frequently than unhealthy ones.

The use of innovative soil fertility management practices can be a potentially useful method of widening the scope of MSD management strategies available to small-scale maize farmer in the tropics (Magenya et al., 2008). The availability of inorganic fertilizers has brought about the elimination of many diseases through improved plant resistance, disease escape or altered pathogenicity (Huber et al., 2007). Dordas (2009) suggested that nutrient supply through fertilizers is an important practice that can help in the control of plant disease. The use of fertilizers is a more direct means of supplying nutrients to plants to reduce disease severity that can control MSD (Dordas, 2009). Also, fertilizer use is a relatively risk-free direct investment in a crop, the initial cost of which will almost always be recouped through higher yields; unlike insecticides and herbicides which are frequently perceived by resource-poor farmers as “grudge” inputs that minimize losses due to potential threats such as poisoning and pollution (Martin et al., 2009). However, the effect of inorganic fertilizer application in reducing yield decline due to MSD remain to be demonstrated; even if there is no direct effect, they will still certainly have a great impact on over-all African maize production (Martin et al., 2009).

Relationship Between Soil Chemical Properties and Plant Diseases

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 & Nicolls, 2003). Several physico-chemical parameters of the soil, such as soil pH, nitrogen, carbon and organic matter content, as well as several cations have been often related to disease suppression (Bonilla et al., 2012).

Soil organic matter affects many soil functions which are related to soil health, such as moisture retention, infiltration among other properties (Dordas, 2009). Soil organic matter can impact not only the total soil nutrient content but also nutrient availability, and that can affect disease incidence by increasing plant resistance, improving plant growth and influencing the pathogen’s environment (Dordas, 2009). According to Altieri et al. (2003) high soil organic matter enhances the level and diversity of soil macro and micro biota and provides an environment that enhances plant health. For example, Cytospora canker of hazel nut caused by the fungus, *Cytospora corylicola*, was found to correlate negatively with organic matter content of soils (Lamicchane et al., 2014). Also, Abbasi et al. (2002) cited in Lamicchane et al. (2014) observed that the severity of bacterial spot of tomato and bacterial spot of radish, caused by *X. campestris pvs. vesicatoria* and *armoraciae*, respectively, were suppressed under high soil organic matter content. Most literature point out only the indirect effect of soil organic matter on plant disease, especially those of viral diseases and the few that try to show the direct relationships do so when dealing with only soil-borne diseases.

Soil pH is also important in the occurrence and severity of plant diseases. Plants and pathogens require different pH optimal for their growth and reproduction (Alhussaen, 2012). Litchfouse (2009) observed that soil pH influences plant disease infection and development, directly by its effect on soil-borne pathogen and indirectly through the availability of soil nutrients to the host plant. Broders et al. (2009) noted that pH level had a significant positive linear relationship with species diversity and disease incidence of *Pythium ultimum* on tomatoes. Also, Club root, Rhizoctonia canker and Fusarium wilts of fruit and vegetable crops were all controlled by liming (to increase soil pH) which favoured nitrification in the soil (Huber et al., 2007). Bonanomi et al. (2010) showed a rather contrasting result that pH amendment in general did not statistically correlate with disease suppression except for Fusarium species (cited in Bonilla et al, 2012). If one should pose a question: Does the pH level of soil (which directly affects host plant) also affect vectors that transmit the diseases, and thus the pathogen they carry? If yes how? This presents a gap in the literature that needs to be addressed.

Soil exchangeable cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Al^{3+} and H^{+}) are also related to plant disease control. Soil properties namely, total carbon, cation exchange capacity, clay, exchangeable acidity, iron, manganese, total nitrogen, organic matter and silt, were all observed to be positively correlated with the Take-all disease (Ownley, Duffy & Weller, 2003). Calcium has been recognized as a very important nutrient in plants in terms of disease susceptibility because of the two major roles it performs in plants. First, calcium is an important component of the cell wall structure and second, it is important for the stability and function of the plant membrane (Spectrum Analytic Inc., 2000). Leaf spot disease for example, has been identified to be often proportional to the degree of calcium deficiency in the plant. Close correlation between the calcium content of the skin of potato tubers and bacterial soft rot of the tubers caused by various species of the bacteria *Erwinia* has also been identified (Huber et al., 2007; Spectrum Analytic Inc., 2000). Magnesium has also been reported to reduce susceptibility to pathogen-produced macerating enzymes as long as calcium levels remain sufficient, though there is little information about their role in plant diseases (Huber et al., 2007). From the perspective of the individual cations in the soil, it can be deduced that the overall cation exchange capacity (CEC) of the soil can exert strong influence on plant disease incidence and severity.

Disease Reduction with Soil Nutrients

Dordas (2009) defined “Resistance” of a plant as its ability to limit the penetration, development and reproduction of the invading pathogens. Although plant disease resistance and tolerance are genetically controlled (Agrios, 2005), they are affected by the environment, especially by nutrients

(Dordas, 2009). Nutrients affect the development of a disease by affecting plant physiology or by affecting pathogens, or both. First and foremost, the effect of mineral nutrition on disease resistance begins directly with the plant itself by responding to fertilization resulting in increased growth, which may constitute a form of disease escape (Huber et al., 2007).

Furthermore, the level of nutrients can affect the physiology and biochemistry, and especially the integrity of the cell walls, membrane leakage and the chemical composition of the host plant (Dordas, 2009). For instance, plants contain preformed anti-microbial compounds, and have active response mechanisms where inhibitory phytoalexins, phenols, flavonoids, and other defence compounds accumulate around infection sites of resistant plants (Huber et al., 2007). So when plants are supplied with sufficient nutrients, a general form of disease resistance may be provided by maintaining a high level of these inhibitory compounds in their tissues or by quick response to invasion by a pathogen (Huber et al., 2007).

Sometimes, differences in metabolism of different forms of a nutrient such as N, deny an obligate pathogen of essential intermediate compounds needed for survival, pathogenesis, or reproduction (Agrios, 2005). Sufficient nutrients supplied to plants may also shorten a susceptible growth stage for some plant-pathogen interactions. In some cases, specific nutrients may change the abiotic and biotic soil environment to favour specific nutrient uptake, biological control, or enhance genetic resistance (Huber et al., 2007). However, nutrient effects on diseases may vary, a particular element which decreases the severity of some diseases, may increase others, and some have an opposite effect in different environments (Huber et al.).

Major plant nutrients (N, P and K) and their Effects on Vectors and Viral Diseases

Magenya et al. (2009) proposed 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 MSD. The leafhopper (*C. mbila*), is also known to move to different plant tissues while feeding, and this behaviour as suggested by Lett et al. (2001) may be dependent on nutritive and health status of the host plant.

More often than not, nutrient conditions favourable for good plant growth are favourable for virus multiplication, and this holds true particularly for nitrogen (N) and phosphorus (P) (Spectrum Analytic Inc., 2000). However, despite the rapid multiplication of the virus, visible symptoms of the infection do not necessarily correspond to an increase in mineral nutrient supply to the host plant (Spectrum Analytic Inc., 2000). According to Spann and Schumann (2013), symptoms of virus infections sometimes disappear when N supplies are large, even though the entire plant is infected and visible symptoms depend upon the competition for N between the virus and the host cells. This competition varies with different diseases and can be influenced by environmental factors, such as temperature (Spann et al., 2013). Also, in an observation by Chaboussou (2004), inhibition of plant viral agents was strongly correlated to plant deficiency in nutrients needed for viral growth and reproduction.

Nitrogen is the most important nutrient for plant growth and also has major effect on diseases. Although N is one of the most important nutrients for plant growth and disease development, reports of its effect on disease development are often inconsistent and contradictory (Dordas, 2009). Prasad et al. (2003) (as cited in Magenya et al., 2008), investigated the influence of N levels (0, 60, 120 and 200 Kg ha^{-1}) on the population build-up of the brown plant hopper (*Nilaparvata lugens*, BPH) on rice cultivars and demonstrated that BPH population build-up was low (up to 60 kg N ha^{-1}) irrespective of the resistance of the rice cultivars.

Haltrich et al. (2000) (as cited in Magenya et al., 2008), stipulated that nitrogen in plant tissues is the principal attracting component of phytophagous insects because they found a positive correlation between migrations and reproduction of leafhoppers with soluble nitrogen content of host plants. Lu et al. (2004) demonstrated that increasing plant N significantly decreased the relative water content in rice plants due to damage by the brown plant hopper (*Nilaparvata lugens Stal*). In contrast, Magenya et al. (2009) observed a negative correlation between the levels of N in soils and species of *Cicadulina*. Chaboussou (2004) reported that in contrast to nitrate fertilizers, alkaline phosphate fertilizers have a beneficial effect against viral diseases, such that, by promoting maturity, they speed up the stage of resistance in the plant brought about by age (Huber et al., 2007) .

The role of phosphorus in disease resistance is variable and seemingly inconsistent. For example, a number of studies have shown that P application can reduce leaf curl virus disease in tobacco, yellow dwarf virus disease in barley, brown stripe disease in sugarcane and blast disease in rice (Dordas, 2008). Other studies reported a rather contrary result that application of P increased the severity of flag smut in wheat (Dordas, 2008). Magenya et al. (2009) noticed that fields with low soil phosphorus contents experienced a high percentage of yield loss. Chaboussou (2004) (as cited in Magenya et al. (2009)), also reported that phosphorus acts against viral diseases by promoting plant maturity, thus restricting the pathological effects of the virus.

Of all the nutrients that affect plant diseases and pests, potassium (K) is reported to be the most effective. As a mobile regulator of enzyme activity, K is involved in essentially all cellular functions that influence disease severity. According to Huber and Graham (1999), K can decrease the susceptibility of host plants up to the optimal level for growth, and beyond this point, there is no further increase in resistance which can be achieved by increasing the supply of K and its contents in plants (Dordas, 2008). It has been shown that K fertilization can reduce the intensity of several infectious diseases of obligate parasites, including tobacco mosaic virus. Magenya et al. (2009) also reported that a positive relationship exists between the K contents and the population of leafhopper (*C. mbila*) which transmits the MSV.

Balanced nutrition has a lot of advantages for the crop in question; the benefits of balancing N and K fertility is likely to result in both improved nutrition and disease suppression effects, even though there is no defined critical N:K ratio that suppresses disease (Spectrum Analytic Inc., 2000). Feeding intensity and reproduction by sucking insects tend to be higher on plants with higher amino acid content and this condition is typical of plants with a K deficiency, or a relative excess of N compared to these nutrients; and while the physical damage from the insects is important, they may also be vectors for viruses (Spectrum Analytic Inc., 2000). Also, Dordas (2008) reported that a crop receiving optimum K, but excess N was usually more susceptible to diseases. Phosphorus and N stimulate root growth of cereal plants so that P and N sufficient plants are able to compensate for tissue lost through root rots such as take-all and *Pythium* (Huber, 1980). The above findings indicate that balanced nutrition at the right time, when the nutrient can be most effective for disease control may also lead to higher yields.

Influence of Tillage on Plant Disease and Yield

Disease control through nutrient manipulation can be achieved by either modifying nutrient availability or soil nutrient uptake (Dordas, 2008). According to Dordas (2008), the most common way to influence nutrient availability is by fertilizer application. However, changing the environment through pH modification, tillage, moisture control and specific crop sequences can have a striking influence on nutrient availability. Tillage can affect disease resistance and also plant growth, by increasing the availability of certain elements and accentuate the benefits of nutrient amendment (Huber et al., 2007). The tillage methods practised for maize production in the world are extremely varied, ranging from the most primitive to the most sophisticated (Arthur, 2014). According to Khurshid et al. (2006), tillage contributes up to about 20% yield increase in crop production.

Conventional tillage involves intensive working of the soil to produce a fine tilth (Arthur, 2014). Minimum tillage is the least soil manipulation needed for satisfactory planting, growth and yield. No or zero tillage on the other hand, is the elimination of all tillage, except for the opening of a narrow slit for the placement of seed and fertilizer into the soil (Iqbal et al., 2005). The minimum and zero tillage are also regarded as conservative tillage. No-tillage accumulates residues on the soil surface; and therefore concentrates the pathogen propagule number on the soil surface this might or might not have impact on disease incidence. Adoption of conservation tillage by farmers has led to an increase in the incidence and severity of many stubble-borne diseases (Dordas, 2008).

Standing residues or residues lying on the soil surface are colonized by soil organisms more slowly, and pathogen survival and growth in the undisturbed residues are favoured in this system (Dordas, 2008). Krupinsky and Tanaka (2001) observed a higher incidence of leaf spot disease with no-till plots than conventional tillage in years with higher precipitation. Also, net blotch of barley was found to be more severe in no-till fields than in either minimum or conventional-till fields (Gilbert, 2005). On the other hand, tillage can affect the behaviour of vectors that carry diseases. Aphids that carry barley yellow dwarf virus are less likely to land in fields with abundant crop residue on the soil surface (Bowden, 2015). However, conventional tillage reduces crop debris that serves as a refuge for many pathogens. It also destroys volunteer plants that serve as a reservoir for pathogens, such as viruses or rusts that require a living host (Bowden).

The effect of tillage systems on crop yield is not consistent with all crop species, in the same manner as various soils may react differently to the same tillage practice (Arthur, 2014). Research conducted in the past, and recently, has confirmed the inconsistency of the result of tillage on maize yield. On a maize field fertilized with 110 kg N ha^{-1}, 48 kg P ha^{-1} and 91 kg K ha^{-1}, the yield obtained with no-tillage averaged 10% less than those obtained with conventional tillage (Arnon, 1975). Also, in an experiment conducted to examine the effects of tillage and NPK application on maize, taller plant height, thicker stem girth and higher grain yield were recorded on tilled plots with comparatively slow growth and reduced yield on no-till plots (Arthur, 2014). In contrast, Jones et al. (1968) noted that no-tillage, in comparison with conventional tillage, markedly decreased surface run-off and improved yields of dry matter and of grain. They attributed this mainly to improvements in moisture supply, in particular when they occur during the period of maximum stress. The use of minimum tillage resulted in higher grain yield; an average of 304 kg ha^{-1} maize was produced relative to yield in conventional tillage (Arnon, 1975). Contrary, yield of 6223 kg ha^{-1} was obtained in conventional tillage, which was better than 3761 kg ha^{-1} in minimum tillage (Arthur, 2014).

Effects of N, P and K Application on Maize Grain Protein and Mineral Content

Maize is a key source of food and livelihood for millions of people in the world. Therefore, the absolute and relative amounts of proteins produced in maize should be of major importance. This is because maize is reported to provide an estimated 15% of the world's protein supply (Emily et al., 2010). The protein content of the grain is about 10% and is also of considerable value to livestock since it forms a major component of their feed. The quality characteristics of maize are usually influenced by genotype, environmental factors, management practices and interactions between these factors (Singh et al., 2012). Fertilizer application for example, has been recognized to influence crop yield and quality attributes like protein content (Kow & Nabwami, 2015).

Nitrogen, which is required by plants in the largest amounts among the three primary nutrients (N, P and K), forms an integral part of many important components in plants, including amino acids and enzymes, and also plays a role in almost all metabolic processes (Kow et al., 2015). According to

Amanullah et al. (2009) and Hammad et al. (2011) (cited in Sebetha et al., 2015), protein content in maize grain is improved with optimum N rate of application. Application of various N levels significantly influences seed protein content and without application of nitrogen, seed quality is likely to be decreased. Ruduluv et al. (2012) reported a highest protein content of 13.86% in maize grain on plots fertilized with 200 kg N ha^{-1} and 50 kg of both P and K ha^{-1}. Likewise, Almodares et al. (2009) and Mensah (2014) showed that crude protein content increased significantly by increasing nitrogen fertilizer levels. Also, significant differences between different treatments in grain protein content were observed by Sharifi and Namvar (2016) where the maximum grain protein content (14.3%) was recorded at application rates of 225 kg N ha^{-1}, the minimum protein content was recorded in plots without fertilizer.

Intensive protein synthesis requires, in addition to fairly high levels of nitrogen, a balanced supply of potassium and phosphorus. Phosphorus is known to improve crop quality in a number of ways, including reduced grain moisture content, increased sugar content, increased protein content (Kow et al., 2015). Potassium stands out as a cation having the strongest influence on quality attributes that determine crop marketability and consumer preference (Kow et al., 2015). The general effect of K, except when it is supplied at excessively high levels, according to Arnon (1975), is to increase the effectiveness of nitrogen and in conjunction with phosphorus to counteract the unfavourable effect of high N-fertilization on the quality of the protein.

Ruduluv et al. (2012) found that P and K fertilization increased crude protein content of maize grains in all the years of experimentation. However, the application of the maximum dose of K and P (150 kg ha^{-1}) led to a decrease in raw protein content. Also, a maximum of 25% protein content was reported by Malik, Farrukh, Ali and Mahmood (2003) as cited by Kow et al. (2015) from a plot fertilized at a combination of 50-75 Kg NP ha^{-1} as compared to other combinations of NK and NPK. Higher N and P combinations led to higher protein content (10.8%) which was statistically at par with N: P combination (150:100) and (120:80) but the lowest protein content (9.5%) was produced by control plots (Mensah, 2014). Several researchers have reported the effect of balanced N, P and K fertilization on maize quality; for example, NPK treatment increased protein content by 1.68%, in comparison with the NP treatment. This represented a relative increase of 17% in the protein content of the grain.

According to Essel (2014), nutrient uptake and distribution in different parts of maize plants vary primarily with the fertility of the native soil, application of chemical fertilizer and environmental conditions. The mineral constituents of grains can vary considerably, both in quantity and in proportion to each other. For instance, Bak, Gaj and Budka (2016) observed that maize grain nitrogen content was affected by mineral fertilizer application and the highest of 15.7 g N kg^{-1} was obtained when NPK (150:63:67) was applied, and the lowest of 13.2 g N kg^{-1} was obtained in the control.

The concentration of P in maize grain was significantly affected by both P and K rates, at a constant nitrogen application and ranged narrowly from 2.24 to 2.48 g kg^{-1} when compared to the control; the highest grain P concentration was observed in the treatment with the minimal P and K rates where NPK 150:31:34 was applied (Bak et al., 2016). Potassium concentrations in the maize stem and leaves were observed to be related to fertilizer application. However, grain K concentration was not related to K application rates (Lei et al., 2008).

Summary

The major causes of maize yield decline in Ghana are low soil fertility, pest and disease that include maize streak disease. However, the yield losses associated with low fertility status of Ghanaian soils have not yet been quantified and no monetary value has been placed on them. Studies have also shown that crop response to inorganic fertilizer on farmers' field is still low, despite higher responses that had been achieved in field trials that mimicked farmer growing conditions.

In Ghana, farmers lose about 20% of their produce to MSD and it is the least predicted disease. So far, the potential of the various MSD control measures that are in place has not been fully realized. Some researchers across Africa, have suggested the use of plant nutrition especially fertilizer application, in widening the scope of MSD management; it has however not yet been demonstrated. Previous studies did not state categorically that low soil fertility and MSD occur simultaneously, but indicate that balanced nutrition at the right time, when the nutrient can be used effectively for disease control, may also lead to higher yields. Tillage can also affect disease resistance, plant growth and yield by increasing the availability of certain elements and accentuate the benefits of applied nutrients.

CHAPTER THREE

MATERIALS AND METHODS

The study was conducted in the Volta Region of Ghana and was in two parts; a baseline survey and field experiments. This chapter provides a brief description of the study areas and details of the experimental design and sampling techniques that were employed in the studies. It also provides detailed descriptions of various activities undertaken during the baseline and field experiments, the types of data, how and when they were collected, as well as the protocols used in laboratory analyses of the samples. Lastly, the chapter highlights the statistical tools that were employed in the processing and analyses of the data.

The Baseline Survey

Study Area

A baseline survey was conducted from July to August, 2015 at randomly selected farmer fields within three different agro-ecological zones, in the Volta Region. The Volta Region is located along the south eastern part of Ghana and shares a boundary with the Republic of Togo. The region lies between latitudes 3° 45’N and longitude 8° 45’ N (FAO, 2005). The agro-ecological zones involved in the studies were coastal savanna, forest-savanna transition and semi-deciduous forest zones.

Coastal savanna zone

The coastal savanna agro-ecological zone has a bimodal rainfall pattern, with a mean annual rainfall varying between 600 mm and 1200 mm. The mean annual maximum and minimum temperatures are 30.5 and 22.9 ºC respectively. Relative humidity varies from 55 to 65 % during the day and fall to about 40 % during the major dry season (FAO, 2005). The vegetation is made up mainly of grassland, interspersed with dense short thickets of less than five meters high, with a few trees. The dominant soils present in this zone are the Harplic Nitisols. These are well-drained red tropical soils with diffuse boundaries and a sub- surface horizon with more than 30% clay. Nitisols are generally fertile soils in spite of their low level of available phosphorus and normally have low base status. Farmers in this zone grow mainly maize and cassava, often intercropped, as their principal staples.

Semi-deciduous forest zone

The Semi-deciduous forest zone is characterized by a bimodal rainfall pattern, with mean annual totals ranging from 1200-1600 mm. The mean temperature is about 26.5 ºC. Relative humidity in the morning is over 90% (FAO, 2005). The vegetation mainly consists of trees and the Haplic Nitisols are the dominant soils found on level to hilly land under tropical rain forest vegetation (Barry et al., 2005). These are well-drained red tropical soils with diffuse boundaries and a sub-surface horizon with more than 30% clay. Nitisols are strongly weathered soils with generally low level of available phosphorus and low base status but far more productive than most red tropical soils. Maize in this zone is grown in scattered plots, usually intercropped with cassava, plantain, and/or cocoyam as part of a bush fallow system. Although some maize is consumed in the forest zone, it is not a leading food staple and much of the crop is sold (Morris et al., 1999).

Forest-Savanna transitional zone

This zone is also characterized by a bimodal rainfall distribution pattern, with mean annual totals ranging from 1100-1400 mm. The mean temperature is about 26.5 ºC (FAO, 2005). The vegetation consists of trees which occur in association with tall to medium grass such as *Andropogon* and *Pennisetum* spp. The soil types are Lixisols and interspersed with Haplic/Ferric Lixisols which are strongly weathered soils in which clay has washed out of the eluvial horizon (FAO, 2005). The Lixisols have low levels of reserve and available nutrients, exchangeable bases not more than 2 $cmol_c$ kg^{-1} and have higher soil pH. Maize in this zone is planted in both the major and minor seasons, usually as a mono-crop or in association with yam and/or cassava (Morris et al., 1999).

Data Collection

Data was collected from six maize growing districts, two selected from each of the three agro-ecological zones (Table 1). In each district, three farming communities were selected and from each community, four maize farms were randomly selected and surveyed; making a total of 72 maize farms. On each farm selected, a transect of 5 m width were made along the diagonal; maize plants were randomly selected within the transect and were assessed for incidence and severity of MSD. The incidence of MSD per farm was determined by visually observing and recording the number of maize plants showing the disease symptoms and the percentage incidence was calculated (Equation 1).

$$\text{Incidence } \mathbf{(\%)} = \frac{Number\ of\ infected\ plants}{Number\ of\ plants\ assessed} \times 100 \qquad [1]$$

Table 1

Major Maize Growing Districts Selected from Various Agro-ecological Zones for Maize Streak Disease Study

Ecological zone	Selected district
Coastal savanna	1. Akatsi South 2. Ketu North
Semi-deciduous forest	3. Ho West 4. Kpando
Forest-savanna transition	5. Krachi East 6. Nkwanta South

The plants were also scored for disease severity based on a visual rating scale (1 to 5) developed by Bosque-Perez et al. (1992) and modified by Oppong et al. (2014). Table 2 shows the rating scale of the MSD severity.

Table 2

Visual Rating Scale for 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% leaf area, plants severely stunted or dead	Very severe infection

Data on the agronomic practices such as tillage operation, nutrient management and cropping system on each farm were also collected and documented. On the maize farms, any form of soil turning including ploughing, harrowing, ridging and traditional mounds were regarded as tillage, while direct seeding without soil pulverization was regarded as no-tillage. Also, on farms where there was nutrient addition either organic or inorganic fertilizer regardless of the rates of application, this was regarded as a nutrient managed field while on maize farms where there was no nutrient addition it was regarded and documented as there being no nutrient management.

Soil sampling

On each selected maize farm, soil samples were collected at a depth of 0-20 cm from 10 different spots, along transects in a Z pattern (MoFA, 2012), to form a composite sample and stored for laboratory analyses.

Field Experiments

Study Area

Field trials were established at Nkwanta in the Volta Region of Ghana, which lies between latitudes 7º 30’ and 8º 45’N and longitude 0º 10’ and 0º 45’E. The average annual rainfall ranges from 922 mm and 1,874 mm (Ghana Statistical Service [GSS], 2014). Nkwanta is found in the Forest-savanna transitional zone and the dominant soil types are Haplic/Ferric Lixisols (GSS, 2014). Such soils have low levels of reserve and available nutrients, exchangeable bases not more than 2 $cmol_c\ kg^{-1}$ and have higher soil pH. The trials were conducted under rain-fed conditions in both the major (June-September, 2015) and minor (September-December, 2015) cropping seasons.

Pre-planting Soil Sampling

Soil samples were collected at a depth of 0-20 cm in a Z pattern before planting for the determination of soil physico-chemical properties. The samples were bulked and composite samples picked for laboratory analyses. For the pre-planting soil sampling, core samples were also collected with cylindrical cores for bulk density determination. The bulked soil samples were air dried, sieved through a 2 mm mesh, and stored for the physico-chemical analyses.

Treatments and 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 (N: P_2O_5: K_2O) fertilizer application rates (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.

Each block was divided in two main plots, according to the levels of tillage system. An alley pathway of 2 m separated the no-till and conventionally tilled plots from each other. The main plots were further divided into two sub plots according to the number of varieties. Each sub-plot was further divided into seven sub-sub plots of 5 m x 4 m, according to the fertilizer application rates, and 1 m spacing was left between plots.

Field Establishment and Planting

On the no-tillage plots, the vegetation was slashed followed by Glyphosate herbicide application at a rate of 1L ha^{-1}. Direct seeding of maize was done through the mulch after two weeks of herbicide application. On the conventionally tilled plots, soil was ploughed and harrowed to a depth of 20 cm. Maize seeds were sown simultaneously on the no-till and conventionally tilled plots at a spacing of 80 cm between rows and 40 cm within rows up to a depth of 5 cm. Three (3) seeds were sown per hill and later thinned to two per hill after emergence.

Fertilizer Application

The recommended fertilizer application rate by MoFA for the Volta Region was N: P_2O_5: K_2O kg ha^{-1} 100: 60: 60. Therefore, in deciding the fertilizer application rates to be investigated in the study, the recommended application rate was maintained while the P and K rates were varied. The split fertilizer application method was adopted in the study so as to ensure maximum nutrient utilization by crops and to minimize losses of nutrients, especially nitrogen, due to leaching and volatilization.

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 and the top-up application was done six weeks after planting, where necessary.

Weed Control

Weeds were controlled twice during the growing period using herbicides on the no-tillage plots and hoe on the conventionally tilled plots.

Data Collection

Data collection on growth and disease started on the 2nd and continued on the 4th and 7th weeks after first fertilizer application during both the major and minor cropping seasons. Yield data was collected at physiological maturity about eight weeks after silking. On each plot, 12 plants from middle rows were randomly selected and tagged for growth, disease and yield assessments.

Data on growth

The growth parameters measured during the study were plant height (cm) and stem girth (mm). Plant heights were measured above the soil surface to the tip of the flag leaf, using a graduated wooden pole. The stem girth was measured using vernier calipers 5-25 cm above the soil surface, depending on the stage of plant growth.

Data on MSD incidence and severity

The study resorted to natural MSD infection without any artificial inoculation. The incidence of MSD was determined by visual observation and recording the presence or absence of disease symptoms of the maize plants. Disease incidence per plot was estimated as the percentage of selected plants displaying MSD symptoms (Figure 2; Equation 1) (Oppong et al., 2014). The plants were also scored for disease severity based on 1-5 visual scale described in Table 2 (Figure 1 & 2).

Figure 1: Healthy maize plants (score 1)

Figure 2: Plants showing severe streaking (score 5)

Data on yield

Harvesting of grains was done at physiological maturity that is approximately 55 days after silking. Ears were harvested from the 12 tagged plants on each plot and dehusked. The cobs were air dried to 13-15% moisture content for two weeks. After drying the cobs, the following yield parameters were measured: number of cob-bearing plants per plot, cob length, cob weight, number of grains per cob, 100-seed weight and grain yield per hectare.

The number of cob-bearing plants was obtained by counting the number of plants which bore cobs from the 12 tagged plants. The number was then extrapolated to per plot basis (Equation 2). These cobs were weighed on an electronic balance and the weight was divided by 12 to obtain the mean weight per cob (Equation 3). The number of grains produced per cob was counted and the averages worked out (Equation 4). Cobs from each plot were threshed and the grains weighed; this was divided by 12 to obtain grain yield per cob (Equation 5). Hundred seeds were counted from each plot and weighed to get 100-seed weight. Yield per plot was extrapolated to per hectare basis.

$$\text{Cob-bearing plant plot}^{-1} = \frac{number\ of\ plants\ bearing\ cobs}{12} \times 125 \qquad [2]$$

$$\text{Cob weight (g)} = \frac{total\ weight\ of\ cobs}{number\ of\ cobs} \qquad [3]$$

$$\text{Number of grains cob}^{-1} = \frac{total\ number\ of\ grains\ of\ harvested\ cobs}{number\ of\ cobs} \qquad [4]$$

$$\text{Grain yield cob}^{-1}\ \text{(g)} = \frac{grain\ yield\ of\ 12\ plants}{number\ of\ cobs} \qquad [5]$$

$$\text{Grain yield (kg ha}^{-1}) = \frac{grain\ yield\ of\ 12\ plants}{12} \times 62500 \qquad [6]$$

Soil and Leaf Sampling and Preparation

In order to ascertain nutrients content in the soil and maize leaves after treatments application, soil and leaf samples were collected from each plot at silking time; at the 9th week after planting. Soil samples were collected at a depth of 0-20 cm at six randomly selected points in every plot, using auger. The soil samples were mixed thoroughly from all cores to obtain a representative soil sample for each plot. The samples were air dried, sieved through a 2 mm size mesh, and stored in transparent bags for laboratory analyses.

Leaf samples were collected from four plants in each plot. On each plant, leaf opposite and just below the upper-most ear (the second most fully expanded leaf) was sampled using a knife (Arnon, 1975). The leaf samples were stored in labelled envelopes for transportation. The leaf samples were oven dried at 60 ˚C till a constant weight was attained. The dry biomass was mechanically ground using a dry mill, transferred into clearly labelled transparent bags and stored for laboratory analyses (Galicia, Nurit, Rasales & Palacios-Rojas, 2009).

Grain Sampling

For the determination of the quantity of P, K and crude protein content of maize grains as influenced by different rates of application of N, P and K fertilizers, maize grains were sampled from each plot at harvest and stored in refrigerator for laboratory analyses.

Soil Analyses

Soil samples collected from maize fields during the baseline survey were analysed for their physico-chemical properties. 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 exchange acidity (H^+ and Al^{3+}). The soil samples collected from each plot at silking time were analysed for total nitrogen, available phosphorus and exchangeable potassium contents.

Soil pH

Soil pH was measured in a 1:2.5 soil-water ratio using a glass electrode pH meter following the method of Rowel (1994). Approximately 10 g of air dried soil was weighed into a plastic bottle with a screw cap; 25 ml of distilled water was added and shaken for 15 minutes on a mechanical shaker. After calibrating the pH meter with buffers of pH 4.0 and 7.0, the pH was measured by inserting the electrode into the top of the soil water suspension and the reading was recorded. Each soil sample was replicated three times, and the average pH for each sample was calculated.

Soil Particle Size Distribution

The particle size distribution of the soil was determined using the pipette sampling technique described by Rowel (1994). A 10 g air-dry soil sample was weighed into a 500 ml beaker and 10 ml of H_2O_2 was added. The beaker was allowed to stand till frothing ceased, and another 10 ml of H_2O_2 was added. The content was gently heated on a Bunsen flame and stirred simultaneously to break the froth. H_2O_2 was further added, with gentle heating, to a total of 100 ml of peroxide solution. Finally, the temperature was raised to boiling to complete the destruction of the organic matter, and the content was allowed to cool.

To disperse the soil, the peroxide-treated soil was transferred to a 500 ml bottle using distilled water, and 10 ml of a dispersing agent was added. The content was made up to 200 ml and then shaken overnight on a mechanical shaker. After dispersing the soil, the content of the bottle was transferred to a 500 ml measuring cylinder, and topped up to 500 ml with distilled water.

Sampling of silt was done by drawing 20 ml of suspension with a special pipette, after thorough mixing with a plunger and allowed to settle for 32 seconds. The sedimentation started again after stirring for 8 h and clay was sampled at a depth of 10 cm. Each of the 20 ml suspensions was transferred into labelled weighed beakers and dried at 105˚C. After drying, the beakers were cooled in a desiccator and reweighed. These gave the mass of silt and clay, plus a small residue of the dispersing agent. After another 8 h, the sand was sampled by pouring away most of the supernatant liquid and quantitatively transferring the sediment known to be sand into a beaker. Stirring, settling and decanting were done repeatedly until the supernatant was clear. The sand was transferred into a weighed beaker, dried at 105 ˚C, cooled in a desiccator and reweighed. The mass of oven-dry soil was also determined and used for the calculation. The textural class of the soil was determined using the textural triangle, after calculating the percentage of each particle size in the samples.

Calculations

$$\%\ \text{sand} = MS \times \frac{100}{MdS} \qquad [7]$$

The total mass of silt in the soil sample (TSi) = mass of silt in 20 ml × 500/20,

$$\%\ \text{silt} = TSi \times \frac{100}{MdS} \qquad [8]$$

% clay = 100% - (% sand + % silt) [9]

Where

MS = mass of sand

MdS = mass of oven-dry soil.

TSi = total silt in soil sample

TC = total clay in soil sample

Bulk Density

The core sampler with its soil content was dried in the oven at 105 ˚C to a constant weight. The volume of the core sampler was determined by measuring the height and radius of the core sampler.

Calculation

$$pb = \frac{W2 - W1}{V} \qquad [10]$$

Where

pb (g cm^{-3}) = Dry bulk density

W2 (g) = Weight of core cylinder + oven-dried soil

W1 = Weight of empty core cylinder

V (cm^{-3}) = Volume of core cylinder (π r^2 h), where:

π = 3.142

r = radius of the core sampler

h = height of the core sampler (cm)

Organic Carbon

The organic carbon content of the soil was determined using the Walkley-Black method (FAO, 2008). A 0.5 g of soil sample was weighed in duplicates and transferred into a 500 ml Erlenmeyer flask; a blank was also included, and the weights were recorded. By means of a pipette, 10 ml of 0.167 M potassium dichromate ($K_2Cr_2O_7$) was added to the soil sample which was gently swirled. Twenty millimetre of concentrated H_2SO_4 was then added and the flask was allowed to stand for 30 minutes. After 30 minutes of standing, the content was diluted with 200 ml of distilled water and swirling was repeated to ensure thorough mixing. In order to complex any Fe^{3+} which would otherwise interfere in the end point, 10 ml and 0.2 g of H_3PO_4 and NaF respectively were added before the addition of a diphenylamine indicator. The excess Cr_2O_7 was back titrated with 0.5 M ferrous solution to a green colour end point.

Calculation:

The organic carbon content of the soil was calculated as:

$$\%\, organic\ carbon(OC) = \frac{(B-S)\times Morality\ of\ F2+ \times 0.300}{weight\ of\ soil} \times \frac{100}{77} \times 100 \qquad [11]$$

Where

B = Blank titre value

S = sample titre value

0.300 = 12/4000 = milli-equivalent weight of carbon

100/77 = the factor converting the carbon actually oxidized to total carbon

100 = the factor to change from decimal to percentage.

$$\%\ \text{organic matter} = OC \times \frac{100}{58} \qquad [12]$$

Total Nitrogen (N)

The total nitrogen in the soil samples was determined by the modified Micro-Kjeldahl method as described by Rowel (1994). A 0.5 g of soil was weighed into a digestion flask and 0.2 g catalyst and 3ml of concentrated

H_2SO_4 were added; two blanks were included. The flask and content was heated gently, gradually increasing the heat to 380˚C, for 2 hours on a block digester. On completion of digestion, the flask was allowed to cool and the content was diluted with 100 ml distilled water.

The steam distillation apparatus was set up and steam was passed through it for 20 minutes. After flushing the apparatus, a 100 ml conical flask containing 5 ml of boric acid indicator was placed under the condenser of the apparatus. Using a pipette, 20 ml aliquot of the sample digest was transferred to the reaction chamber through the trap funnel and10 ml of alkali mixture was added, commencing the distillation to collect 50 ml of the distillate. The distillate was then titrated against M/140 HCl from a green to a wine red colour.

Calculation:

$$\% N = \frac{(\mathrm{S-B}) \times \text{solution volume}}{100 \times \text{aliquot} \times \text{sample weight}} \qquad [13]$$

Where:

S = Sample titre value

B= Blank titre value

Available Phosphorus (P)

The available phosphorus in the soil samples was determined using Bray No. 1 method by using ascorbic acid. One gram of soil sample was weighed into a 15 ml centrifuge tube and 10 ml of extracting solution (15 ml of NH_4 + 25 ml of 0.5 M HCl in 460 ml distilled water) was added. The content was filtered after shaking for 5 minutes on a mechanical shaker; 2 ml aliquot of the extract was pipetted into a 25 ml volumetric flask. 100 ml of 5 µg P ml^{-1} was prepared from stock solution of P. From 5 µg P ml^{-1} solution, a set of working standards of P containing 0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 µg P ml^{-1} were prepared in 25 ml volumetric flasks. Both the blank and P standards contained the same volume of extracting solution as the soil samples. 10 ml of distilled water was added to each flask and 4 ml of reagent (12 g ammonium molybdate in 250 ml water + 0.2908 g of potassium antimony tartarate in 100 ml distilled water + 2.5 M H_2SO_4 1L distilled water and made up to 2 L. To every 200 ml of this solution, 1.156 g of ascorbic acid was dissolved) also added, before topping up to the volume with distilled water. The colour was allowed to develop for 15 minutes before determining the absorbance on the spectrophotometer at 882 nm. Excel software was used to plot a calibration, using the concentrations and absorbance of the standard solutions; from the curve, the concentrations of the soil samples were extrapolated.

Calculation:

$$\mu g\ P\ g^{-1}\ soil = C \times \text{dilution factor} \qquad [14]$$

Where:

C = concentration obtained from the graph.

Exchangeable Cations

Exchangeable cations (bases) are those that are replaced by other cations from the soil. The ones that are mostly found in soils include $Ca^{2+,}$ $Mg^{2+,}$ K^+, Na^+; all these are extracted and determined in 1 M NH_4OAc extract of soil (FAO, 2008). Five grams of soil sample was weighed into a 100 ml extraction bottle to which 20 ml ammonium acetate solution was added and stirred. The solution was allowed to stand overnight. The suspension was transferred into a funnel fitted with filter paper; the soil was successively leached with 20 ml of ammonium acetate into 100 ml volumetric flask, allowing the funnel to drain between each addition. The filtrate was made up to the 100 ml mark with ammonium acetate. Aliquots of the extract were used for the determination of $Ca^{2+,}$ $Mg^{2+,}$ K^+ and Na^+.

Exchangeable potassium and sodium were determined by flame analysis using a flame photometer. Working standards of 0, 2, 4, 6, 8 and 10 $\mu g\ ml^{-1}$ of both K^+ and Na^+ were prepared in ammonium acetate, aspirated into the flame photometer to record the readings (emissions). Soil extracts were then aspirated and their emissions were also recorded. A calibration curve was plotted using standards and their emissions. The concentrations of K^+ and Na^+ in the samples were read from the curve.

Exchangeable Ca^{2+} and Mg^{2+} were determined by titration. This method involved chelation of the cations with ethylene diaminetetra-acetic acid (EDTA). The usual procedure involved the determination of Ca^{2+} and Mg^{2+} together, using solochrome black indicator. For the calcium, an aliquot of 25 ml of the extract was placed in a 250 ml conical flask and the solution was diluted to 150 ml with distilled water. 10 drops of each of KCN, $NH_2OH.HCl$ and triethanolamine (TEA) were added; enough of NaOH was added to raise the pH to 12 or slightly higher. Five (5) drops of Calcon indicator was added and the solution was titrated from red to blue end point with EDTA.

The exchangeable magnesium was determined by placing an aliquot of 25 ml of the sample extract in 250 ml and adding distilled water to make a total volume of 100 ml. 20 ml of 20% tungstate solution and enough buffer solution was added to obtain a pH of 10. The solution was heated and the content was filtered through filter paper. The paper and precipitate were washed with a solution containing 50 ml of buffer per litre. 10 drops of each KCN, $NH_2OH.HCl$, $K_4Fe(CN)_6$ and TEA were added and allowed to stand for few minutes for the reaction to take place. Afterwards, 10 drops of EBT indicator was added and the solution was titrated from red to a permanent blue end point with EDTA.

The acidic cations Al^{3+} and H^+ were extracted with KCl solution. Approximately 10 g of soil sample was weighed into a beaker; 30 ml of 1M KCl was added and allowed to stand overnight. The soil was successively leached with 10 ml of KCl into 100 ml volumetric flask and the solution was made up to the mark. Fifty millilitres of the KCl extract was pipetted into a 250 ml conical flask and 5 drops of phenolphthalein indicator added. The solution was titrated to a pink end point with NaOH.

Calculation

$$\text{cmol}_c\ K^+\text{kg}^{-1} = \frac{C\times10}{wt\times39.1} \qquad [15]$$

$$\text{cmol}_c\ Na^+\text{kg}^{-1} = \frac{C\times10}{wt\times22.99} \qquad [16]$$

$$\text{cmol}_c\ Ca^{2+}\text{kg}^{-1} = \frac{4\times T}{wt} \qquad [17]$$

$$\text{cmol}_c\ Mg^{2+}\text{kg}^{-1} = \frac{4\times T}{wt} \qquad [18]$$

$$\text{cmol}_c\ H^+ + Al^{3+}kg^{-1} = \frac{2 \times T}{wt} \qquad [19]$$

Where:

C = concentration of extract from standard curve

T = sample titre value.

The effective cation exchange capacity (ECEC) of the soil was calculated by summation of the basic cations.

$ECEC = Ca^{2+} + Mg^{2+} + K^{+} + Al^{3+} + H^{+}$

Grain Analyses

Maize grain samples were ground to a very fine powder. The ground grain samples were digested for the determination of N, P and K. This is necessary for the destruction of the organic matter, through acid oxidation before a complete elemental analysis can be carried out (IITA, 1985).

Approximately 0.2 g of the ground sample was weighed into a 100 ml Kjeldahl flask, 4.5 ml of concentrated H_2SO_4 (digestion reagent) was added and the samples digested at 360 ˚C for two hours. Blank digestions (digestion of the digestion mixture without grain sample) were carried out in the same way. After the digestion, the digests were transferred quantitatively into 100 ml volumetric flasks and made up to volume.

Grain Crude Protein

The steam distillation apparatus was set up and steam was passed through it for 20 minutes. After flushing the apparatus, a 100 ml conical flask containing 5 ml of boric acid indicator was placed under the condenser of the apparatus. Using a pipette, 20 ml aliquot of the sample digest was transferred to the reaction chamber through the trap funnel and 10 ml of alkali mixture was added, commencing the distillation to collect 50 ml of the distillate. The distillate was then titrated against 140 M HCl from green to wine red.

Calculation:

$$\% N = \frac{(S-B)\times \text{solution volume}}{100\times \text{aliquot}\times \text{sample weight}} \quad [20]$$

Where

S = Sample titre value

B = Blank titre value

The crude protein was estimated from nitrogen value (Galicia et al., 2009) and in the case of maize the calculation is:

% Protein = % of nitrogen x 6.25 [21]

(6.25 is the conversion factor for maize)

Grain Phosphorus

The procedure requires the preparation of colour forming reagent and P standard solutions. The colour forming reagent is made up of reagents A and B. Reagent A is made up of 12 g ammonium molybdate in 250 ml distilled water 0.291 g of potassium antimony tartarate in 100 ml distilled water and I L of 2.5 M H_2SO_4. The three solutions were mixed together in a 2 L volumetric flask and made up to volume with distilled water. Reagent B was prepared by dissolving 1.056 g of ascorbic acid in every 200 ml of reagent A.

A stock solution of 100 µg P ml^{-1} was prepared from which 5 µg P ml^{-1} solution was also prepared. From the 5 µg P ml^{-1} solution, a set of working standards of P, with concentrations of 0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 µg P ml^{-1} were prepared in 25 ml volumetric flasks. One millilitre aliquots of the digested samples were pipetted into 25 ml volumetric flasks. Additionally, 1 ml aliquot of the blank digest was pippeted into each of the working standards to give sample and standard the same background solution.

Also, 10 ml of distilled water was added to the standards as well as the samples, after which 4 ml of reagent B was added, and their volumes made up to 25 ml with distilled water and mixed thoroughly. The flasks and contents were allowed to stand for 15 minutes for colour development, after which the absorbance of the standards and samples were determined using a Spectrophotometer, at a wavelength of 882 nm. A calibration curve was plotted using their concentrations and absorbance. The concentrations of the sample solutions were extrapolated from the standard curve.

Calculation

$$\mu g\ P\ g-1\ = \frac{C \times solution\ volume}{sample\ weight} \quad [22]$$

Where: C = concentration of the sample solution

Grain Potassium

Potassium in the digested samples was determined using a flame photometer as described by Stewarts et al. (1974). In the determination, the following working standards of K were prepared: 0, 2, 4, 6, 8 and 10 µg ml^{-1}. The working standards, as well as the sample solutions, were aspirated individually into the flame photometer and their emissions (readings) recorded. A calibration curve was plotted using the concentrations and emissions of the working standards. The concentrations of the sample solutions were then extrapolated from the standard curve using their emissions.

Calculation

$$\mu g\ k\ g - 1 \ = \frac{C \times solution\ volume}{sample\ weight} \qquad [23]$$

Where: C = concentration of the sample solution

Leaf Nutrient Analyses

The N, P and K content of the ground leaf samples were determined using the same protocol as that for maize grains, as described by IITA, (1985).

Data Analysis

All data were analysed using the GenStat Discovery Edition 4 statistical software. Relationships between variables were established using Pearson correlation. The t-test was used to determine the impact of tillage practices and nutrient management on MSD in the baseline study. Analysis of variance was performed to test the treatments and their interaction effects for significance at 95% confidence interval. The F probability value indicates the strength of significance at $\rho \leq 0.05$. The least significant difference (l.s.d) was used for means comparison.

Summary

Seventy two (72) maize farms were randomly selected from three agro-ecological zones across the Volta Region for MSD incidence and severity assessment. On each farm, soil samples were also collected for physical and chemical analyses. Field experiments were conducted by mimicking farmers growing conditions at Nkwanta, in two cropping seasons. The split-split plot design was adopted. Data collection on growth and disease started at two weeks after fertilizer application and at two weeks intervals till plant silking. Data on yield were collected at maturity. MSD assessment was made using symptoms description; incidence of MSD was determined by visually observing and recording the presence or absence of maize plants showing the disease symptoms. The plants were also scored for disease severity based on 1-5 visual scale. There was no serological and molecular detection and confirmation of the MSD virus. Soil and leaves samples were collected at silking time and grains samples were collected after maize harvest. Soil, maize leaves and grains were analysed using existing protocols with slight modifications. Analysis of variance was performed to test the treatments and their interaction effects for significance. All relationships between variables were established using Pearson correlation.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter deals with results and discussion of the base line study across three agro-ecological zones of the Volta Region and field experiments at Nkwanta. They are presented in accordance with the research objectives. The chapter begins with the results and discussion of the physico-chemical properties of soils, the maize streak disease (MSD) prevalence, and the relationship between soil properties and MSD incidence and severity in the Volta Region. The impact of tillage and nutrient management on MSD incidence and severity across the three agro-ecological zones of the Volta Region has also been presented. Further, the physico-chemical properties of the soils at Nkwanta are presented and briefly discussed. The results of the effects of tillage systems, maize variety and different rates of fertilizer application as well as their interactions on MSD, plant height, grain yield and grain nutrient contents of maize are also reported and discussed. Additionally, results of the effect of treatments on maize leaf N, P and K contents at silking time and their relationship with the disease incidence and severity is also covered in this chapter.

Physico-chemical Characteristics of Soils of the Three Agro-ecological Zones of the Volta Region

The soils of the three different agro-ecological zones of the Volta Region were dominated by sand particles which ranged from 57. 9% in the forest-savanna transitional zone to 71.7% in the coastal savanna zone (Table 3). The soils contain enough clay and silt particles which put all of them in the textural class of sandy loam.

Table 3

Particle Size Distribution of Soils of the Agro-ecological Zones

Agro-ecological Zone		**Soil Physical Property**		
		Clay (%)	**Silt (%)**	**Sand (%)**
Coastal savanna	Mean	13.9	14.4	71.7
	Min.	9.5	5.9	54.7
	Max.	19.7	27.8	82.4
	Std. deviation	2.5	5.8	6.51
Semi-deciduous Forest	Mean	15.9	22.4	61.8
	Min.	9.6	11.6	40.1
	Max.	30.3	36.1	76.3
	Std. deviation	5.0	7.5	9.7
Forest-Savanna transition	Mean	13.6	28.5	57.9
	Min.	10.3	11.8	34.1
	Max.	20.7	49.5	76.7
	Std. deviation	2.3	11.9	12.8

The sandy loam soils which were the dominant soil types across the Volta Region quickly drain excess water but can also hold significant amounts of water or nutrients for plants use. Plants grown in this type of soil will require more frequent irrigation and fertilization than soils with a higher concentration of clay and silt. Such soils are often deficient in specific micronutrients and may require additional fertilization to support healthy plant growth.

The organic carbon content of the soils of the transitional zone was higher than that of the coastal savanna zone and semi-deciduous forest zone with mean and standard deviation of 1.18 and 0.13 (%) respectively (Table 4). Nonetheless, the levels of soil organic carbon in all the agro-ecological zones were low. Soil organic carbon is one of the most important constituents of the soil due to its capacity to affect plant growth as both a source of energy and nutrients for soil microorganisms and a trigger for nutrient availability through mineralization. A direct effect of low soil organic carbon is reduced microbial biomass, activity, and nutrient mineralization due to a shortage of energy sources. This may reduce the effect of mineral fertilizers on crop yield in such soils. The higher organic carbon content at the forest and transition zones compared to the coastal savanna zones could be attributable to the high vegetative cover in the forest and transition zones which could add more litter to the soil. Also, soil erosion as well as practices like burning, crop and residue removal can further exacerbate the low soil organic carbon content of this region (MoFA, 2015).

The total nitrogen contents of the soils in all the three agro-ecological zones across the Volta Region were low (Table 4) (total N $< 0.13\%$) as per the standards of Ministry of Food and Agriculture (2012). Nitrogen is of special importance because plants need it in rather large amounts and it is easily lost from the soil.

Table 4

Chemical Characteristics of Soils the Agro-ecological Zones

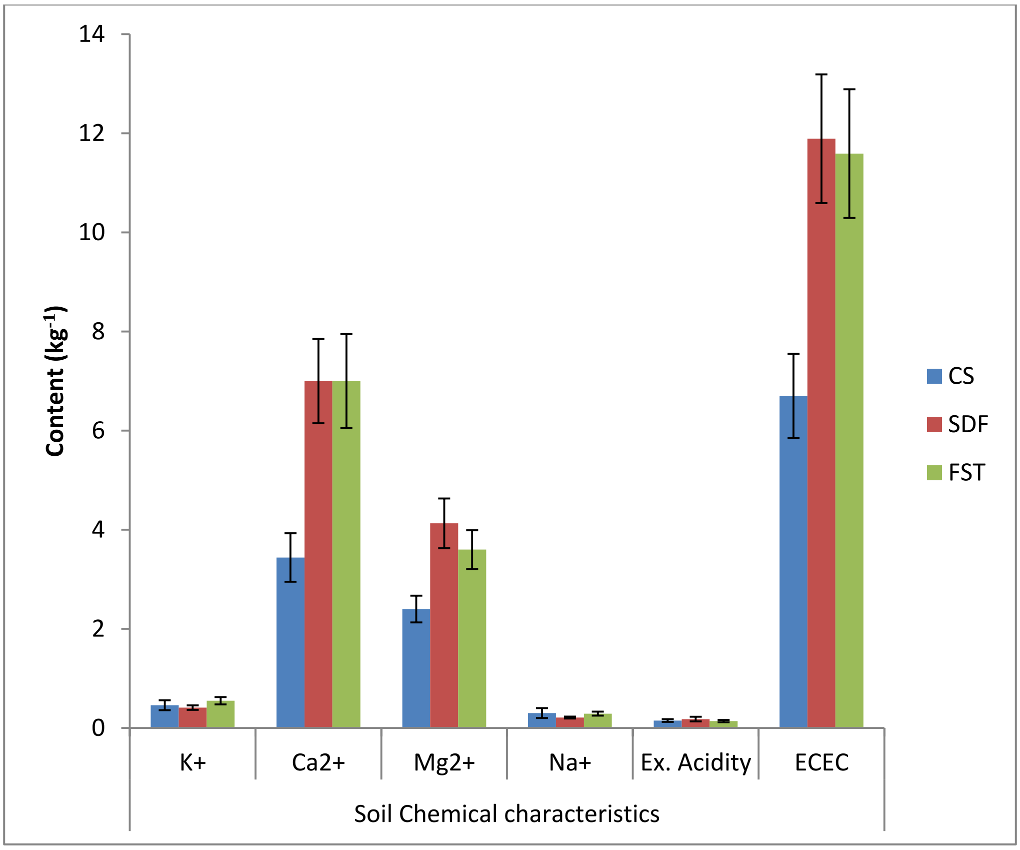
Agro-ecological Zone		**Soil Chemical Property**			
		Organic carbon (%)	Total N (%)	P (µg g^{-1})	pH
Coastal savanna	Mean	0.58	0.05	9.08	6.6
	Min.	0.02	0.01	0.8	5.7
	Max.	2.61	0.23	40.36	7.4
	Std. deviation	0.63	0.05	7.96	0.52
Semi-deciduous Forest	Mean	0.99	0.08	13.53	6.6
	Min.	0.02	0.01	1.51	5.6
	Max.	1.99	0.17	7.84	7.5
	Std. deviation	0.52	0.04	12.18	0.48
Forest-Savanna transition	Mean	1.18	0.10	16.02	6.6
	Min.	0.02	0.01	3.35	5.6
	Max.	0.0	0.18	39.54	7.9
	Std. deviation	0.13	0.05	11.18	0.54

There has to be a continuous release of available nitrogen from soil organic matter or it must be supplied from exogenous sources such as inorganic fertilizers to ensure a steady rate of growth and sustain the production of maize in this region. The total N content of soils in the coastal savanna was lower than that in the semi-deciduous forest and transitional zone (Table 4).

These differences in soil total nitrogen may stem from differences in cropping systems and agronomic practices across the different zones.

The available phosphorus (P) contents of the soils in all the agro-ecological zones were low (Table 4) (available P < 0.20 µg g^{-1}) as per the standards of Ministry of Food and Agriculture (2012). The available P content of soils of the forest-savanna transition zone ranged from 3.35 to 39.5, with mean of 16.07 and standard deviation of 11.18 (µg g^{-1}). The low level of soil total N and available P across the region recorded in this study, is in agreement with the report of MoFA (2015) that the extent of nutrient depletion is widespread in all the agro-ecological zones of Ghana, with nitrogen and phosphorus being the most deficient nutrients. The low nutrients of soils across the region can be attributed to disappearing fallows, continuous cropping without fertilization and agricultural intensification (Agyare, 2012).

The exchangeable potassium (K^+) content of the soils in all the maize farms across the three agro-ecological zones were adequate for crop production (Figure 3) (exchangeable K^+ 0.45-0.70 $cmol_c$ kg^{-1}) according to the standards of Ministry of Food and Agriculture (2012). This means that such soil can sustain maize production for that season but the nutrient removed by the current crop need to be replaced for the subsequent crop production. The mean exchangeable K contents ranged from 0.41 to 0.56 ($cmol_c$ kg^{-1}) in the semi-deciduous forest zone and forest-savanna transition zone respectively.



CS= Coastal Savanna, SDF= Semi-deciduous Forest, FST= Forest-Savanna Transition

Figure 3: Soil chemical characteristics of the three agro-ecological zones

The soil exchangeable Ca^{2+} and Mg^{2+} in soils of coastal savanna zone were lower than the other agro-ecological zones (Figure 3). The semi-deciduous forest zone had the highest of Ca^{2+} and Mg^{2+} of 6.96 and 4.12 ($cmol_c$ kg^{-1}) respectively. The soils of coastal savanna zone were low in exchangeable Ca^{2+} content (< 5 $cmol_c$ kg^{-1}).

Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilizers and other ameliorants .The effective CEC of soils varies according the clay contents, the type of clay, soil pH and amount of organic matter. The lower ECEC recorded for the soils of coastal savanna zone could be attributed to its low clay and organic carbon content. Such soils are likely to develop deficiencies in potassium (K^+), magnesium (Mg^2+) and other cations. Soil pH was similar in all the agro-ecological zones and was in the slightly acidic range which can be said to be in the optimum range for crop production.

The differences of soil physical and chemical characteristic of the different agro-ecological zones may be due to difference in climatic condition which includes precipitation and temperature, vegetation types and land use types. Temperature and precipitation influence the speed of weathering of parent materials and thus soil properties such as mineral composition and organic matter content. Temperature directly influences the speed of chemical reactions in the soil. Agricultural activities may be similar among these agro-ecological zones, the differences in cropping systems and agronomic practices such as tillage and nutrient management may also account for differences in soil chemical characteristics of the agro-ecological zones.

Maize Streak Disease Prevalence in the Three Agro-ecological Zones

Maize streak disease incidence and severity for each of the three agro-ecological zones studied are shown in Table 5. The forest-savanna transitional zone had a mean incidence of 89.7%. The maximum incidence in this zone was 100% meaning all the plants assessed were infected with MSV and showed the disease symptoms. The semi-deciduous forest zone had the lowest mean MSD incidence of 77.5% among the three agro-ecological zones across the Volta Region with maximum and standard deviation of 100 and 13.0 (%) respectively.

The mean MSD severity score ranged from 2.6 in the semi-deciduous forest zone to 3.1 in the forest-savanna transitional zone. This means that maize plants across the Volta Region were moderately infected and slightly stunted. Maize yields in this region are likely to be reduced as a result of the MSD infection. The lowest severity was recorded in the semi-deciduous forest zone, with a mean severity of 2.6 which was still in the moderate infection range.

Table 5

Variation in MSD Prevalence Among Agro-ecological Zones

Agro-ecological Zone		**MSD Incidence (%)**	**MSD Severity**
Coastal savanna	Mean	86.4	2.7
	Min.	67.5	2.1
	Max.	97.7	3.6
	Std. deviation	1.8	0.4
Semi-deciduous Forest	Mean	77.5	2.6
	Min.	50	1.9
	Max.	100	3.1
	Std. deviation	13.0	0.4
Forest-Savanna transition	Mean	89.7	3.1
	Min.	49.1	2.3
	Max.	100	3.7
	Std. deviation	10.8	0.3

The mean MSD incidence across the study areas of the Volta Region was 84.5%, and was comparatively higher than the mean incidence (18.5%) recorded across the country as reported by Oppong et al (2014). This could have serious consequences on maize production among the smallholder farmers in the Volta Region. Low MSD incidence and severity recorded for the semi-deciduous forest zone was consistent with the results obtained by Magenya et al. (2009) and Oppong et al. (2014). Differences in the climatic conditions, vegetation type, cropping systems and agronomic practices prevailing at the different agro-ecological zones could affect the leafhopper populations and MSD prevalence as posited by Asare-Bediako et al., (2016). The low MSD level in semi-deciduous forest zone could be as a result of heavy rainfall in the forest zones, especially during the major raining season; this could cause insect mortality and hence impact the disease prevalence in these zones. There is the likelihood of non-existent of alternative host plants for the MSV vector in the semi-deciduous forest zone which could eventually reduce the leafhopper population and the disease incidence in this zone.

Relationship Between Soil Nutrients Contents and Maize Streak Disease Prevalence in the Agro-ecological Zones

There was no significant correlation between soil organic carbon content and MSD incidence and severity across the agro-ecological zones in the Volta Region (Table 6). An increase in soil total carbon, leads to greater biological diversity in the soil, thus increasing biological control of plant diseases and pests. The very weak relationship between soil organic carbon and disease prevalence across the region might be due to their soils being low in organic carbon content. The relationship between the major plant nutrients (N, P and K) and MSD incidence and severity were not significant. The MSD incidence and severity on maize farms neither correlated with soils' ECEC, exchangeable acidity nor soil pH. There was no relationship among the soil

Table 6

Correlation Matrix for Soil Chemical Characters and MSD Incidence and Severity

	Correlation Coefficient (r)	
Soil Parameter	**Incidence**	**Severity**
Organic carbon (%)	- 0.03	0.04
Total nitrogen (%)	- 0.04	- 0.02
Ex. K ($cmol_c$ kg^{-1})	- 0.11	0.06
ECEC ($cmol_c$ kg^{-1})	0.10	0.09
Ex. Acidity ($cmol_c$ kg^{-1})	- 0.06	0.06
Available P (μg g^{-1})	- 0.06	0.05
pH	0.13	0.03

Sample size = 65

chemical characteristics and MSD prevalence in the Volta region hence the null hypotheses is accepted. This could be attributed to the fact that the soils were low in inherent nutrient content to be able to support plant growth and therefore reduced crops ability to counter MSD impact.

Effect of Tillage and Nutrient Management of Maize Farms on Maize Streak Disease Incidence and Severity in the Volta Region

Across the three agro-ecological zones of the Volta Region, 78.4% (representing 56 maize farms) out of the 72 maize farms surveyed were under the no-tillage system, while only 21.6% (representing 16 maize farms) of the maize farms had under gone some type of tillage (either traditional or conventional tillage). Also, 80% (representing 58 maize farms) of the of the 72 maize farms depended solely on the inherent soil nutrients for maize production without any form of nutrient addition, while only 20%

(representing 14 maize farms) maize farms were under soil nutrient management. Tillage practices on farmers' field had no significant (P> 0.05) effect on MSD incidence (Table 7). The tilled maize farms had a higher disease incidence (92.5%) compared to (83.3%) to the no-tillage.

Table 7

Effects of Tillage and Fertilizer Practices on Maize Farms on MSD Incidence and Severity in the Volta Region

Agronomic practice	Incidence (%)	Severity
Tillage system		
No-tillage	83.3	2.80
Conventional Tillage	92.5	3.21
Probability function	0.09 NS	0.024*
Nutrient management		
No nutrient management	84.2	2.78
Nutrient management	85.8	2.82
Probability function	0.66 NS	0.77 NS

NS= not significant, * denotes significance at $\rho \leq 0.05$

However, MSD severity was significantly ($\rho < 0.05$) affected by tillage practices, with mean severity on tilled maize farms being significantly ($\rho < 0.05$) higher than severity on maize farms where no-tillage system was adopted. The application of herbicides under no-tillage aimed at killing grasses that may have served as alternative hosts for the leafhopper could have contributed to the reduced MSD under this particular tillage system (Martin et al., 2009).

Irrespective of the type, rates and method of application, nutrient management had no significant ($\rho > 0.05$) effect on both MSD incidence and severity on farmers' field (Table 7). Both incidence and severity (85.8% and 2.82 respectively) were higher on maize farms where nutrient was managed compared to incidence and severity (84.2% and 2.78 respectively) on non-fertilized maize farms. Soils across the three agro-ecological zones were low in nutrient content and therefore may be inadequate to support growth of plants and hence the failure to detect significant impact of nutrient management on MSD.

Effect of Tillage System and Fertilizer Application on Incidence and Severity of Maize Streak Disease on two Maize Varieties

Physico-chemical Characteristics of Soils at Nkwanta

The soil of the experimental field had high bulk density (> 1.4 g cm^{-3}) being a sandy loam (Table 8). High bulk density is an indicator of low soil porosity and soil compaction. It impacts infiltration, rooting depth/restrictions, available water capacity, soil porosity, plant nutrient availability, and soil microorganism activity, which influence key soil processes and productivity. Careful management on the land is required to create an ideal bulk density for optimum plant growth and healthy soil.

The total nitrogen (N), available phosphorus (P) exchangeable potassium (K^+), calcium Ca^{2+} and organic carbon content of the soil of the experimental field were low except for magnesium content (total N < 0.13%; available P < 0.20 µg g^{-1}; exchangeable K^+ < 0.45 $cmol_c$ kg^{-1}, Ca^{2+} < 5 $cmol_c$ kg^{-1}, Mg^{2+} < 0.5 $cmol_c$ kg^{-1}) as per the standards of Ministry of Food and Agriculture (2012). External source of nutrients are needed in this soil in order to improve crop yields. Organic matter is related to the cycling, retention, and supply of nutrients plant growth. Thus, they contribute to

Table 8

Physico-chemical Characteristics of Soil of the Experimental Field

Soil Parameter	**Value**
Bulk density (g cm^{-3})	1.6
Soil pH	6.6
Organic carbon (%)	0.70
Total N (%)	0.01
Available P (µg g^{-1})	8.20
Exchangeable bases ($cmol_c$ kg^{-1})	
Ca^{2+}	3.08
Mg^{2+}	1.84
K^{+}	0.12
Na^{+}	0.17
Exchangeable acidity ($cmol_c$ kg^{-1})	3.80
ECEC ($cmol_c$ kg^{-1})	6.08
Sand (%)	62.3
Silt (%)	24.7
Clay (%)	13.0
Textural class	Sandy loam

the gradual and continuous liberation of plant nutrients. The effects of mineral fertilizer will also be suppressed when organic matter is low. The soil was also slightly acidic which can be said to be optimum for crop production.

Maize Streak Disease Incidence

The MSD incidence recorded from the field experiments is presented in Table 9. The stage of growth of the plant at which MSD attacks it, is very important; this determines the overall effect of the disease on yield, therefore, the initial MSD incidence was recorded at two weeks after first fertilizer application.

Table 9

Incidence and Severity of MSD as Affected by Tillage System, Maize Variety and Fertilizer Application

	Major season				Minor season			
Treatment	Initial incidence (%)	Initial severity	Peak incidence (%)	Peak severity	Initial incidence (%)	Initial severity	Peak incidence (%)	Peak severity
Tillage								
T1 (No-till)	1.2	1.01	17.9	1.21	49.4	1.73	88.8	2.58
T2 (Conventional tillage)	7.9	1.05	41.6	1.67	53.3	1.85	90.0	2.72
l.s.d	3.01	0.039	6.860	0.215	NS	NS	NS	0.124
F pr.	0.006*	0.046*	0.002*	0.007*	0.379	0.267	0.092	0.038*
Maize variety								
V1(Obatanpa)	5.1	1.03	29.8	1.42	50.7	1.74	89.4	2.62
V2(Domabin)	4.0	1.03	29.7	1.47	51.9	1.84	89.4	2.68
l.s.d	NS	NS	NS	NS	NS	NS	NS	0.054
F pr.	0.647	0.884	0.993	0.567	0.553	0.082	1.00	0.047*
Fertilizer rate ($N:P_2O_5:K_2O$ kg ha^{-1})								
F1(0:0:0)	8.0	1.1	33.2	1.61	48.4	2.03	89.0	2.86
F2(100:30:60)	3.2	1.0	28.2	1.39	51.9	1.81	89.0	2.59
F3(100:80:60)	2.6	1.0	28.2	1.40	50.0	1.71	89.0	2.62
F4(100:60:60)	4.3	1.0	30.9	1.44	52.2	1.72	90.0	2.57
F5(100:60:30)	4.1	1.0	33.1	1.46	51.8	1.75	89.0	2.66
F6(100:60:80)	5.2	1.0	27.6	1.40	50.8	1.80	90.0	2.62
F7(60:60:60)	4.7	1.0	26.9	1.40	54.0	1.71	90.0	2.64
l.s.d	NS	NS	NS	NS	NS	0.152	NS	0.121
F pr.	0.622	0.854	0.469	0.115	0.777	<0.001*	0.826	<0.001*
Mean	4.57	1.03	29.7	1.44	51.30	1.79	89.4	2.65

*Denotes significance at $\rho \leq 0.05$, NS= not significant.

In the major season, tillage system adopted, significantly ($\rho < 0.05$) affected initial disease incidence. The incidence of 1.2% was recorded under no-tillage system and was significantly ($\rho < 0.05$) lower than the incidence (7.9%) recorded under conventional tillage system (Table 9). Maize variety and fertilizer application did not significantly ($\rho > 0.05$) affect initial disease incidence. However, in the minor season, all treatments did not significantly affect the initial disease incidence.

The peak MSD incidence was recorded at silking time (on the 7th week after first fertilizer application). In the major season, peak MSD incidence (41.6%) was significantly ($\rho < 0.05$) higher on the conventionally tilled plots than on the no-tillage plots (17.9%). Peak incidence was not significantly affected by maize variety and fertilizer application in the major season (Table 9). All treatments did not significantly affect peak MSD incidence in the minor season.

Tillage and varietal interaction had no significant effect on initial and peak MSD incidence in both the major and minor season (Table 10). Also, interaction between tillage and fertilizer application as well as variety and fertilizer application did not have any significant effects on initial and peak MSD incidence in both seasons. There were also no interaction effects between tillage, variety and fertilizer on initial and peak MSD incidence in both seasons. In the Major season, interaction T2V2F1 recorded the highest peak MSD incidence (52.8%), the lowest peak incidence of 4.2% was recorded in T1V2F6 (Table 10). However, in the minor season, the peak

Table 10

Incidence and Severity of MSD as Affected by Interaction Between Tillage System, Maize Variety and Fertilizer Application

	Major season				Minor season			
Treatment interactions	Initial incidence (%)	Initial severity	Peak incidence (%)	Peak severity	Initial incidence (%)	Initial severity	Peak incidence (%)	Peak severity
T×V (F pr.)	0.647	1.00	0.633	0.597	0.259	0.224	1.00	0.410
T×F (F pr.)	0.489	0.795	0.479	0.342	0.854	0.229	0.826	0.317
V×F (F pr.)	0.855	0.481	0.237	0.331	0.467	0.262	0.368	0.633
T×V×F								
T1V1F1	4.2	1.03	19.5	1.25	48.8	1.88	85.8	2.68
T1V1F2	0.0	1.00	17.2	1.21	44.8	1.65	85.8	2.53
T1V1F3	0.0	1.00	19.2	1.19	51.4	1.65	90.0	2.50
T1V1F4	0.0	1.00	12.0	1.14	56.9	1.75	90.0	2.50
T1V1F5	0.0	1.00	29.8	1.38	52.3	1.70	90.0	2.58
T1V1F6	4.2	1.03	23.7	1.27	52.7	1.70	90.0	2.53
T1V1F7	0.0	1.00	10.2	1.06	55.2	1.63	90.0	2.50
T1V2F1	0.0	1.00	15.9	1.29	51.2	1.78	90.0	2.70
T1V2F2	4.2	1.01	20.5	1.24	56.8	1.88	90.0	2.55
T1V2F3	4.2	1.03	16.2	1.23	52.4	1.68	85.8	2.63
T1V2F4	0.0	1.00	24.1	1.28	48.8	1.55	90.0	2.48
T1V2F5	0.0	1.00	20.5	1.22	48.9	1.73	85.8	2.68
T1V2F6	0.0	1.00	4.2	1.65	52.7	1.90	90.0	2.60

Table 10, continued

	Major season				Minor season			
Treatment interactions	Initial incidence (%)	Initial severity	Peak incidence (%)	Peak severity	Initial incidence (%)	Initial severity	Peak incidence (%)	Peak severity
T1V2F7	0.00	1.00	17.7	1.56	55.2	1.70	90.0	2.70
T2V1F1	13.5	1.06	44.6	1.72	51.2	2.08	90.0	3.05
T2V1F2	4.2	1.03	35.3	1.52	56.8	1.83	90.0	2.65
T2V1F3	6.0	1.06	43.8	1.67	52.4	1.83	90.0	2.70
T2V1F4	8.4	1.03	45.0	1.65	48.8	1.75	90.0	2.58
T2V1F5	10.2	1.03	36.0	1.56	48.9	1.68	90.0	2.65
T2V1F6	12.6	1.09	42.6	1.65	52.4	1.73	90.0	2.70
T2V1F7	8.4	1.03	37.6	1.56	50.2	1.50	90.0	2.58
T2V2F1	14.4	1.09	52.8	2.19	52.4	2.38	90.0	3.00
T2V2F2	4.2	1.01	40.0	1.58	56.1	1.88	90.0	2.63
T2V2F3	0.0	1.00	33.7	1.51	48.8	1.70	90.0	2.65
T2V2F4	8.8	1.15	42.5	1.69	58.1	1.83	90.0	2.73
T2V2F5	6.0	1.05	46.2	1.67	56.1	1.90	90.0	2.73
T2V2F6	4.2	1.01	39.9	1.66	50.2	1.88	90.0	2.65
T2V2F7	10.2	1.05	42.0	1.74	63.1	2.00	90.0	2.78
l.s.d	NS	NS	NS	NS	NS	NS	NS	NS
F pr.	0.895	0.510	0.237	0.526	0.418	0.228	0.368	0.860

NS= not significant, T1= no-tillage, T2= conventional tillage, V1=*Obatanpa*, V2= *Domabin*, F1 (00:00:00), F2 (100:30:60), F3 (100:80:60), F4 (100:60:60), F5 (100:60:30), F6 (100:60:80) and F7 (60:60:60) incidence ranged from 85.8% to 90% and many of the treatments recorded 90% disease incidence. Comparing the two seasons, a higher mean peak incidence (89.4%) was recorded for the minor season and a lower incidence (29.7%) was recorded for the major season.

Maize Streak Disease Severity

Disease severity is the area of relevant host tissues or organ (leaf or entire plant) covered by symptom or damaged by the disease, expressed as a proportion of the total area. A visual rating scale of 1-5 was adopted in this study. The initial severity and peak MSD severity data are presented in Table 9. Tillage system significantly ($\rho < 0.05$) affected the initial disease severity in the major season. The severity recorded for the conventional tillage was significantly ($\rho < 0.05$) higher than that under the no-tillage, with initial severity scores of 1.05 and 1.01 respectively (Table 9). This means that the degree of infection of the MSD was higher on maize plant that grew on the conventionally tilled plots. Maize variety and fertilizer application did have any significant effects on initial MSD severity in the major season.

In the minor season however, fertilizer application significantly ($\rho < 0.05$) affected initial severity. There was a significantly ($\rho < 0.05$) higher initial severity in F1 (0:0:0) than the fertilizer treated plots. There were no significant differences among the different fertilizer rates (Table 9). Tillage and maize variety did not affect the initial disease severity in the minor season. Lower initial severity (1.73) was recorded for no-tillage system; this was not significantly ($\rho > 0.05$) different from 1.85 under conventional tillage. The lowest initial severity was recorded for *Obatanpa*, which was not significantly ($\rho > 0.05$) different from that recorded for *Domabin*.

Peak MSD severity was recorded at silking time (on the 7^{th} week after first fertilizer application) and was significantly ($\rho < 0.05$) affected by tillage systems in the major cropping season (Table 9). Peak MSD severity score (1.67) was significantly ($\rho < 0.05$) higher in the conventional tillage system than in the no-tillage system (1.21). Peak MSD severity was not significantly affected by maize variety and the fertilizer application in the major season.

Peak severity was significantly affected by tillage system, variety and fertilizer application in the minor season. Peak severity was significantly ($\rho <$ 0.05) higher under conventional tillage than under no-tillage system. The disease was mildly severe on *Obatanpa* variety than on *Domabin,* with mean severity scores of 2.62 and 2.68, respectively. Peak severity which ranged from 2.57 in F4 (100:60:60) to 2.66 in F5 (100:30:60) was not significantly different among the different fertilizer treatments but these were significantly ($\rho < 0.05$) different from F1 (0:0:0).

All treatment interactions had no significant effects on initial and peak MSD severity in both the major and minor seasons (Table 10). In the Major season, interaction T2V2F1 had the highest peak MSD severity (2.19), while the lowest peak severity score (1.06) was recorded in T1V1F7 (Table 10). In the minor season, the highest peak severity score of 3.05 was recorded in T2V1F1 which was not significantly ($\rho > 0.05$) different from the other treatment interactions. A mean severity score of 2.65 was recorded in the minor season which was higher than the peak severity score of 1.4 recorded in the major season.

Lower MSD severity was recorded under no-tillage than conventional tillage. This corroborated with the result from the baseline studies that tillage practices on famers' fields had a significant impact on MSD. This agrees with the findings of Gilbert and Woods (2001) who observed that septoria leaf blotch and stagonospora leaf blotch were more prevalent in conventionally tilled fields than no-tillage fields. Also, lower MSD incidence was recorded under no-tillage than conventional tillage. Reduced MSD incidence under no-tillage might have resulted from the effect this particular tillage system has on the abundance and behaviour of the leaf hopper (*C. mbila*); the vector that transmits the maize streak virus to plants. Also, the application of herbicides under no- tillage aimed at killing grasses that may have served as alternative hosts for the leafhopper could have contributed to the reduced MSD under this particular tillage system (Martin et al., 2009). Reduced MSD severity under no-tillage might have resulted from healthier plants which were better able to withstand the disease due to soil improvement by surface residue left under no-tillage.

The two maize varieties (*Obatanpa* and *Domabin*) did not differ in terms of disease incidence. This result is contradicts the observations made by Bua and Chelimo (2010) working with three maize varieties which were artificially inoculated, and realized that MSD incidence significantly varied with maize variety. Both *Obatanpa* and *Domabin* can be rated as moderately resistant to MSD with mean severity scores ranging between 2.6- 2.7 (Bosque-Perez et al., 1992). The two varieties did not differ in terms of disease incidence but differed slightly in terms of severity especially when the disease pressure was high in the minor season. The differences among the maize varieties for resistance to MSD indicated the potential inherent genetic diversity in genotypes as reported by Karavina et al. (2014). Also, Bua and Chelimo (2010) working with three maize varieties which were artificially inoculated, realized that MSD severity significantly varied among maize varieties.

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 therefore, is not in good agreement with Magenya et al. (2009) report 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 MSD.

The impact of fertilizer application on MSD was realized only in the minor season. The disease severity was significantly affected by NPK application. This result is in agreement with the findings of Huber et al. (2007) who reported that take all disease of wheat was reduced when balanced NPK was applied. This could be attributed to the fact that fertilizer application does not necessarily affect MSD occurrence, but it has significant impact on the ability of plant to limit penetration and development of the invading virus. Also, the ability of the MSD infested plant to maintain its own growth, in spite of the infection is in a way affected by fertilizer application. In general, higher MSD incidence and severity were recorded on FI (0:0:0), and can be deduced that fertilizer application has a beneficial effect against MSD. Hence the hypothesis that fertilizer application does not affect MSD incidence and severity is rejected. The fertilized plants were able to obtain sufficient nutrients and hence grew stronger, healthier and had the ability to compensate for the viral damage.

Incidence and severity in general were higher in the minor cropping season (89.4 and 2.7 respectively) and low in the major cropping season (29.76 and 1.44 respectively). This result is consistent with the report by Bosque-Perez et al. (1992) that late season planting suffer higher MSD incidence than early season plants. This may be as a result of the number of viruliferous leaf hoppers being low in the major rainy season but increased in the minor season when the rainfall intensity reduces; and hence, disease incidence increased as suggested by Martin et al. (2009). Similarly, Magenya et al. (2008) and Martin et al. (2009) observed that droughts or irregular rains around the time that maize was planted tend to be associated with severe MSD.

Plant Height of two Maize Varieties as Influenced by Tillage System and Fertilizer Application

Plant height is a measure of growth related to the efficiency in exploitation of environmental resources. It is directly linked with the productive potentials of plants in terms of grain yield (Olusegun, 2015). Tillage effect on plant height was significant, the conventional tillage recorded heights of 203.1 cm while 143.6 cm was recorded for no-tillage (Table 11). There was no varietal effect on plant heights (Table 11). Plant height was significantly ($\rho < 0.05$) affected by fertilizer application. There was significant difference of plant height between F1 (0:0:0) and the other fertilizer treatments which showed no significant differences among themselves (Table 11). The highest of 182.9 cm was recorded in F7 (60:60:60).

Table 11

Plant Height as Affected by Tillage System, Maize Variety and Fertilizer Application

Treatment	Plant height (cm)
Tillage	
T1 (No-tillage)	143.5
T2 (Conventional tillage)	203.1
l.s.d	12.87
F pr.	<0.001*
Maize variety	
V1 (Obatanpa)	176.9
V2 (Domabin)	169.8
l.s.d	NS
F pr.	0.344
Fertilizer rates ($N:P_2O_5:K_2O$ kg ha^{-1})	
F1 (00:00:00)	150.6
F2 (100:30:60)	178.5
F3 (100:80:60)	171.8
F4 (100:60:60)	171.3
F5 (100:60:30)	180.7
F6 (100:60:80)	177.4
F7 (60:60:60)	182.9
l.s.d	16.96
F pr.	0.005*
Mean	173.3

*Denotes significance at $\rho \leq 0.05$, NS= not significant.

Tillage and varietal interaction had no significant effect on plant height (Table 12). Also, interactions between tillage and fertilizer application as well variety and fertilizer application did not have any significant effects on plant height.

Table 12

Interactive Effects of Tillage System, Maize Variety and Fertilizer Application on Plant Height

Treatment interaction	Plant height (cm)
	P value
T×V	0.460
T× F	0.169
V×F	0.516
L ×V×F	0.760

T = Tillage system, V= Maize variety F= Fertilizer application

The increased growth in conventional tillage may be attributed to better aeration and increase in the proliferation of roots for uptake of more nutrients by plants in this plot. This result is consistent with those obtained by Aikins et al. (2012), Imran et al. (2014) and Shahid et al. (2016), all identified that plant shoot development was dependent on root development, and increases with depth of tillage, leading to more vegetative growth of plants under conventional tillage.

The increased growth on fertilized plots is also similar to the results obtained by Arthur (2014) who observed comparatively taller plant heights on fertilized plots than that on plots where no fertilizer was applied. The result from this study is also in agreement with the findings of Law-Agbomo et al. (2008) and Memon et al. (2012) who all observed that plant growth increased with fertilizer application. The fertilizer treated plants received the nutrients needed for growth whilst unfertilised plants had to rely on native soil fertility. The taller plants produced by *Obatanpa* variety under conventional tillage system with applied fertilizer may be as a result of increase in the use of more nutrients in soils which are permeable, well aerated and with sufficient nutrient available for plant to absorb resulting from tillage and fertilizer application.

Effects of Tillage System and Fertilizer Application on Yield Components of two Maize Varieties

The number of cob-bearing plants has a direct effect on the final grain yield of maize. Data regarding the number of cob-bearing plants per plot is presented in Table 13. Tillage and fertilizer application had no significant effects on the number of cob-bearing plants per plot; mean numbers ranged from 83 plants in F1 (0:0:0) to 94 plants in F6 (100:60:80). However, *Domabin* maize variety recorded significantly ($\rho < 0.05$) higher number of cob bearing plant than *Obatanpa*.

This result from the present study is in contrast to that obtained by Igbal et al. (2003) who noted the number of cob-bearing plants was significantly affected by fertilizer application, and suggested that the trait could be influenced by plant nutrition. The number of cob-bearing plants affected by maize variety suggested that the trait was genetically controlled.

Maximum cob length of 15.9 cm was obtained for *Domabin* which was significantly ($\rho < 0.05$) longer than 13.7 cm obtained in *Obatanpa*. Tillage had no significant ($\rho > 0.05$) effect on cob length. Cob length increased significantly ($\rho < 0.05$) with fertilizer application (Table 13). The maximum cob length (15.52 cm) was recorded in F5 (100:60:30) which was significantly ($\rho < 0.05$) different from the cob length (13.33 cm) obtained in the F1 (0:0:0).

The result is similar to that obtained by Sani et al. (2014); they posited that genotypes had significant effect on cob length. The significant response of cob length to fertilizer may probably be due to adequate supply of nitrogen which enhanced photosynthetic activities of the plant. The cob length in F5 was however, not significantly different from F2, F4, F6 and F7, but significantly ($\rho < 0.05$) higher than F3 where 80 kg P_2O_5 ha^{-1} was applied. Application of high levels of phosphorus with low potassium was reported to be capable of causing nutrient imbalance and consequently yield depression in maize and hence the length of cobs may decrease (Onasanya et al., 2009).

The number of grains per cob is also another important component which contributes towards grain yield of maize crop (Shahid et al., 2016). Tillage system significantly ($\rho < 0.05$) affected the number of grains produced per cob; conventionally tilled plots had significantly ($\rho < 0.05$) higher number of grains per cob (348) than 309 grains per cob recorded under no-tillage (Table 13). Maize variety did not significantly ($\rho > 0.05$) affect the number of grains produced per cob.

The number of grains produced per cob was however, significantly ($\rho < 0.05$) affected by fertilizer application. F1 (0:0:0) had the least number of 295 grains per cob which was significantly ($\rho < 0.05$) lower than that attained by the fertilizer treatments. Though the highest number of 375 grains was produced by plants in F5 (100:30:60), this was not significantly different from those for the rest of the fertilizer treatments.

Table 13

Yield Components of Maize as Affected by Tillage System, Maize Variety and Fertilizer Application

Treatment	Number of cob bearing-plant plot^{-1}	Cob length (cm)	Number of grains per cob	Grain weight per cob (g)	100-seed weight (g)	Grain yield (kg ha^{-1})
Tillage						
T1 (No-tillage)	88	14.6	309	78.9	28.1	3127
T2 (Conventional tillage)	90	15.1	384	97.6	27.5	3941
l.s.d	NS	NS	45.8	17.17	NS	453.0
F pr.	0.643	0.116	0.013*	0.040*	0.463	0.011*
Maize variety						
V1(Obatanpa)	86	13.7	341	96.3	31.2	3759
V2(Domabin)	91	16.0	352	80.2	24.3	3309
l.sd	4.6	1.108	NS	11.70	1.518	434.6
F pr.	0.050*	0.003*	0.457	0.015*	<0.001*	0.044*
Fertilizer rate ($N:P_2O_5:K_2O$ kg ha^{-1})						
F1(0:0:0)	83	13.3	295	72.3	26.4	2757
F2(100:30:60)	93	15.5	353	90.5	28.3	3801
F3(100:80:60)	92	14.5	338	87.0	27.3	3539
F4(100:60:60)	86	15.1	365	91.5	27.8	3588
F5(100:60:30)	85	15.5	376	99.7	28.1	3758
F6(100:60:80)	94	15.3	351	88.0	28.1	3673
F7(60:60:60)	89	14.8	347	88.7	28.5	3624
l.s.d	NS	0.834	38.5	16.90	NS	653.2
F pr.	0.390	<0.001*	0.004*	0.002*	0.185	0.040*
Mean	88.7	14.86	346.4	88.3	27.77	3534

* Denotes significance at ($\rho \leq 0.05$), NS = not significant.

The significant effect of tillage on number of grains per cob is in agreement with observations made by Memon et al. (2012), Shahid et al. (2016) and Wang et al. (2015) that tillage has significant effect on number of grains produced per cob; the maximum grain number per cob was found under conventional tillage system, while the minimum number of grains per cob was found under no tillage system. This could be as a result of more aeration and better water retention of the sandy loam soil under conventional tillage compared to no-tillage system, and hence provides a more favourable environment for plant growth and productivity.

The effect fertilizer application on this particular trait confirms the role of major plant nutrients in their effect on flowering, seed formation and maturation. This result also bears similarities with the observations made by Asghar et al. (2010) that NPK application significantly affected the number of grain produced per cob. Also, Ali et al. (2002), Mazengia (2011) and Shahzad et al. (2015) observed that different rates of N and P application produced grain numbers per cob which were at par, but significantly different from the control plots, where no fertilizer application was made.

The grain weight per cob indicates the extent to which the photo assimilates have been accumulated in the grains of a cultivar compared to its vegetative organs (Rizwan et al., 2003). Grain weight per cob directly influences grain yield per hectare. Tillage, variety and fertilizer application each affected grain yield per cob significantly (Table 13). Conventional tillage produced significantly ($\rho < 0.05$) higher grain weight per cob (97.6 g) than no tillage (78.9 g). Also, *Obatanpa* produced a significantly ($\rho < 0.05$) higher grain weight per cob than *Domabin*; a result that contradicts that obtained by Iqbal et al. (2003) that maize varieties do not vary in terms of weight of grains their individual cobs produce. The fertilizer rate T5 (100:60:30) produced the maximum weight of 99.7 g grain per cob which was not significantly different from F2, F4 and F7 but was significantly ($\rho < 0.05$) different from F1, F3 and F7. F1 (0:0:0) had the minimum grain weight of 72.3 g per cob.

The grain weight per cob affected by maize variety suggested that the trait was genetically controlled. A decrease in grain weight per cob obtained in F1 (0:0:0) may be explained in terms of lesser availability of nutrients. A similar trend was also seen in the cob length which agrees with findings of Onasanya et al. (2009).

One hundred (100) seed weight expresses the magnitude of seed development which is an important factor for deriving the total grain yield per hectare (Olusegun, 2015). The results for 100-seed weight are presented in Table 13. Tillage system and fertilizer application had no significant effect on 100-seed weight. The100-seed weight was significantly ($\rho < 0.05$) different between the two maize varieties, with the maximum mean weight of 28.1 g obtained by *Obatanpa* and a minimum weight of 27.5 g obtained by *Domabin*. This could be due to some inherent genetic and physiological differences that existed between the two varieties, since *Obatanpa* had comparatively bigger and heavier seeds than *Domabin*.

Conversely, Olusegun (2015) and Tahiru et al. (2015) detected significant effect of fertilizer application on 100-seed weight. The result from this study is in agreement with that obtained by Tahiru et al. (2015) who obtained higher 100-seed weight in *Obatanpa* and suggested that the extended grain filling period in the late maturing variety produced heavier seeds compared to the early maturing maize varieties.

Effect of Tillage System and Fertilizer Application on Grain Yield (kg ha^{-1}) of two Maize Varieties

The final grain yield per hectare in maize is the effect of various yield components like number of cob-bearing plants, number of cobs per plant, number of grains per cob and weight of grain per cob. Conventional tillage recorded a mean grain yield of 3941 kg ha^{-1} which was significantly ($\rho < 0.05$) higher than the 3127 kg ha^{-1} produced under no-tillage system. The yield difference between conventional tillage and no-tillage was 21%.

The lower grain yields under no-tillage treatment can be attributed to slow early crop growth which resulted in shorter plant heights as compared to conventional tillage. Slow growth was witnessed under no-tillage system and its plants also lagged behind in terms of yield components such as number of grains per cob and grain weight per cob reported in this study. The significant effect of tillage on grain yield is in agreement with the observations made by Memon et al. (2012), Shahid et al. (2016) and Shahzad et al. (2015). The finding from this work bears some similarities with that of Arthur (2014) who obtained higher grain yield in conventional tillage in the major season.

Also maize variety significantly ($\rho < 0.05$ affected the grain yield; *Obatanpa* gave mean grain yield of 3759 kg ha^{-1} which was significantly higher than grain yield of 3309 kg ha^{-1} produced from *Domabin*. This was 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. Similarly, Tahiru et al. (2015) observed that *Obatanpa* gave a higher yield on two different types of soils. This result is also in conformity with the findings of Adiniyan (2014), Alias et al. (2003), Khan et al. (2014) and Sani et al. (2014) that significant yield differences exist among different maize varieties; but contradicts the results of Asghar et al. (2010) and Iqbal et al. (2003).

Fertilizer application significantly ($\rho < 0.05$) affected the final grain yield per hectare (Table 13). Fertilized plots, gave 24.8% more grains than T1 (0:0:0). However, further increase beyond a certain rate will result in yield decrease. The highest grain yield of 3801 kg ha^{-1} was obtained in F2 (100:30:60) which was not significantly different from the grain yield obtained on other fertilizer treatments but was significantly ($\rho < 0.05$) higher than F1 (0:0:0).

The effect of fertilizer application on maize grain yield is in accordance with the findings of Olusegun (2015) that phosphorus fertilizer rate at 30 kg ha^{-1} produced grain yield of 3091.5 kg ha^{-1}, beyond which there was a significant reduction while the least value was recorded in the control plot. Mensah et al. (2016) also obtained a maximum yield of 4953 kg ha^{-1} at 120 kg ha^{-1} N and 30 kg P ha^{-1}. According to Arnon (1975), where other factors are fairly constant, yield increases are usually directly proportional to the increases of N in the leaf that result from fertilizer application. This could probably explain the lack of significant yield differences among the different fertilizer treatments. This result is supported by the findings of Adeniyan (2014), Arthur (2014), Jaliya et al. (2008), and Tahiru et al. (2015) that fertilizer application significantly affect maize yield.

Interactive Effects of Treatments on Yield Components and Grain Yield of Maize

The interaction between tillage and maize variety had no significant effect on the number of cob-bearing plants, cob length, grain weight per cob, 100-seed weight and grain yield per hectare (Table 14). The interactive effect of tillage and variety on the number of grains produced by each cob was significant ($\rho < 0.05$). The highest number of grains, approximately 408 was produced by *Domabin* cobs under conventional tillage which was significantly ($\rho < 0.05$) different from 296 produced by *Domabin* cobs under no-tillage system.

Table 14

Interactive Effects of Tillage and Maize Variety on Yield Components and Grain Yield of Maize

Tillage × Variety	Number of cob bearing-plant plot^{-1}	Cob length (cm)	Number of grains cob^{-1}	Grain weight per cob (g)	100-seed weight (g)	Grain yield (kg ha^{-1})
T1V1	84	13.5	322	89.5	31.5	3394
T1V2	92	15.7	296	68.3	24.6	2861
T2V1	89	14.0	361	103.1	30.9	4125
T2V2	90	16.2	408	92.1	24.0	3757
l.s.d	NS	NS	45.30	NS	NS	NS
F pr.	0.194	0.920	0.030*	0.329	0.958	0.658

* Denotes significance at $\rho \leq 0.05$, NS= not significant, T1= no-tillage, T2= conventional tillage, V1=*Obatanpa*, V2= *Domabin*.

Also, *Domabin cob*s gave a significantly ($\rho < 0.05$) higher number of grains (408) than *Obatanpa* (361) under conventional tillage system. But under no-tillage system, *Obatanpa* cobs gave more grains (322) than *Domabin* (296).

This would mean that different maize varieties differ in the uptake and utilization of soil nutrients from different soil depths; this trait is dependent on roots architecture and the extents of roots development as well as the penetrability of the soil as influenced by tillage systems.

The interaction between tillage and fertilizer application had no significant effect on the number of cob bearing-plants per plot, cob length and 100-seed weight, but significantly affected number of grains produced per cob, weight of grains per cob and overall grain yield per hectare (Table 15). F1, F3, F6 and F7 under conventional tillage gave a significantly ($\rho < 0.05$) higher grain number than their counterparts under no-tillage. Plots which received no fertilizer under conventional tillage gave grain number of 343; this was significantly ($\rho < 0.05$) higher than that produced by F3 and F6 under no-tillage system. T1F4 gave a higher grain yield per cob than T2F4, even though the difference was not significant. But F2, F6 and F7 under conventional tillage gave significantly ($\rho < 0.05$) higher grain weight per cob than their counterparts under no-tillage system. Lowest grain weight per cob of 60 g was recorded in T1F1 while the highest of 105.6 g was recorded in T2F5.

The highest grain yield of 4599 kg ha^{-1} was produced on conventionally tilled plot where NPK 100:60:80 was applied (T2F6). This was not significantly ($\rho < 0.05$) higher than F2, F3, F5, F7 under conventional tillage and F4 under no-tillage. The least grain yield of 2295 kg ha^{-1} was produced on no-tillage plots on which no fertilizer was applied (T1F1). The conventional tillage led to a short-term reduction in the soil bulk density and therefore improved the penetrability of the soil and might have improved

Table 15

Interactive Effects of Tillage and Fertilizer Application on Yield Components and Grain Yield of Maize

Tillage × fertilizer interactions	Number of cob bearing plant plot^{-1}	Cob length (cm)	Number of grains cob^{-1}	Grain weight per cob(g)	100-seed weight (g)	Grain yield (kg ha^{-1})
T1F1	81	12.48	247	60.0	26.08	2295
T1F2	97	15.39	331	83.0	28.65	3598
T1F3	92	13.99	279	76.0	27.07	3110
T1F4	90	15.34	355	93.4	28.05	3892
T1F5	80	15.78	357	93.8	29.32	3288
T1F6	88	14.89	283	71.6	28.76	2747
T1F7	87	14.26	309	74.5	28.46	2963
T2F1	84	14.19	343	84.7	26.72	3219
T2F2	89	15.55	376	97.9	27.92	4004
T2F3	92	14.95	397	98.0	27.58	3969
T2F4	81	14.88	376	89.7	27.45	3284
T2F5	89	15.26	394	105.6	26.86	4228
T2F6	100	15.71	419	104.5	27.35	4599
T2F7	92	15.34	385	102.8	28.52	4284
Lsd.	NS	NS	59.03	19.32	NS	901.8
F pr.	0.515	0.080	0.029*	0.050*	0.487	0.018*

* Denotes significant at $\rho \leq 0.05$, NS= not significant, T1= no-tillage, T2= conventional tillage, F1 (00:00:00), F2 (100:30:60), F3 (100:80:60), F4 (100:60:60), F5 (100:60:30), F6 (100:60:80) and F7 (60:60:60),

the availability and uptake of applied nutrients by maize plants. These results are consistent with the findings of Memon et al. (2014) and Shahid et al. (2016) that tillage and NPK application interactively affect maize grain yield. Though, the grain yield on no-tillage plot was generally low, F4 (100:60:60) gave a yield of 3892 kg ha^{-1} under no-tillage system which was higher than 3284 kg ha^{-1} obtained under conventional tillage.

The interaction between variety and fertilizer application had no significant effect on any of the yield components of maize (Table 16), which

Table 16

Interactive Effects of Maize Variety and Fertilizer Application on Yield Components and Grain Yield of Maize

Variety × fertilizer interaction	Number of cob bearing-plant $plot^{-1}$	Cob length (cm)	Number of grains cob^{-1}	Grain weight per cob	100-seed weight (g)	Grain yield (kg ha^{-1})
V1F1	84	14.71	271	71.3	29.70	2817
V1F2	88	16.40	353	96.2	31.67	3823
V1F3	88	15.75	323	98.3	31.29	3829
V1F4	85	16.31	361	101.5	30.76	3959
V1F5	85	16.54	376	112.7	31.51	4195
V1F6	92	16.32	374	101.3	31.31	4084
V1F7	83	13.81	331	92.6	32.41	3609
V2F1	81	11.96	320	73.3	23.10	2697
V2F2	98	14.54	354	84.7	24.90	3779
V2F3	96	13.19	353	75.7	23.37	3250
V2F4	87	13.90	369	81.5	24.74	3218
V2F5	84	14.50	375	86.8	24.68	3320
V2F6	96	14.28	328	74.8	24.80	3261
V2F7	96	15.79	363	84.8	24.56	3639
l.s.d	NS	NS	NS	NS	NS	NS
F pr.	0.101	0.920	0.267	0.141	0.894	0.636

NS= not significant, V1= *Obatanpa*, V2= *Domabin*, F1 (00:00:00), F2 (100:30:60), F3 (100:80:60), F4 (100:60:60), F5 (100:60:30), F6 (100:60:80) and F7 (60:60:60).

were the number of cob bearing-plants per plot, cob length and 100-seed weight, number of grains produced per cob, weight of grains per cob, as well as on overall grain yield per hectare.

Tillage, variety and fertilizer application interaction had no significant ($\rho > 0.05$) effect on the number of cob bearing-plant per plot, cob length, weight of grains per cob and 100-seed weight (Table 17). However, tillage, variety and fertilizer interaction significantly ($\rho < 0.05$) affected the number of grains produced per cob.

Table 17

Interactive Effects of Tillage, Maize Variety and Fertilizer Application on Yield Components and Grain Yield of Maize

Treatment interaction	Number of cob bearing-plant plot^{-1}	Cob length (cm)	Number of grains cob^{-1}	Grain weight per cob	100-seed weight (g)	Grain yield (kg ha^{-1})
T1V1F1	80	10.98	232	60.7	29.73	2312
T1V1F2	93	14.55	361	92.2	32.11	3783
T1V1F3	96	12.53	287	88.7	30.19	3800
T1V1F4	90	14.55	368	109.1	31.22	4539
T1V1F5	75	14.98	384	111.3	32.43	3591
T1V1F6	85	13.90	350	92.7	31.90	3447
T1V1F7	70	12.78	272	71.5	33.17	2286
T1V2F1	83	13.97	263	59.3	22.42	2278
T1V2F2	101	16.23	301	73.9	25.18	3414
T1V2F3	88	15.45	272	63.3	23.95	2419
T1V2F4	90	16.12	341	77.6	24.89	3245
T1V2F5	85	16.57	331	76.3	26.21	2984
T1V2F6	90	15.88	216	50.4	25.63	2046

Table 17 continued

Treatment interaction	Number of cob bearing plant plot^{-1}	Cob length (cm)	Number of grains cob^{-1}	Grain weight per cob	100-seed weight (g)	Grain yield (kg ha^{-1})
T1V2F7	103	15.75	346	78	23.74	3640
T2V1F1	88	12.92	309	82	29.66	3322
T2V1F2	83	14.53	346	100	31.23	3863
T2V1F3	80	13.85	360	108	32.38	3857
T2V1F4	80	13.25	354	94	30.30	3379
T2V1F5	96	14.03	368	114	30.59	4799
T2V1F6	98	14.65	399	110	30.72	4722
T2V1F7	96	14.85	390	114	31.65	4931
T2V2F1	80	15.45	378	87	23.79	3115
T2V2F2	96	16.57	407	96	24.61	4144
T2V2F3	103	16.05	434	88	22.78	4080
T2V2F4	83	16.50	397	85	24.60	3190
T2V2F5	83	16.50	420	97	23.14	3656
T2V2F6	101	16.77	440	99	23.98	4475
T2V2F7	88	15.83	380	92	25.38	3638
Lsd	NS	NS	81.23	NS	NS	1289.4
F pr.	0.101	0.427	0.049*	0.254	0.572	0.032*

* Denotes significance at $\rho \leq 0.05$, NS= not significant, T1= no-tillage, T2= conventional tillage, F1 (00:00:00), F2 (100:30:60), F3 (100:80:60), F4 (100:60:60), F5 (100:60:30), F6 (100:60:80) and F7 (60:60:60).

T2V2F6 produced the highest number of approximately 440 grains per cob and the lowest was produced in T1V2F6. Also, T2V1F6 produced double the number of grains per cob produced in T2V2F6.

Tillage, variety and fertilizer application interaction significantly (ρ < 0.05) affected the final grain yield per hectare (Table 17). The highest grain yield of 4931 kg ha^{-1} was produced by *Obatanpa* on conventionally tilled plots on which NPK 60:60:60 was applied (T2V1F7), and the least grain yield of 2046 kg ha^{-1} was obtained on no till plot where *Domabin* was grown and fertilized with 100:80:60 (T1V2F6). This implies that with *Domabin*, NPK application beyond 100:80:60, under no-tillage system, is required to produce same yield as *Obatanpa* fertilized with NPK 60:60:60 under conventional tillage. This might be due to the genotypic variation among the varieties because plant genotypes differ in their responses to changing soil fertility and other soil conditions. They may also differ in terms of efficient utilization of applied the nutrients. This means that improved maize varieties are better able to utilize the minimum amount of nutrient in well aerated and permeable soils.

Effect of Treatments and their Interactions on Mineral and Crude Protein Content of Maize Grains

Phosphorus (P) (%) Content of Maize Grain

Maize grain phosphorus content was not affected by tillage system (Table 18). The no-tillage gave the highest mean grain P content of 0.25 % which was not significantly ($\rho > 0.05$) different from 0.22 % produced under conventional tillage. *Domabin* produced the highest grain P content (0.24%) but was not significantly ($\rho > 0.05$) different from 0.22% produced by *Obatanpa*. This could be that tillage and variety do not affect the contents of phosphorus in maize grain. This was consistent with the observation made by Al-Kaisi et al. (2007). They obtained similar results (of no difference between no-tillage and conventional tillage) in terms of the contents of phosphorus in the grains.

F7 (60:60:60) gave the highest maize grain P content of 0.25%, but was not significantly different from the other treatments. The lowest grain P content of 0.21% was produced by F2 (100:30:60). This could be as a result of heavy nitrogen applications, in conjunction with low phosphorus, causing reduction in the P content of the grains due to increased growth and thus resulted in P dilution.

Table 18

Effect of Tillage, Maize Variety and Fertilizer Application and their Interactions on P, K and Crude Protein Content of Maize Grain

Treatment	Phosphorus (%)	Potassium (%)	Crude protein (%)
Tillage			
T1 (No-till)	0.24	0.34	9.3
T2 (Conventional tillage)	0.22	0.31	8.5
l.s.d	NS	0.014	NS
F pr.	0.07	0.011*	0.132
Maize variety			
V1(Obatanpa)	0.22	0.34	8.0
V2(Domabin)	0.24	0.32	9.9
l.s.d	NS	NS	1.30
F pr.	0.147	0.660	0.016*
Fertilizer NPK kg ha^{-1}			
F1(0:0:0)	0.22	0.32	7.9
F2(100:30:60)	0.21	0.33	8.9
F3(100:80:60)	0.23	0.33	9.1
F4(100:60:60)	0.23	0.33	8.3
F5(100:60:30)	0.24	0.33	8.2
F6(100:60:80)	0.25	0.33	9.3
F7(60:60:60)	0.25	0.34	10.8
l.s.d	NS	NS	1.70
F pr.	0.059	0.581	0.035*
Mean	0.23	0.33	8.9
Treatment interactions		**P value**	
T×V	0.997	0.660	0.223
T×F	0.288	0.079	0.476
V×F	0.346	0.039*	0.229
T×V× F	0.055	0.059	0.115

* Denotes significance at $\rho \leq 0.05$, NS= not significant. T = tillage, V = variety and F = fertilizer application.

The phosphorus content of maize grain was not affected by interaction between the various treatments. Fertilizer application had no significant ($\rho > 0.05$) effect on maize grain P content. This is in agreement with the observation made by Bak et al. (2016) that differentiated fertilizer rates had no conclusive effect on in P concentrations in the grains of maize. Converse to this result, Bashir et al. (2011) and Sebatha et al. (2015) reported that NPK application has a significant effect on grain P content, and even different levels of N fertilizer treatment had significant effect on P content of the grains.

Potassium (K) (%) Content of Maize Grains

Maize plants under no-tillage produced a significantly ($\rho < 0.05$) higher grain K (0.34%) than those under conventional tillage (Table 18). Also, maize grain K content was not significantly ($\rho > 0.05$) different between the two maize varieties even though *Obatanpa* had the highest (0.34%) grain K content compared to 0.31 % produced by *Domabin*. This could be attributed it to the fact that effect of fertilizer application on nutrient content may not be cultivar specific. This contradicts the results of Bashir et al. (2012) who found a rather significant variation in maize varieties, in terms of grain K accumulation. Similarly, Stanislawska-Glubiak et al. (2011) observed that maize grain K content under no-tillage was higher than that under conventional tillage, though not significant.

The highest mean grain K content of 0.34 % was obtained in F7 (60:60:60) which was not significantly ($\rho > 0.05$) different from the other fertilizer treatments and F1 (0:0:0). The lowest grain K content of 0.32 % was obtained in F1. Fertilizer application effect on the maize grain K content was not significant. According to Arnon (1975), K-content of the seed of most crops is usually far less affected by K-fertilization than that of the vegetative parts. This result however contradicts the observation made by Bak et al. (2016), Bashir et al. (2012) and Lei et al. (2000) that K in grains was significantly affected by fertilizer application and that the application of nitrogen and phosphorus enhanced grain potassium content. Variety-fertilizer interaction significantly ($\rho < 0.02$) affected grain K content. There were no tillage-varietal, tillage-fertilizer as well as tillage-variety-fertilizer interactions effect on grain K content. This could be attributed it to the fact that effect of improved fertilizer application on nutrient content is not related with varietal differences.

Crude Protein (%) Content of Maize Grains

The no-tillage system gave a higher grain crude protein content (9.3%) and was not significantly ($\rho > 0.05$) different from 8.5% produced under conventional tillage (Table 18). The nutrients loss especially nitrogen from soil under no-tillage was minimal and hence resulted in increased availability for growth and accumulation in the grains at maturity. Shahzad et al. (2015) reported a rather contrary result that seed protein was significantly affected by tillage operations and that conventional tillage resulted in higher protein content than no-tillage.

The crude protein content of maize grain was significantly ($\rho < 0.05$) different between the maize varieties, *Domabin* gave grain crude protein content of 9.9 %, and was significantly ($\rho < 0.05$) higher than 8.0% produced by *Obatanpa* (Table 18). The differential response to fertilizer application between cultivars may have occurred because many varieties keep the integrity of leaf area for a longer period, which contributes to the greater synthesis of photo-assimilates during grain filling. Emily et al. (2012) also reported that protein along with the ratios of amino acids can be quite variable between cultivars and are also influenced by environmental conditions. Similar result was obtained by Faisal et al. (2012) that grain protein content was significantly affected by maize varieties.

Fertilizer application significantly ($\rho < 0.05$) affected the maize grain crude protein content (Table 18). The F7 (60:60:60) gave the highest grain crude protein content of 10.8 %, and was significantly different from the other fertilizer treatments, but F3 (100:80:60) and F6 (100:60:80). The lowest crude protein of 7.9 % was recorded for F1 (0:0:0); this was 26.2% less than that produced by F7. The decrease in the protein content, with the application of highest doses of nitrogen and potassium fertilizer can be attributed to the fact that while potassium is needed in large quantities for plant growth and protein biosynthesis, it stimulates more intense carbohydrate synthesis and transport than synthesis of nitrogen substances. So, when applying large amounts (higher than 60 kg ha^{-1}) of potassium fertilizers, carbohydrate synthesis and their transportation from other organs to grains are increased, and therefore, protein content decreases. This result is similar to the findings of Rheman et al. (2011) and Radulov et al. (2012) that NPK application significantly increased protein contents of maize grain. The attainment of the highest protein content at NPK rate 60:60:60 is in concordance with the results of Radulov et al. (2012) that the application of the maximum dose of K and P beyond 50 kg ha^{-1} led to a decrease in protein content. Crude protein content of maize grain was not significantly affected by interactions between the various treatments (Table 18).

Relationship Among MSD, Plant Height, Yield and Crude Protein Contents of Maize Grains

Regardless of the tillage system, maize variety and rate of fertilizer application, MSD incidence and severity at the initial stage of growth of plants correlated significantly with both MSD incidence and severity at the stage at which peak growth was attained (Table 19). There was significant positive correlation between initial and peak MSD incidence and severity, and plant height meaning the prevalent and severe the MSD symptoms, the taller the plant grows. Initial MSD incidence and severity did not correlate significantly with grain yield of maize (Table 19). MSD prevalence at silking time was strongly correlated with maize grain yield.

Inexplicably, mean disease incidence and mean severity score were found to have positive and strong correlation with mean plant height and grain yield (Table 19). The mean MSD incidence and severity at peak disease infection in the major season were 29.7% and 1.4 respectively, which implies that although the disease incidence occurred, the plants were still able to maintain their own growth and yield in spite of infection as reported by Dordas (2009). These findings however disagree with that of Bosque-Perez et al. (1998) who reported a significant negative correlation of MSD incidence at 32 days of planting with plant height and grain weight. The disease has been reported by Bua et al. (2010) and Bosque-Perez, et al. (1998) to significantly reduce maize growth and yield. No significant relationship was detected between MSD prevalence and maize grain crude protein content meaning the disease had no effect on grain crude protein content.

Table 19

Correlation Matrix for MSD Incidence and Severity, Plant Height, Yield and Crude Protein Content of Maize Grains

	Initial Incidence (%)	Initial severity	Peak incidence (%)	Peak severity	Height (cm)	Grain Yield (kg ha^{-1})
Initial severity	0.80*					
Peak incidence	0.36*	0.32*				
Peak severity	0.34*	0.33*	0.91*			
Height (cm)	0.27*	0.23*	0.60*	0.46*		
Grain yield (kg ha^{-1})	0.17	0.09	0.40*	0.30*	0.51*	
Crude protein (%)	- 0.18	- 0.15	- 0.15	- 0.16	- 0.09	- 0.30*

Sample size = 83, * denotes significance at $\rho \leq 0.05$.

There was no significant relationship between plant height and crude protein content of the grains, but grain yield negatively correlated ($r = -0.34$, $\rho < 0.05$) with crude protein content of the grains, and the relationship was significant. This means that when grain yield increases, the protein content of grains reduces. In cereals, the grain yield is mostly represented in most of the carbohydrates and therefore an increase in yield will eventually result in reduce protein content. Similarly, Dragičević et al. (2014) and Abou-Deif et al. (2012) observed significant negative correlation between maize yield and protein content.

Effects of Fertilizer Application, Maize Variety and Tillage System on N, P and K Contents of Maize Leaves at Silking Time

For the accurate estimation of nutrient status of maize plant, the total N, P and K contents of leaves at silking time were used. Plants under conventional tillage accumulated significantly ($\rho < 0.05$) higher nitrogen (N) (1.64%) in their leaves than those under no-tillage (Table 20). Lower soil temperatures associated with no-tillage which reduces mineralization from soil organic matter, increased immobilization in the surface of the soil because of the enrichment of organic carbon from residue, and denitrification either independently, or in combination might have reduced the use and hence decreased the N content of maize plants under no-tillage compared to conventionally tilled treatments. This result is contrary to that obtained by Ozpinar and Ozpinar (2009) that effect of different tillage systems on leaf N content was not significant.

Table 20

Effects of Tillage, Variety and Fertilizer Application on N, P and K Contents of Maize Leaves at Silking Time

Treatment	Nitrogen in leaf (%)	Phosphorus in leaf (%)	Potassium in leaf (%)
Tillage system			
T1 (No-tillage)	1.28	0.28	1.42
T2 (Conventional tillage)	1.64	0.29	1.29
l.s.d	0.292	NS	0.044
F pr.	0.034*	0.632	0.007*
Maize variety			
V1 (Obatanpa)	1.40	0.29	1.39
V2 (Domabin)	1.52	0.28	1.22
l.s.d	NS	NS	0.058
F pr.	0.280	0.105	0.023*
Fertilizer application (NPK kg ha^{-1})			
F1 (00:00:00)	1.14	0.26	1.31
F2 (100:30:60)	1.69	0.28	1.36
F3 (100:80:60)	1.65	0.29	1.35
F4 (100:60:60)	1.39	0.28	1.38
F5 (100:60:30)	1.42	0.27	1.32
F6 (100:60:80)	1.51	0.31	1.42
F7 (60:60:60)	1.41	0.30	1.35
l.s.d	0.324	0.017	0.051
F pr.	0.030*	< 0.001*	0.001*
Mean	1.46	0.28	1.36

* Denotes significance at $\rho \leq 0.05$, NS= not significant.

The two maize varieties did not differ significantly ($\rho > 0.05$) in terms of content of N in their leaves. This means that the different maize varieties do not differ in terms of nitrogen use for growth and yield. This contradicts the observation made by Fosu-Mensah et al. (2016) that higher N levels were found in *Dorke* than in *Obatanpa* variety.

Fertilizer application significantly ($\rho < 0.05$) affected the N content of the leaves of maize plants (Table 20). F2 (100:30:60) had the highest leaf nitrogen content (1.69%); this was not significantly different from the rest of the fertilizer treatments, but was significantly ($\rho < 0.05$) higher than F1 (00:00:00). According to Arnon (1975), where other factors are fairly constant, yield increases due to different levels of application of N-fertilizers are usually directly proportional to the increases of N in the leaf that result from fertilizer application. This can be said to be similar to the results obtained in this work as the N content of maize leaf increased with increasing N application rates. The highest (1.81%) was obtained in F2 (100:30:80), although not significantly different from the other fertilizer treatments, was significantly different from F1 (0:0:0). The same trend was observed in maize grain yield obtained in this work. The result was consistent with the result obtained Bashir et al. (2012) that N in leaves increased significantly with urea application.

Phosphorus in the leaves was not significantly ($\rho > 0.05$) affected by tillage system and maize variety (Table 20). The 0.29% P recorded under conventional tillage was not significantly ($P > 0.05$) different from 0.28% recorded under no-tillage. Conventional tillage directly affects the availability and absorption of nutrients by plants, as a result of improved aeration and decomposition of organic matter, and thus resulted in the accumulation of marginally higher nutrients in the leaves of plants grown under conventional tillage than under no-tillage. This result is similar to that obtained by Stanisławska-Glubiak et al. (2011); they did not find any significant effects between different tillage systems in terms P content. Phosphorus in the leaves was not significantly ($\rho > 0.05$) affected by maize variety (Table 24). *Obatanpa* and *Domabin* maize varieties did not differ significantly in terms of P content of their leaves.

However, leaf P content was significantly ($\rho < 0.05$) affected by fertilizer application. F6 (100:60:80) had the highest leaf P (0.31%); this was significantly ($\rho < 0.05$) higher than (0.29%) in F3 where the highest quantity of 80 kg ha^{-1} of P_2O_5 ha^{-1} was applied. Also, F2 (100:30: 60) recorded a significantly higher leaf P content than F5 (100:60: 30); F1 recorded the least P content. Phosphorus content of maize leaves was highest at the highest rates of K_2O application. This means that phosphorus application significantly increase maize leaf phosphorus content. Contrary, Bąk et al. (2016) reported that differentiated fertilizer rates had no conclusive effect on differences in phosphorus concentrations in maize leaves.

Maize plants grown under no-tillage system accumulated significantly ($\rho < 0.05$) higher K in their leaves than those under conventional tillage (Table 20). Similarly, Shahzad et al. (2015) reported that tillage significantly affected K content of maize leaves. The two maize varieties varied significantly ($\rho < 0.05$) in terms of accumulation of K in their leaves. *Obatanpa* accumulated more K in the leaves than *Domabin*. The mechanism of differential accumulation of a particular nutrient such as potassium by maize varieties according to Arnon (1975) may be due to differences in disease resistance. Significantly higher K content of the leaf of *Obatanpa* than *Domabin* reflected in significantly lower MSD severity, and taller plants recorded for *Obatanpa* maize variety; this compared to higher peak MSD severity and shorter plants by *Domabin* variety. Increase disease resistance in *Obatanpa* could be related to its ability to use more K. This was also made evident in the higher grain yield produced by *Obatanpa* in this work.

The highest leaf K content of 1.42% was recorded in F6 (100:60:80) even though was not significantly different from leaf K content recorded for F4 (100:60:60), but was significantly ($\rho < 0.05$) different from the rest of the fertilizer treatments. This means that potassium fertilizer application improves maize ability to accumulate and use K in their system for growth, reproduction and disease suppression. Contrary to this result, Skowronska et al. (2010) reported that the content of K in maize leaves was not significantly influenced by K fertilization but P accumulation in plants was slightly intensified with K fertilization during tasseling.

Interactive Effects of Treatments on the Leaf N, P and K Contents of Maize Leaves at Silking Time

Tillage and varietal interaction did not significantly ($\rho > 0.05$) affect leaf N and P content but significantly ($\rho < 0.05$) affected K accumulation in maize leaves (Table 21). *Obatanpa* grown under no-tillage (T1V1) was better able to accumulate more K than *Obatanpa* under conventional tillage (T2V1) likewise for *Domabin*. Based on the results from this work it can be inferred that higher N content of maize leaf is associated with higher disease severity. In the first instance, peak MSD severity in the minor season was significantly higher on conventional tillage plot (Table 9) and maize varieties grown under this tillage system, also accumulated higher nitrogen in their leaves than their counterpart under no-tillage. Also, *Domabin* was less tolerant to MSD but accumulated higher nitrogen in their leaves (Table 9 and 21).

Table 21

Interactive Effects of Tillage and Maize Variety on N, P and K Contents of the Maize Leaves at Silking Time

Tillage ×Variety interactions	Nitrogen in leaf (%)	Phosphorus in leaf (%)	Potassium in leaf (%)
T1V1	1.20	0.27	1.45
T1V2	1.36	0.28	1.38
T2V1	1.60	0.29	1.34
T2V2	1.67	0.28	1.25
Lsd	NS	NS	0.058
F pr.	0.673	0.619	0.023*

* Denotes significance at $\rho \leq 0.05$, NS= not significant, T1= no-tillage, T2= conventional tillage, V1= *Obatanpa*, V2= *Domabin*.

Also, tillage and fertilizer application interactively affected P and K but not N content of maize leaves at silking time (Table 22). Maize plant in F7 (60:60:60) under conventional tillage, accumulated significantly ($\rho < 0.05$) higher P in leaf than their counterparts under no-tillage. On the other hand, F3 and F5 (under no-tillage) recorded more P in their leaves than their counterpart under conventional tillage. The highest leaf phosphorus content (0.33%) was recorded in T2F6 and the lowest was recorded in T2F5.Under conventional tillage system, 0.34% of leaf P (recorded for F6) was not significantly different from F7, but was significantly ($\rho < 0.05$) higher than F4 (with the same level of P application), and F3 (which received 20 kg ha^{-1} more of P_2O_5 application).

Table 22

Interactive Effects of Tillage and Fertilizer Application on N, P and K Contents of the Maize Leaves at Silking Time

Tillage× fertilizer interactions	Nitrogen in leaf (%)	Phosphorus in leaf (%)	Potassium in leaf (%)
T1F1	1.03	0.26	1.33
T1F2	1.57	0.27	1.43
T1F3	1.52	0.30	1.38
T1F4	1.20	0.27	1.45
T1F5	1.27	0.30	1.38
T1F6	1.23	0.30	1.44
T1F7	1.14	0.26	1.35
T2F1	1.25	0.26	1.30
T2F2	1.82	0.28	1.29
T2F3	1.77	0.28	1.33
T2F4	1.59	0.28	1.30
T2F5	1.58	0.24	1.26
T2F6	1.79	0.33	1.41
T2F7	1.79	0.32	1.35
Lsd.	NS	0.027	0.071
F pr.	0.887	<0.001*	<0.001*

* Denotes significance at $\rho \leq 0.05$, NS= not significant, T1= no-tillage, T2= conventional tillage, F1 (00:00:00), F2 (100:30:60), F3 (100:80:60), F4 (100:60:60), F5 (100:60:30), F6 (100:60:80) and F7 (60:60:60)

Tillage and fertilizer interaction also significantly ($\rho < 0.05$) affected leaf K content at silking time (Table 22). Under no-tillage system, plots which received F2 (100:30:60), F4 (100:60:60) and F5 (100:60:30) resulted in significantly ($\rho < 0.05$) higher leaf K content than their counterparts under conventional tillage. The highest leaf K content (1.44%) was recorded by maize plant in T1F6. The lowest leaf potassium content was recorded in T2F5.

The changes in the soil nutrient reserve as a result of different rates of fertilizer application and under different tillage systems might have a direct bearing on nutrient availability and this could have resulted in differences in the use and accumulation by maize plants growing in such soils. The significant tillage and fertilizer interaction effect on phosphorus and potassium content of maize leaves was also reported by Essel (2014) and Shahzad et al. (2015). They however, found that regardless of the rate of fertilizer application, maize plants growing under conventional tillage accumulated more P and K in their tissues than no-till plots. This contradicts the results of this work, in terms of K leaf content, which was generally higher under no-tillage although that for leaf P was not consistent.

Interaction between maize varieties and fertilizer application did not have significant ($\rho > 0.05$) effect on the N content of maize leaf but it significantly ($\rho < 0.05$) affected P and K content of the leaves at silking time (Table 27). Leaf P content in V1F2 was higher than V1F3, even though V1F3 received 66.7% more of applied potassium than V1F2; this was the other way round in the case of *Domabin*. This can be attributed to the fact that various soil and plant mechanisms and processes contribute to differences in the use and concentration of nutrients in organs by plants. Bashir et al. (2012) reported a significant varietal and fertilizer interaction effect on leaf P content.

The highest leaf K (1.46%) was recorded for *Obatanpa* that received NPK application rate of 100:60:60. *Obatanpa* receiving NPK application rates of F2 (100:30:60), F3 (100:80:60), F4 (100:60:60), F5 (100:60:30), accumulated significantly ($\rho < 0.05$) higher K in their leaves than *Domabin* receiving the same treatments. At the highest rate (80 kg ha^{-1}) of K application, the two maize varieties did not differ significantly in terms of K accumulation in their leaves.

Table 23

Interactive Effects of Treatments on N, P and K Contents of the Leaves of Maize at Silking Time

Variety× Fertilizer interactions	Nitrogen (%)	Phosphorus (%)	Potassium (%)
V1F1	1.05	0.26	1.33
V1F2	1.60	0.31	1.43
V1F3	1.73	0.29	1.38
V1F4	1.34	0.28	1.45
V1F5	1.31	0.28	1.38
V1F6	1.46	0.30	1.44
V1F7	1.35	0.30	1.35
V2F1	1.23	0.27	1.30
V2F2	1.79	0.25	1.29
V2F3	1.57	0.5	1.33
V2F4	1.45	0.27	1.30
V2F5	1.54	0.26	1.26
V2F6	1.55	0.33	1.41
V2F7	1.47	0.29	1.35
Lsd	NS	0.024	0.040
F pr.	0.920	<0.001*	0.017*
Tillage × Variety × Fertilizer (F pr.)	0.931	0.441	0.113

* Denotes significance at $\rho \leq 0.05$, NS= not significant, V1= *Obatanpa*, V2= *Domabin*, F1 (00:00:00), F2 (100:30:60), F3 (100:80:60), F4 (100:60:60), F5 (100:60:30), F6 (100:60:80) and F7 (60:60:60),

The differential response of the two maize varieties to K application can be explained in view that it is due to their physiological behaviour for K use efficiency and that might have resulted in differences in disease tolerance to K application. On the contrary, Bashir et al. (2012) reported that variety-fertilizer application has no significant effect on maize leaf K content. Tillage, variety and fertilizer interaction effects on N, P and K content of maize leaves were not significant (Table 23).

Interrelationship Among N, P and K Content of Maize Leaves at Silking Time, Plant Height and MSD Prevalence

The plant itself is an integrator of all the factors affecting nutrient availability, and according to Arnon (1975), analyses of a metabolically active part of the plant, such as a fresh leaf, gives an accurate estimate of the nutrient status of the plant.

The correlation of leaf N with leaf P was positive while with leaf K was negative, even though these were not significant. The significant positive relationship between leaf P and K reflected in the result of this work because where the highest leaf P content was attained, the highest leaf K content was also reported, and vice versa (Table 24). Further, maize plants which accumulated maximum P in their leaves received the highest rate of K_2O_5 application (80 kg ha^{-1}), and vice versa. This means that increasing K application enhances maize plants ability to utilize more phosphorus for growth and reproduction since K is associated with movement of water, nutrients, and carbohydrates within the plant. On the contrary, Arnon (1975) reported that the P content of maize leaves was found to be essentially unaffected by the potassium fertilizer treatments.

Table 24

Correlation Matrix for N, P and K Content of Maize Leaves, Plant Height and MSD Incidence and Severity

	Nitrogen in leaf	Phosphorus in leaf	Potassium in leaf	Plant height	Initial incidence	Peak incidence	Initial severity
Phosphorus in leaf	0.13						
Potassium in leaf	- 0.17	0.50*					
Plant height	0.39*	0.30*	- 0.01				
Initial incidence	0.12*	-0.03	- 0.08	0.27*			
Peak incidence	- 0.06	0.02	- 0.11	0.23*	0.20		
Initial severity	0.08	-0.13	- 0.17	0.60*	0.58*	0.14	
Peak severity	0.03	-0.02	- 0.30*	0.46*	0.16	0.14	0.32*

Sample size = 82, * denotes significance at $P \leq 0.05$.

There was a significant positive correlation ($r = 0.39$, $\rho < 0.05$) between nitrogen content of maize leaves and plant height (Table 24); this might have resulted in shorter height of maize plants which received low or no nitrogen application (Table 11). Nitrogen, in particular, appears to control growth more than any other nutrient and there by determines the yield potentials that can be expected through the use of phosphorus and potassium fertilizers (Kow et al. 2015). Leaf phosphorus content also correlated positively with plant height and the relationship was significant (Table 24). This agrees with the findings of Arnon (1975) that the N and P contents of maize leaves were found to be positively correlated with growth, and leaf N was the dominant indicator of growth and yield, although leaf P was also important.

However, K content of leaf correlated negatively with plant height. The correlation of N and P contents of maize leaves at silking time and peak MSD incidence and severity were not significant. Nitrogen in leaf correlated positively with initial incidence and severity, as well as peak severity, but negatively with peak incidence (Table 28). Similarly, Haltrich et al. (2000) (as cited in Magenya et al., 2008), stipulated that nitrogen in plant tissues is the principal attracting component of phytophagous insects because they found a positive correlation between migrations and reproduction of leafhoppers with soluble nitrogen content of host plants.The phosphorus in leaf of maize correlated positively with initial severity, but negatively with initial incidence, peak incidence and severity. There was a significant negative correlation ($r = - 0.30$, $\rho < 0.05$) between leaf K content and peak MSD severity. According to Zafar et al. (2013), the basic experimental evidence that support the effects of mineral nutrient in reducing disease severity is the comparison of mineral concentrations in tissue of resistant and susceptible cultivars or diseased and non-diseased tissues. A similar trend was obtained in this work, where maize plants grown under no-tillage accumulated significantly higher K in their leaves and were also associated with lower MSD severity. Also *Obatanpa* maize variety accumulated higher potassium in their leaves and was associated with low peak severity. The highest disease severity was recorded in T1 (with no fertilizer application) (Table 9) and maize plants grown on this plot accumulated the least K in their leaves (Table 24). Therefore, the hypothesis that no relationship exists in maize leaf nutrients (N, P and K) content and MSD incidence and severity is rejected.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The main objective was to determine the influence of different rates of N, P and K application, maize variety and tillage on the incidence and severity of MSD, as well as on growth and maize grain yield. The assessment of the relationship between soil nutrient content and the prevalence and severity of MSD demanded a baseline study which was conducted on maize farms across three agro-ecological zones of the Volta Region. The determination of the influence of fertilizer application on the incidence and severity of MSD, yield and mineral content of grain resulted in the establishment of field experiments at Nkwanta in two planting seasons. Additionally, results of the effects of tillage and fertilizer application on the N, P and K contents of maize leaves were determined at silking time and their effect on plants ability to counter disease was determined.

Soil properties varied among the three agro-ecological zones of the Volta Region. Soils across the region were low in organic carbon and in the major nutrients, especially nitrogen and phosphorus except for potassium which was moderate for maize production. This fell within the nutrients status of soils found in all agro-ecological zones across the country. The MSD was found in almost every farm surveyed across the three agro-ecological zones of the Volta Region. Despite the disease varying among the agro-ecological zones, MSD incidence was high and severity was moderate in the region. No relationship was however detected between soil macro nutrient contents and MSD prevalence in all the agro-ecological zones. Also, nutrient management on farmers' fields did not have any significant impact on the incidence and severity of the disease. It was also noted that soil nutrients on maize farms across the agro-ecological zones were not adequate to support maize production, even on the nutrient managed fields. However, tillage practices on farmers' fields significantly affected MSD severity.

The effect of fertilizer application on MSD incidence was inconsistent. However, fertilizer application effectively reduced the MSD impact on growth and yield. However, no differences were encountered among the different fertilizer treatments. Tillage was found to significantly affect both incidence and severity of MSD in all seasons. Incidentally, lower MSD incidence and severity were recorded under no-tillage system even though it was associated with poor plant growth and lower yield. Both maize varieties used in the study can be rated as moderately resistant to MSD, but *Obatanpa* was more tolerant to the disease than *Domabin*. Also the disease pressure was higher in the minor cropping season. Stunted growth and grain yield reduction were strongly associated with MSD, but MSD did not bring about any deterioration of grain quality, in terms of content of the crude protein.

Maize growth and yield were significantly affected by fertilizer application, and the plots with no added fertilizer experienced the lowest growth and yield. However, no yield differences were encountered among the different fertilizer treatments. Tillage also significantly affected growth and yield; higher plant height and yield were observed under conventional tillage system than no-tillage system. Between the two maize varieties, *Obatanpa* out performed

Domabin, in terms of grain yield. Also, tillage-fertilizer and tillage-variety-fertilizer interactions significantly affected some yield components and overall grain yield. F6 (100:60:60) under conventional tillage gave a higher yield of 4559 kg ha^{-1} which was not significantly different from 3892 kg ha^{-1} produced by F4 (100:60:60) under no-tillage.

Fertilizer application affected the crude protein content of maize grains; in all F7 (60:60:60) accumulated the highest grain crude protein (10.8%) which was not significantly different from F3 (100:80:60) and F6 (100:60:80). Maize genotypes on the other hand varied in terms of their crude protein content; *Domabin* produced higher amount of grain crude protein than *Obatanpa*.

Potassium content of maize leaves at silking time was significantly affected by the type of tillage system and maize variety. Maize plants grown under no-tillage system accumulated significantly higher K in leaves than under conventional tillage. Also, K contents of leaves of *Obatanpa* were higher than D*omabin*. Fertilizer application significantly affected N, P and K contents in maize leaves at silking time. Both P and K concentration in maize leaf were highest at the highest K application rate F6 (100:60:80), and this reflected in a significant positive correlation between leaf P and leaf K contents. There was also a significant negative correlation between potassium content in maize leaves and peak MSD severity. It was inferred based on the results of this work that high N in leaf was associated with high MSD severity, while high leaf K was associated with reduced MSD severity.

Conclusions

1. Soils across the region were low in organic carbon and in major nutrients, except for exchangeable potassium. There was no relationship between soil chemical properties and MSD prevalence in the region and hence MSD prevalence in the Volta region cannot be said to be related to inherent soil chemical characteristic.
2. No-tillage system was effective in minimizing the occurrence and severity of MSD, but to increase maize yield under this system, additional inputs like fertilizer application will be required.
3. Conventional tillage together with fertilizer application and improved maize varieties can help improve yield of maize.
4. Balanced application of N, P and K may be a key factor in improving crude protein content of maize grains.
5. Increase in the potassium content of maize leaves resulting from fertilizer application has the potential to improve plants ability to counter or reduce the impact of MSD on grain yield.

Recommendations

Soils across all the three agro-ecological zones were low in nutrients especially nitrogen and phosphorus, and MSD was also found to be prevalent in the area. It is recommended that fertilizer application be incorporated as a part of maize production practices, if maize production in this region is to be improved. Conventional tillage practice together with fertilizer application and the use improved maize varieties can help improve yield of maize and hence it is recommended for adoption by maize farmers at Nkwanta. Lastly, farmers in the Volta region are encouraged to adopt fertilizer application rate (N P_2O_5 K_2O 100:60:60) recommended by MoFA since the different rates employed in this research did not perform any better than the recommended rate in terms of their effect on MSD incidence and severity, as well as on maize grain yield.

Suggestions for Further Research

Further research would be encouraged to determine the cause of high incidence severity of MSD in the Volta Region. Further research is suggested to find out whether the reduced MSD under no-tillage stems from its effect on vector behaviour or mainly resulted from improved nutrition of plants. Also research should focus on tracing and establishing the missing link between low incidence and severity of MSD, and yet reduced growth and lower yield associated with no-tillage system. Efforts should also be channelled into the discovery of strategies to improve maize yields under no-tillage system. Lastly, further research is encouraged to evaluate the effectiveness of inorganic fertilizer application on MSD prevalence across the three agro-ecological zones of the Volta Region.

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APPENDICES

Appendix A

Properties of Soils in the Agro-ecological Zones of the Volta Region

Table 1

Summary statistics showing the particle size distribution of soils of the agro-ecological zones

Agro-ecological Zone		**Soil Physical Property**		
		Clay (%)	**Silt (%)**	**Sand (%)**
Coastal savanna	Mean	13.9	14.4	71.7
	Min.	9.5	5.9	54.7
	Max.	19.7	27.8	82.4
	Std. deviation	2.5	5.8	6.51
	Variance	6.4	33.3	42.4
Semi-deciduous Forest	Mean	15.9	22.4	61.8
	Min.	9.6	11.6	40.1
	Max.	30.3	36.1	76.3
	Std. deviation	5.0	7.5	9.7
	Variance	25.0	56.6	94.8
Forest-Savanna transition	Mean	13.6	28.5	57.9
	Min.	10.3	11.8	34.1
	Max.	20.7	49.5	76.7
	Std. deviation	2.3	11.9	12.8
	Variance	5.3	141.2	163.2

Table 2

Summary statistics of the chemical characteristics of soils of the agro-ecological zones

Agro-ecological Zone		**Soil Chemical Property**			
		Organic carbon (%)	Total N (%)	P (µg g^{-1})	pH
Coastal savanna	Mean	0.58	0.05	9.08	6.6
	Min.	0.02	0.01	0.8	5.7
	Max.	2.61	0.23	40.36	7.4
	Std. deviation	0.63	0.05	7.96	0.52
	Variance	0.40	0.003	3.35	0.27
Semi-deciduous Forest	Mean	0.99	0.08	13.53	6.6
	Min.	0.02	0.01	1.51	5.6
	Max.	1.99	0.17	7.84	7.5
	Std. deviation	0.52	0.04	12.18	0.48
	Variance	0.27	0.002	148.3	0.23
Forest-Savanna transition	Mean	1.18	0.10	16.02	6.6
	Min.	0.02	0.01	3.35	5.6
	Max.	0.0	0.18	39.54	7.9
	Std. deviation	0.13	0.05	11.18	0.54
	Variance	0.36	0.003	2.33	0.29

Table 3

Summary statistics of the chemical characteristics of soils of the agro-ecological zones

Agro-ecological Zone		**Soil Chemical Property ($cmol_c$ kg^-)**		
		K^+	**Ca^{2+}**	**Mg^{2+}**
Coastal savanna	Mean	0.46	3.44	2.35
	Min.	0.15	1.34	0.8
	Max.	2.35	12.02	5.47
	Std. deviation	0.48	2.36	1.29
	Variance	0.23	5.57	1.66
Semi-deciduous Forest	Mean	0.41	7.00	4.11
	Min.	0.19	2.6	0.80
	Max.	1.11	17.89	10.40
	Std. deviation	0.21	3.90	2.27
	Variance	0.04	15.18	5.15
Forest-Savanna transition	Mean	0.55	6.70	3.2
	Min.	0.17	3.19	1.60
	Max.	1.31	17.84	8.81
	Std. deviation	0.35	4.07	1.85
	Variance	0.13	16.56	3.42

Table 4

Summary statistics of the chemical characteristics of soils of the agro-ecological zones

Agro-ecological Zone		**Soil Chemical Property ($cmol_c$ kg^-)**		
		Na^+	**Ex. Acidity**	**ECEC**
Coastal savanna	Mean	0.30	0.15	6.70
	Min.	0.08	0.03	3.19
	Max.	2.4	0.45	17.8
	Std. deviation	0.47	0.13	4.07
	Variance	0.23	0.02	1.56
Semi-deciduous Forest	Mean	0.21	0.18	11.87
	Min.	0.10	0.05	4.29
	Max.	0.57	1.00	29.26
	Std. deviation	0.11	0.21	5.97
	Variance	0.01	0.05	35.69
Forest-Savanna transition	Mean	0.29	0.14	11.59
	Min.	0.12	0.03	4.45
	Max.	0.79	0.45	33.82
	Std. deviation	0.18	0.11	6.25
	Variance	0.03	0.01	39.02

Appendix B

Variation in MSD Prevalence in the Agro-ecological Zones of the Volta Region

Table 1

Summary Statistics of the MSD incidence and severity among agro-ecological Zones

Agro-ecological Zone		MSD Incidence (%)	MSD Severity
Coastal savannah	Mean	86.4	2.7
	Min.	67.5	2.1
	Max.	97.7	3.6
	Std. deviation	1.8	0.4
	Variance	80.0	0.2
Semi-deciduous Forest	Mean	77.5	2.6
	Min.	50	1.9
	Max.	100	3.1
	Std. deviation	13.0	0.4
	Variance	168.6	0.1
Forest-Savanna transition	Mean	89.7	3.1
	Min.	49.1	2.3
	Max.	100	3.7
	Std. deviation	10.8	0.3
	Variance	116.1	0.1

Appendix C

Correlation Between Selected Soil Parameters and MSD Incidence and Severity

Table 1

Correlation matrix for selected soil properties and MSD incidence

Incidence							
Organic carbon	-0.042						
Total N	- 0.050	0.992					
K	- 0.124	0.216	0.236				
ECEC	- 0.104	0.156	0.176	0.486			
Exchange Acidity	- 0.066	0.234	0.211	- 0.068	- 0.079		
P	- 0.024	0.256	0.255	0.360	0.284	0.108	
pH	0.163	-0.394	- 0.378	0.028	0.099	0.628	- 0.149
	Incidence	Organic carbon	Total N	K	Exchangeable Acidity	P	pH

Number of observation= 65

Table 2

Correlation matrix for selected soil properties and MSD severity

Severity							
Organic Caobon	0.037						
Total N	0.020	0.992					
K	0.062	0.051	0.075				
ECEC	-0.088	0.125	0.147	0.466			
Exchangeable Acidity	0.060	0.238	0.216	-0.084	-0.085		
P	0.049	0.269	0.267	0.209	0.264	0.097	
pH	-0.020	-0.401	-0.385	0.074	0.110	0.630	-0.156
	Severity	Organic carbon	Total N	K	Exchangeable Acidity	P	pH

Number of observation= 65

Appendix D

Effects of Fertilizer Management and Tillage Practices on farmer's field on MSD Incidence and Severity

Table 1

Two sample t-test showing the effect of fertilizer management on farmer's field on MSD incidence

Sample	Size	Degree of Freedom	Mean	Variance	Standard deviation	Standard error of means	F probability
No	51	50	84.22	151.8	12.32	1.725	0.667
Yes	13	12	85.83	79.6	8.92	2.475	

Table 2

Two sample t-test showing the effect of fertilizer management on farmer's field on MSD severity

Sample	Size	Degree of freedom	Mean	Variance	Standard deviation	Standard error of means	F probability
Yes	52	61	2.783	0.204	0.452	0.063	0.770
No	13	12	2.823	0.152	0.390	0.108	

Table 3

Two sample t-test showing the effect of tillage practices on farmer's field on MSD incidence

Sample	Size	Degree of freedom	Mean	Variance	Standard deviation	Standard error of means	F probability
No-tillage	29	28	83.26	190.3	13.79	2.561	0.097
Tillage	7		92.54	56.2	7.50	2.834	

Table 4

Two sample t-test showing the effect of tillage practices on farmer's field on MSD severity

Sample	Size	Degree of freedom	Mean	Variance	Standard deviation	Standard error of means	F probability
No-tillage	29	34	2.800	0.189	0.435	0.081	0.024
Tillage	7		3.206	0.059	0.244	0.092	

Appendix E

Effect of Treatments on Incidence and Severity of MSD

Table 1

ANOVA showing initial incidence of MSD as affected by tillage system, maize variety and fertilizer application in the major season

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	1272.65	1272.65	48.49	0.006
Residual	3	78.73	26.24	0.18	
Variety	1	34.14	34.14	0.23	0.647
Tillage. Variety	1	34.14	34.14	0.23	0.647
Residual	6	884.46	147.41	2.16	
Fertilizer	6	301.84	50.31	0.74	0.622
Tillage. Fertilizer	6	375.72	62.62	0.92	0.489
Variety. Fertilizer	6	177.12	29.52	0.43	0.855
Tillage. Variety. Fertilizer	6	152.36	25.39	0.37	0.895
Residual	72	4921.53	68.35		
Total	111	8351.62			

Table 2

ANOVA showing initial severity of MSD as affected by tillage system, maize variety and fertilizer application in the major season

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	0.045	0.045	10.89	0.046
Residual	3	0.012	0.004	0.34	
Variety	1	0.000	0.000	0.02	0.884
Tillage. Variety	1	0.000	0.000	0.00	1.000
Residual	6	0.072	0.012	2.09	
Fertilizer	6	0.015	0.002	0.43	0.854
Tillage. Fertilizer	6	0.018	0.003	0.52	0.795
Variety. Fertilizer	6	0.032	0.005	0.93	0.481
Tillage. Variety. Fertilizer	6	0.030	0.005	0.89	0.510
Residual	72	0.413	0.006		
Total	111	0.672			

Table 3

ANOVA showing peak incidence of MSD as affected by tillage system, maize variety and fertilizer application in the major season

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	15639.7	15639.7	120.04	0.002
Residual	3	390.9	130.3	0.38	
Variety	1	0.0	0.0	0.00	0.993
Tillage. Variety	1	87.8	87.8	0.25	0.633
Residual	6	2084.0	347.3	2.92	
Fertilizer	6	674.2	112.4	0.94	0.469
Tillage. Fertilizer	6	663.1	110.5	0.93	0.479
Variety. Fertilizer	6	980.5	163.4	1.37	0.237
Tillage. Variety. Fertilizer	6	988.7	164.8	1.39	0.232
Residual	72	8562.3	118.9		
Total	111	31679.3			

Table 4

ANOVA showing peak severity of MSD as affected by tillage system, maize variety and fertilizer application in the major season

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	5.762	5.762	44.99	0.007
Residual	3	0.384	0.128	0.61	
Variety	1	0.078	0.078	0.37	0.567
Tillage. Variety	1	0.066	0.066	0.31	0.597
Residual	6	1.269	0.211	3.75	
Fertilizer	6	0.601	0.100	1.78	0.115
Tillage. Fertilizer	6	0.389	0.065	1.15	0.342
Variety. Fertilizer	6	0.396	0.066	1.17	0.331
Tillage. Variety. Fertilizer	6	0.292	0.049	0.86	0.526
Residual	72	4.056	0.056		
Total	111	14.080			

Table 5

ANOVA showing initial incidence of MSD as affected by tillage system, maize variety and fertilizer application in the minor season

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	426.61	426.61	1.06	0.379
Residual	3	1208.31	402.77	4.25	
Variety	1	37.47	37.47	0.40	0.553
Tillage. Variety	1	147.46	147.46	1.55	0.259
Residual	6	569.00	94.83	1.00	
Fertilizer	6	305.62	50.94	0.54	0.777
Tillage. Fertilizer	6	246.61	41.10	0.43	0.854
Variety. Fertilizer	6	537.53	89.59	0.95	0.467
Tillage. Variety. Fertilizer	579.80	96.63	1.02	0.418	
Residual	72	6810.66	94.59		
Total	111	11046.03			

Table 6

ANOVA showing initial severity of MSD as affected by tillage system, maize variety and fertilizer application in the minor season

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	0.450	0.450	1.85	0.267
Residual	3	0.730	0.243	3.67	
Variety	1	0.290	0.290	4.37	0.082
Tillage. Variety	1	0.122	0.122	1.84	0.224
Residual	6	0.398	0.066	1.43	
Fertilizer	6	1.204	0.201	4.31	<.001
Tillage. Fertilizer	6	0.389	0.065	1.39	0.229
Variety. Fertilizer	6	0.366	0.061	1.31	0.262
Tillage. Variety. Fertilizer	6	0.390	0.065	1.40	0.228
Residual	72	3.350	0.047		
Total	111	8.195			

Table 7

ANOVA showing peak incidence of MSD as affected by tillage system, maize variety and fertilizer application in the minor season

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	40.05	40.05	6.00	0.092
Residual	3	20.03	6.68	1.00	
Variety	1	0.00	0.00	0.00	1.000
Tillage. Variety	1	0.00	0.00	0.00	1.000
Residual	6	40.05	6.68	0.63	
Fertilizer	6	30.04	5.01	0.47	0.826
Tillage. Fertilizer	6	30.04	5.01	0.47	0.826
Variety. Fertilizer	6	70.09	11.68	1.11	0.368
Tillage. Variety. Fertilizer	6	70.09	11.68	1.11	0.368
Residual	72	760.99	10.57		
Total	111	1081.40			

Table 8

ANOVA showing peak severity of MSD as affected by tillage system, maize variety and fertilizer application in the minor season

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	0.529	0.529	12.53	0.038
Residual	3	0.127	0.042	3.06	
Variety	1	0.086	0.086	6.23	0.047
Tillage. Variety	1	0.011	0.010	0.78	0.410
Residual	6	0.083	0.014	0.47	
Fertilizer	6	0.883	0.147	5.01	<.001
Tillage. Fertilizer	6	0.211	0.035	1.20	0.317
Variety. Fertilizer	6	0.127	0.021	0.72	0.633
Tillage. Variety. Fertilizer	6	0.075	0.012	0.42	0.860
Residual	72	2.115	0.029		
Total	111	4.520			

Appendix F

Plant Height as Influenced by Tillage, Maize Variety and Fertilizer Application

Table 1

ANOVA showing plant height as affected by tillage system, maize variety and fertilizer application

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	99296.2	99296.2	216.91	<.001
Residual	3	1373.3	457.8	0.34	
Variety	1	1420.3	1420.3	1.06	0.344
Tillage. Variety	1	838.4	838.4	0.62	0.460
Residual	6	8071.7	1345.3	2.39	
Fertilizer	6	11423.8	1904.0	3.38	0.005
Tillage. Fertilizer	6	5297.0	882.8	1.57	0.169
Variety. Fertilizer	6	2966.2	494.4	0.88	0.516
Tillage. Variety. Fertilizer	6	1895.2	315.9	0.56	0.760
Residual	72	40551.2	563.2		
Total	111	175920.9			

Appendix G

Yield Components of Maize as Affected by Treatments

Table 1

ANOVA showing the number of cob bearing-plant per plot as affected by tillage system, maize variety and fertilizer application

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	77.2	77.2	0.26	0.643
Residual	3	880.0	293.3	2.93	
Variety	1	595.9	595.9	5.95	0.050
Tillage. Variety	1	214.5	214.5	2.14	0.194
Residual	6	600.6	100.1	0.35	
Fertilizer	6	1811.4	301.9	1.07	0.390
Tillage. Fertilizer	6	1491.1	248.5	0.88	0.515
Variety. Fertilizer	6	839.0	139.8	0.49	0.810
Tillage. Variety. Fertilizer	6	3142.3	523.7	1.85	0.101
Residual	72	20356.4	282.7		
Total	111	30888.3			

Table 2

ANOVA showing cob length of maize as affected by tillage system, maize variety and fertilizer application

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	8.073	8.073	4.80	0.116
Residual	3	5.043	1.681	0.29	
Variety	1	140.112	140.11	24.39	0.003
Tillage. Variety	1	0.002	0.002	0.00	0.986
Residual	6	34.467	5.744	4.10	
Fertilizer	6	56.730	9.455	6.75	<.001
Tillage. Fertilizer	6	16.646	2.774	1.98	0.080
Variety. Fertilizer	6	2.763	0.461	0.33	0.920
Tillage. Variety. Fertilizer	6	8.479	1.413	1.01	0.427
Residual	72	100.895	1.401		
Total	111	378.574			

Table 3

ANOVA showing number of grains per cob as affected by tillage system, maize variety and fertilizer application

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	159683.	159683.	27.54	0.013
Residual	3	17395.	5798.	1.23	
Variety	1	2973.	2973.	0.63	0.457
Tillage. Variety	1	37632.	37632.	7.99	0.030
Residual	6	28242.	4707.	1.58	
Fertilizer	6	63156.	10526.	3.53	0.004
Tillage. Fertilizer	6	45077.	7513.	2.52	0.029
Variety. Fertilizer	6	23334.	3889.	1.30	0.267
Tillage. Variety. Fertilizer	6	40063.	6677.	2.24	0.049
Residual	72	214999.	2986.		
Total	111	651198.			

Table 4

ANOVA showing grain yield per cob as affected by tillage system, maize variety and fertilizer application

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	9808.2	9808.2	12.03	0.040
Residual	3	2446.0	815.3	1.27	
Variety	1	7195.2	7195.2	11.24	0.015
Tillage. Variety	1	720.7	720.7	1.13	0.329
Residual	6	3839.7	640.0	2.36	
Fertilizer	6	6443.3	1073.9	3.96	0.002
Tillage. Fertilizer	6	3618.7	603.1	2.22	0.050
Variety. Fertilizer	6	2712.7	452.1	1.67	0.141
Tillage. Variety. Fertilizer	6	2169.4	361.6	1.33	0.254
Residual	72	19522.3	271.1		
Total	111	60158.5			

Table 5

ANOVA showing 100-seed weight of maize as affected by tillage, variety and fertilizer application

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	9.074	9.074	0.70	0.463
Residual	3	38.7	12.916	1.20	
Variety	1	1343.7	1343.7	124.76	<.001
Tillage. Variety	1	0.033	0.033	0.00	0.958
Residual	6	64.621	10.770	2.02	
Fertilizer	6	48.584	8.097	1.52	0.185
Tillage. Fertilizer	6	29.399	4.900	0.92	0.487
Variety. Fertilizer	6	11.950	1.992	0.37	0.894
Tillage. Variety. Fertilizer	6	25.666	4.278	0.80	0.572
Residual	72	384.028	5.334		
Total	111	2021.899			

Table 6

ANOVA showing the grain yield (Kg ha^{-1}) of maize as affected by tillage system, maize variety and fertilizer application

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	18524778	18524778	32.66	0.011
Residual	3	1701612	567204	0.64	
Variety	1	568124	5681241	6.43	0.044
Tillage. Variety	1	191134	191134	0.22	0.658
Residual	6	5298931	883155	1.03	
Fertilizer	6	12086061	2014344	2.35	0.040
Tillage. Fertilizer	6	14216435	2369406	2.76	0.018
Variety. Fertilizer	6	3704433	617405	0.72	0.636
Tillage. Variety. Fertilizer	6	12676856	2112809	2.46	0.032
Residual	72	61843711	858940		
Total	111	136153298			

Appendix H

Effect of Treatments on P, K and Crude Protein Composition of Maize Grains

Table 1

ANOVA showing the effect of treatments on phosphorus content of maize grains

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	0.022	0.022	12.45	0.072
Residual	2	0.004	0.002	0.45	
Variety	1	0.013	0.013	3.23	0.147
Tillage. Variety	1	0.000	0.000	0.00	0.997
Residual	4	0.016	0.004	2.90	
Fertilizer	6	0.018	0.003	2.20	0.059
Tillage. Fertilizer	6	0.0105	0.002	1.27	0.288
Variety. Fertilizer	6	0.009	0.002	1.15	0.346
Tillage. Variety. Fertilizer	6	0.019	0.003	2.24	0.055
Residual	48	0.066	0.001		
Total	83	0.158			

Table 2

ANOVA showing the effect of treatments on potassium content of maize grains

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	0.026	0.026	89.57	0.011
Residual	2	0.001	0.000	0.04	
Variety	1	0.012	0.012	1.66	0.267
Tillage. Variety	1	0.002	0.002	0.22	0.660
Residual	4	0.029	0.007	12.50	
Fertilizer	6	0.003	0.000	0.79	0.581
Tillage. Fertilizer	6	0.007	0.001	2.04	0.079
Variety. Fertilizer	6	0.008	0.001	2.44	0.039
Tillage. Variety. Fertilizer	6	0.008	0.001	2.20	0.059
Residual	47	0.027	0.001		
Total	82	0.114			

Table 3

ANOVA showing effect of treatments on crude protein content of maize grains

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	17.427	17.427	6.13	0.132
Residual	2	5.690	2.845	0.46	
Variety	1	99.888	99.888	16.28	0.016
Tillage. Variety	1	12.733	12.733	2.08	0.223
Residual	4	24.545	6.136	1.07	
Fertilizer	6	85.982	14.330	2.50	0.035
Tillage. Fertilizer	6	32.304	5.384	0.94	0.476
Variety. Fertilizer	6	48.647	8.108	1.42	0.229
Tillage. Variety. Fertilizer	6	62.583	10.430	1.82	0.115
Residual	47	269.203	5.728		
Total	82	592.461			

Appendix L

Relationship Between MSD, Plant Height, Yield and Crude Protein Content of Maize Grains

Table 1

Correlation matrix for MSD incidence, severity, height, grain yield and crude protein content

	Initial Incidence (%)	Initial severity	Peak incidence (%)	Peak severity	Height (cm)	Grain Yield (kg ha^{-1})
Initial severity	0.803*					
Peak incidence	0.358*	0.317*				
Peak severity	0.338*	0.330*	0.905*			
Height (cm)	0.273*	0.231*	0.595*	0.461*		
Grain yield (Kg ha^{-1})	0.171	0.086	0.403*	0.295*	0.507*	
Crude protein (%)	- 0.178	- 0.147	- 0.152	- 0.162	- 0.086	- 0.299*

Sample size = 83, * denotes significance at $\rho \leq 0.05$.

Appendix M

Effects of Treatments on N, P and K Accumulation in Maize Leaves at Silking Time

Table 1

ANOVA showing the effect of treatments on leaf nitrogen content at silking time

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	3.562	3.562	27.61	0.034
Residual	2	0.258	0.129	0.57	
Variety	1	0.350	0.350	1.56	0.280
Tillage. Variety	1	0.046	0.046	0.21	0.673
Residual	4	0.899	0.225	1.08	
Fertilizer	6	3.237	0.540	2.60	0.030
Tillage. Fertilizer	6	0.475	0.079	0.38	0.887
Variety. Fertilizer	6	0.407	0.068	0.33	0.920
Tillage. Variety. Fertilizer	6	0.380	0.063	0.30	0.931
Residual	47	9.764	0.208		
Total	82	18.61			

Table 2

ANOVA showing the effect of treatments on leaf phosphorus content at silking time

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	0.000	0.000	0.31	0.632
Residual	2	0.002	0.001	3.15	
Variety	1	0.002	0.002	4.35	0.105
Tillage. Variety	1	0.000	0.000	0.29	0.619
Residual	4	0.001	0.000	0.62	
Fertilizer	6	0.027	0.004	7.73	<.001
Tillage. Fertilizer	6	0.033	0.006	9.61	<.001
Variety. Fertilizer	6	0.018	0.003	5.16	<.001
Tillage. Variety. Fertilizer	6	0.003	0.001	0.99	0.441
Residual	47	0.027	0.001		
Total	82	0.094			

Table 3

ANOVA showing the effect of treatments on leaf potassium content at silking time

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Variance	F Probability
Tillage	1	0.432	0.432	146.48	0.007
Residual	2	0.006	0.003	0.24	
Variety	1	0.156	0.156	12.82	0.023
Tillage. Variety	1	0.001	0.001	0.08	0.788
Residual	4	0.049	0.012	2.32	
Fertilizer	6	0.135	0.023	4.31	0.001
Tillage. Fertilizer	6	0.171	0.029	5.44	<.001
Variety. Fertilizer	6	0.091	0.015	2.89	0.017
Tillage. Variety. Fertilizer	6	0.057	0.010	1.83	0.113
Residual	48	0.251	0.005		
Total	83	1.097			

Appendix N

Interrelationship Between N, P and K Content of Leaves at Silking Time, Growth, and MSD Prevalence

Table 1

Correlation matrix of N, P and K Contents of leaves, plant height and MSD incidence and severity

	Nitrogen in leaf	Phosphorus in leaf	Potassium in leaf	Plant height	Initial incidence	Peak incidence	Initial severity
Phosphorus in leaf	0.133						
Potassium in leaf	- 0.173	0.501*					
Plant height	0.390*	0.299*	- 0.008				
Initial incidence	0.120*	-0.025	- 0.080	0.273*			
Peak incidence	- 0.057	0.017	- 0.110	0.231*	0.196		
Initial severity	0.081	-0.127	- 0.167	0.595*	0.582*	0.140	
Peak severity	0.025	-0.020	- 0.296*	0.461*	0.162	0.141	0.320*

Sample size = 82, * denotes significance at $\rho \leq 0.05$.