

**MINERAL FERTILIZER APPLICATION AND GRAIN YIELD OF TWO  
MAIZE VARIETIES IN THE SUB-SUDANIAN ZONE OF BURKINA FASO**

KNUST



**BY TRAORE ISABELLE OROKYA (ENGINEER IN FORESTRY)**

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**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY  
KUMASI, GHANA SCHOOL OF GRADUATE STUDIES DEPARTMENT  
OF CROP AND SOIL SCIENCES**

**MINERAL FERTILIZER APPLICATION AND GRAIN YIELD OF TWO  
MAIZE VARIETIES IN THE SUB-SUDANIAN ZONE OF BURKINA FASO**

**A thesis presented to the Department of Crop and Soil Sciences, Faculty of  
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the requirements for the award of degree**

**OF**

**MASTER OF PHILOSOPHY IN SOIL SCIENCE**

**By TRAORE ISABELLE OROKYA**

**SEPTEMBER, 2015**

## DECLARATION

I hereby declare that this submission is my own work toward the MPhil and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due to acknowledgment has been made in the text.

TRAORE Isabelle Orokya .....

ID 20360732

Signature

Date

Prof. Robert C. Abaidoo .....

(Supervisor)

Signature

Date

Dr. Andrews Opoku .....

(Co-supervisor)

Signature

Date

Dr. Nana Ewusi-Mensah .....

(Co-supervisor)

Signature

Date

Dr. Korodjouma Ouattara .....

(Co-supervisor)

Signature

Date

Dr. Enock A. Osekre .....

(Head of Department)

Signature

Date

## DEDICATION

With a grateful heart, I dedicate this thesis to the Awesome Almighty God for HE supplied all my needs and never abandoned me even when all seemed to be hopeless.

# KNUST



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## ABSTRACT

A field study was conducted at Farako-Bâ, located in the south Sudan zone of Burkina Faso to update the fertilizer recommendations for maize production according to the soil type and variety of maize. The experiment was a split-plot arranged in a randomized complete block design with three replications on both Luvisol and Ferralsol. The factors were mineral fertilizer options in the sub-plot and maize variety in the main plot. The mineral fertility options used were control, 90 kg N ha<sup>-1</sup>, 90kg N ha<sup>-1</sup>+ 15 kg P ha<sup>-1</sup>, 90 kg N ha<sup>-1</sup>+ 7.5 kg P ha<sup>-1</sup>, 90 kg N ha<sup>-1</sup> + 22.5 kg P ha<sup>-1</sup>, 90 kg N ha<sup>-1</sup>+ 15 kg P ha<sup>-1</sup> +10 kg K ha<sup>-1</sup>, 90 kg N ha<sup>-1</sup> + 15 kg P ha<sup>-1</sup> + 20 kg K ha<sup>-1</sup>, 90 kg N ha<sup>-1</sup> + 15 kg P ha<sup>-1</sup> + 30 kg K ha<sup>-1</sup> and diagnostic (90 kg N ha<sup>-1</sup> + 15 kg P ha<sup>-1</sup>+ 20 kg K ha<sup>-1</sup>+ 15 kg S ha<sup>-1</sup>+ 2.5 kg Zn ha<sup>-1</sup>+ 10 kg Mg ha<sup>-1</sup>+ 0.5 kg B ha<sup>-1</sup>) and the maize varieties were Komsaya and SR21. The weight of plants harvested for grain yield, stover yield and harvest index were computed. The maize grain and stover were ground and analysed for N, P and K uptake. Soil samples were collected at 45, 60 and 75 days after planting and analysed in the laboratory for N, P, K and pH contents.

The results showed that mineral fertilizer significantly influenced soil NH<sub>4</sub><sup>+</sup> - N, available phosphorus, exchangeable K and pH and which differed across soil types. Moreover, grain, stover yields and nutrient uptake of maize grain were significantly affected by both mineral fertilizer and soil type. Among the two maize varieties, Komsaya gave the highest grain yield across fertilizer treatments. Cultivation of Komsaya was the most profitable in terms of returns on investment on both soil types than variety SR21 which was economically viable when grown on a Luvisol.



## CHAPTER ONE

### 1.0 INTRODUCTION

Maize (*Zea mays* L.) is a widely cultivated crop throughout the world and a greater quantity is produced each year than any other grain (Riaz *et al.*, 2014). It is currently the world's third most important cereal after wheat and rice (Belfield and Brown, 2008). Maize has become a major cereal crop and an important component of human and animal diets as well as raw material for industry (USAID/EAT, 2012). It is a widely grown cereal in the tropics (Damsteegt and Igwegbe, 2005) and plays a major role as a food security crop in both rural and urban communities. In industrialized countries, it is largely used as livestock feed and as a raw material for industrial products, while in developing countries, it is mostly used for human consumption (IITA, 2007).

In Burkina Faso, maize is mainly produced under rainfed conditions predominantly in the Hauts-Bassins, Boucle du Mouhoun and Cascades regions with respective yield of 346,500, 199,000 and 123,188 tons over the bulk of production in the country which is about 1,200,000 tons (DGPER, 2010).

In spite of the importance of the crop in the country, the average yield of 1.2 ton ha<sup>-1</sup> is generally low compared to global average of 4 - 5 tons ha<sup>-1</sup> and over 8 tons ha<sup>-1</sup> in the United States of America (FAOSTAT, 2008). This low production according to Shao (1996), may be partly attributed to the use of little or no fertilizers and the predominant use of local varieties.

Research has demonstrated the importance of inorganic fertilizer in crop production (Buah *et al.*, 1998; Workayehu, 2000; Yamoah *et al.*, 2002; Aflakpui *et al.*, 2005b;

Conley *et al.*, 2005). Nutrient inputs from chemical fertilizers are needed to replace nutrients, which are exported and lost during cropping, to maintain a positive nutrient balance. Due to various socio-economic constraints encountered by farmers in the country, most farmers apply little or no fertilizer. On the other hand, farmers who can afford to use fertilizer are following the national blanket fertilizer recommendation which was established since 1992. Different soils are endowed with different physical and chemical properties which make them superior or inferior to other soils within a given locality (Murdock, 1970; van Waverson *et al.*, 1993). Therefore, fertilizer recommendation should take into account the effect of soil types in the agro-ecological zone as soil types may result in different responses of crops to a single fertilizer rate (Ndlangamandla, 1998). Broad or blanket fertilizer recommendations which assume homogeneity of soil conditions have, thus, partly contributed to the low yield of maize in Burkina Faso. Moreover, there is limited information on major soil nutrient dynamics following mineral fertilizer application. Therefore there is a need to carefully target fertilizer recommendation for specific sites to increase maize growth and improve yield sustainability.

Another factor limiting maize production is the predominant use of local varieties which have low yield potential of about 1 ton ha<sup>-1</sup> due to insufficient selection of suitable crop varieties, especially for the marginal areas. It has been demonstrated that modern maize hybrids generally yield more than local open pollinated varieties (Ojiem *et al.*, 1996; Macharia *et al.*, 2010). Therefore, the inclusion of hybrids into the farming system will help in increasing the yield of maize sustainability. By way of addressing these constraints, this study was conducted to update the blanket fertilizer recommendation rates, taking into account the soil types in the agro-ecological zone. The new fertilizer recommendations, will also provide information on fertilizer requirements for both local and hybrid varieties and will reflect farmers' economic situation and ultimately improve maize productivity in Burkina Faso.

Therefore, the main objective of this study was to improve the sustainability of the productivity of maize by determining the appropriate site-specific fertilizer application rates in the sub sudanian zone of Burkina Faso.

The specific objectives of the study were to:

- (i) assess the effect of mineral fertilizer application on soil  $\text{NH}_4^+$  - N, available P and exchangeable K dynamics and their uptake by maize;
- (ii) determine the appropriate rate of mineral fertilizer for optimum grain yield on two benchmark soils;
- (iii) evaluate the cost effectiveness of fertilizer use for smallholder farmers in Burkina Faso.

The above specific objectives were formulated to test the null hypotheses that:

- (i) the application of mineral fertilizers has no effect on soil and plant N, P and K dynamics;
- (ii) the application of mineral fertilizer does not lead to increase in grain yield;
- (iii) the application of appropriate rates of mineral fertilizers are not profitable to smallholder farmers.

## CHAPTER TWO

### 2.0 LITERATURE REVIEW

#### 2.1 Importance of maize in Sub-Saharan Africa

Maize (*Zea mays* L.) is a major staple food and a widely grown cereal in sub-Saharan Africa (Damsteegt and Igwegbe, 2005). Maize has broadly become a major cereal staple which can be used as food, feed for animals and as a source of industrial raw

material (WABS, 2008). In sub-Saharan Africa, maize is grown mostly by smallscale farmers under rainfed conditions mainly for human consumption. It is consumed as green maize fresh on the cob, or is baked, boiled or roasted. The grain can also be dried, ground and boiled into porridge or fermented into beer. Maize is the most important cereal in most African countries (Al-Hassan and Jatoe, 2002).

Maize is an important source of carbohydrate, protein, iron, vitamin B, and minerals. The grains contain 72 % starch, 10 % protein, 4.8 % oil, 8.5 % fibre, 3.0 % sugar and 1.7 % ash (Chaudhary, 1983). *Zea mays* is the most important cereal fodder and grain crop under both irrigated and rainfed agricultural systems in sub-Saharan Africa (Hussan *et al.*, 2003).

## **2.2 Climatic and soil requirements of maize**

Maize requires rainfall of about 600 - 1,200 mm per annum uniformly distributed throughout the year (Awuku *et al.*, 1991). The best maize growing areas in West Africa have minimum rainfall of 1,000 - 1,300 mm per annum, well - distributed during the growth period (Tweneboah, 2000). Maize requires more water during the tasselling - to - silking stage (Awuku *et al.*, 1991) which is considered critical because grain formation is initiated during this short period. Availability of soil moisture at the time of tasselling is therefore vital for the production of high yield in maize (Tweneboah, 2000). Generally, maize has two periods in its growth when insufficient moisture availability can disastrously affect yield. The first is during establishment, when stand can be substantially reduced because of inability of seeds to imbibe water against the gradient of soil water potential thus resulting in poor germination. Rouanet (1987) showed that maize is sensitive to shortage of water 30 - 40 days either side of flowering. This is the second stage that is also a critical period.

Maize can grow in a wide range of environments, however, it is essentially suited for warm climates with adequate moisture. Temperatures of 21 – 30 °C are suitable (Adjetey, 1994). According to Adjetey (1994), high temperature and low moisture result in pollen being shed before silk is receptive or death of tassel and drying of silk. Maximum plant yield are obtained when temperatures of the late vegetative and reproductive phases are relatively lower than 30 °C (Adjetey, 1994). Awuku *et al.* (1991) reported that, maize requires an average temperature of 25 to 30 °C. Tweneboah (2000) stated that the optimum temperature for maize ranges from 18 – 21 °C. The minimum temperature for germination is 10 °C. Germination and especially emergence will be far more rapid and uniform at temperatures above 16 °C. At about 20 °C, maize usually emerges 5-6 days after sowing (Raemaekers, 2001). The critical temperature affecting negatively yield is around 32 °C (Raemaekers, 2001). The amount of light (intensity) received during the growth period influenced maize growth considerably since maize requires a lot of clear sunshine (Adjetey, 1994).

Maize is well adapted to a variety of soils but requires well-drained, deep loams or silty loams with high to moderate organic matter and nutrient contents and pH 5.5 - 8.0 for best production (Tweneboah, 2000). Maize does not like water-logged or shallow soil. According to Baffour (1990), maize normally does very well on moist soils and does badly on pure clayey or sandy soils. The best soils for maize are normally loams and loamy soils rich in humus (Baffour, 1990). Clayey and sandy soils are not conducive for its growth. However, maize is grown on a wide variety of soils and gives high yield if the crop is well managed (Raemaekers, 2001).

### 2.3 Importance of suitable variety selection

The choice of appropriate maize varieties for a given location is important, as it makes a significant contribution to yield improvement. Varieties are selected according to specific factors such as climatic conditions, yield potential, resistance to pest and diseases or duration of growing period to maturity (AOATM, 2011). Therefore, if the wrong cultivar for a given area is planted, there may not be adequate soil moisture for proper growth, especially if the variety has a longer growth period than the rainy period. Furthermore, the differences between modern varieties and traditional varieties must be considered. Wrong variety selection could lead to poor harvest or total crop failure (AOATM, 2011). It is, therefore, important to carefully select varieties that match with local growing conditions including climatic conditions and nutrient level of the site.

Nearly 80 % of smallholder farmers in Africa predominantly grow local maize varieties because they can recycle seeds for many seasons (Odendo *et al.*, 2001).

These varieties have been developed based on specific farmers' criteria and have become, over the years, adapted to local growing conditions (AOATM, 2011). The key farmers' criteria for variety selection, in order of importance, are high yield, early maturity, tolerance to stresses especially *Striga hermontica*, drought and insect pests, low costs of acquiring seed, and ability of a variety to give reasonable yield without application of external inputs, especially fertilizers and pesticides. Most farmers prefer local variety because they are perceived to be able to survive despite the odds of harsh environment, including *Striga hermontica*, low soil fertility and drought (Odendo *et al.*, 2001). Nevertheless, yield of traditional varieties are generally low to moderate due to the poor methods of selecting seeds and to poor management (AOATM, 2011).

Apart from traditional varieties, there are several improved open-pollinated and hybrid varieties of maize in most places of Sub Saharan Africa. These varieties differ from one another in yield potentials, time taken to reach maturity and adaptability to specific growing conditions like drought, pests or diseases (AOATM, 2011). Hybrid varieties are known for high yielding attributes (Odendo *et al.*, 2001). However, hybrid varieties are expensive because new seeds need to be bought for every planting season. Secondly, improved varieties have higher nutrient requirements and will only perform well under improved soil fertility management conditions (AOATM, 2011). On the other hand, improved open-pollinated varieties are often more higher - yielding than traditional varieties and farmers can produce their own seed of open-pollinated maize varieties, thus reducing the costs for purchasing improved commercial varieties (AOATM, 2011).

#### **2.4 Factors affecting maize yield**

Maize yield vary depending upon variety, location, soil nutrient status and application of fertilizers. In sub - Sahara Africa, nitrogen and phosphorus deficiencies are the main causes that restrict agricultural productivity (Sanchez *et al.*, 1997). Nitrogen is a vital plant nutrient and a major yield - determining factor required for maize production (Shanti *et al.*, 1997). It is the most important element for plant growth and development. It is an integral component of many compounds essential for plant growth processes including chlorophyll and many enzymes. It also mediates the utilization of potassium, phosphorus and other elements in plants (Brady, 1984). Its availability in sufficient quantity throughout the growing season is essential for optimum maize growth. Most farmers in developing countries usually rely on the natural soil fertility for crop production, however, subsequent cropping requires additional fertilizer input, most importantly that of nitrogen to maintain good yield.

Phosphorus is another limiting nutrient in maize production. Various factors could be responsible for P availability to crop plants. These include the form of native soil P, the type of P applied to the soil, and soil reaction. The results of various fertilizer experiments carried out in developing countries have led to fertilizer recommendations that gave blanket nutrient requirements for maize in ecologies having varying soil conditions and under varying levels of soil management (FPDD, 1990). For example, hybrid maize cultivation was found to require high fertilizer rate for optimum yield. Sobulo (1980) reported that, maize responded to nitrogen better in the savanna than in the forest ecology, indicating that fertilizer recommendation should be specific to the agro-ecological zone and the soil type. Naseem and Kelly (1999) reported that the use of fertilizers combined with others technologies could help to reverse the decline in yield. Further, these authors demonstrated that chemical fertilizers are among others the most important productivity - enhancing inputs.

### **2.5 Status of soils and fertilizer use in Burkina Faso**

Increased cultivation on less productive lands is a major cause of declining yield in many parts of SSA (Naseem and Kelly, 1999). The soils in Burkina Faso in general are poor in nutrients contents, low in organic matter (< 1 %), highly compacted with reduced cation exchange capacity (Bationo *et al.*, 2006).

Soil fertility decline is one of the most important constraints to increases in agricultural production in the country (Bationo *et al.*, 2006). One of the consequences of soil fertility decline is the decrease in various crops yield and soil degradation on 24 % of arable land. To address the poor and declining soil fertility issue, research on soil fertility was conducted earlier by International Research

Institutes (IRAT, IRCT, IITA, ICRISAT) and later by the national research institute INERA (Institute of Environmental and Agricultural Research) to provide farmers

with soil fertility management technology. Use of locally available resources such as compost and rock phosphate was recommended as a feasible strategy for addressing the declining soil fertility but could not sufficiently resolved the decline in soil fertility, low yield and reduce poverty unless efforts are made to support the use of fertilizer in combination with local resources such as organic matter and rock phosphates. The strategy called for an urgent need to formulate site - specific fertilizer recommendations. It efficiently called for interventions to develop dealer networks and enforcement on fertilizer quality control. However, there has been little improvement in fertilizer use on food crops except in the cotton production zones since the implementation of the national strategy for fertilizer. Crop production depends essentially on extensification more than intensification. The mean annual losses per hectare were approximately 22 kg N, 25 kg P, and 15 kg K during the 1980s (Stoorvogel and Smaling, 1990). In Burkina Faso, estimates indicate that in 1983, for a total of 6.7 million hectares of land cultivated, soil nutrient mining amounted to a total loss of 95,000 tons of N, 28,000 tons of  $P_2O_5$  and 79,000 tons of  $K_2O$  (Bationo *et al.*, 1998). Most of the fertilizers are used on cash crops, mainly cotton. Fertilizer is used on only about 18 % of the cultivated area of cereals, mainly maize. Mineral fertilizer is costly for cereal producers and only farmers producing cash crops can generally afford it. As a result, many grain producers have given up using fertilizer, and simply pray for good rains.

## **2.6 Fertilizer recommendations used in Burkina Faso**

In Burkina Faso, fertilizer use often fails to meet expectations because of its „panterritorial blanket“ recommendation, regardless of the complexity and diversity of the context in which smallholder farmers are operating. Fertilizer recommendations

have been developed since 1974 for only the cash crops (peanuts, cotton). Having no references, the extension service had no choice but to use the recommendation for cotton for cereals. However, later during the 1980s, with the support of a World Bank project known as fertilizer for food crops, experiments were conducted to develop fertilizer recommendations for the main cereals (maize, sorghum and millet). These experiments were conducted at three main agro ecological zones (Hien *et al.*, 1992) and only tried to account for annual rainfall differences and failed to account for other key weather data of high relevance like temperatures, daylight, or for soil characteristics, market information and other site-specific ecological characteristics. The current recommendations are still general and do not take into account differences in resource endowment in the country (soil type, labour capacity, climate risk, and so on) (Hien *et al.*, 1992). Worse still, most farmers are not aware of these recommendations.

### **2.7 Summary of literature review**

The literature reviewed the importance of mineral fertilizer, the selection of a suitable variety to improve crop production. For the sustainability of crop production, it is important to use inorganic fertilizer efficiently and adequately hence the need to determine the optimal site - specific rate of mineral fertilizer.

These observations justify the need to update the blanket fertilizer recommendation to reflect the soil type and the type of crop variety in a particular agro-ecological zone.

## CHAPTER THREE

### 3.0 MATERIALS AND METHODS

#### 3.1 Description of the experimental site

##### 3.1.1 Location

The experiment was conducted at the sub-station of the *Institut de l'Environnement et de Recherches Agricoles (INERA)* at Farako-Bâ near Bobo-Dioulasso town in the southern part of the province of Houet (Figure 3.1). Farako-Bâ is situated on latitude  $11^{\circ} 06''$  N and longitude  $4^{\circ} 20''$  W and 405 m above sea level in the province of Houet.

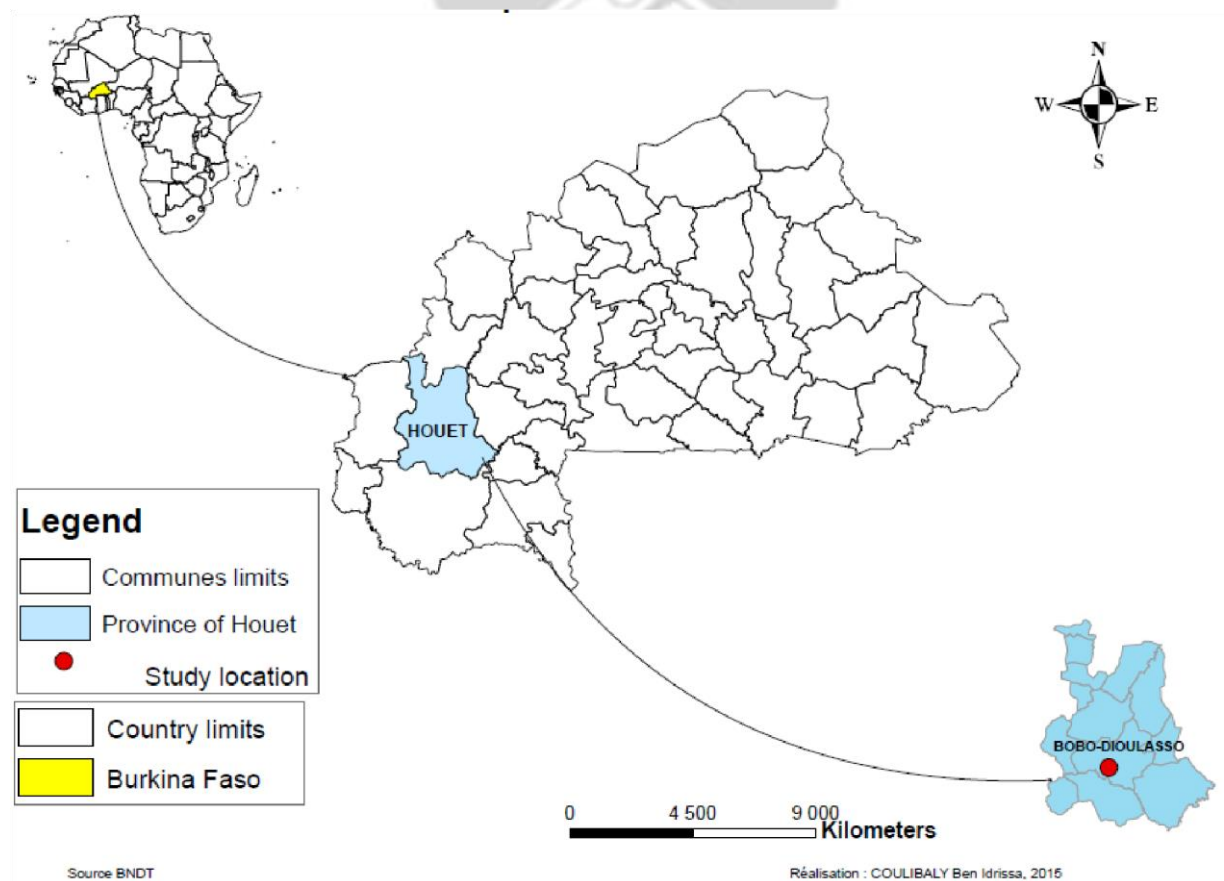


Figure 3.1 Location of the study area

### 3.1.2 Climate

Farako-Bâ lies within the Sudan agro ecological zone (Fontes and Guinko, 1995). The rainfall pattern of the area is unimodal. The rainy season starts from April-May and ends in October-November, with a peak rainfall in August (Figure 3.2). The mean daily temperature ranges from 10 to 32 °C (Meteorological Department of INERA / Farako-Ba, 2014)

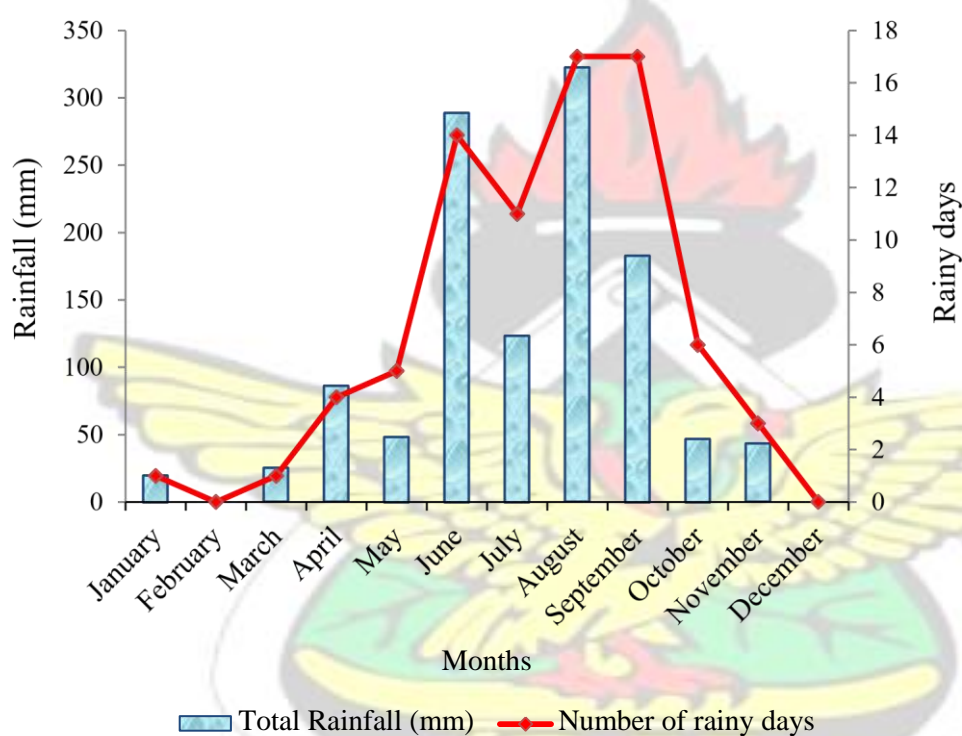


Figure 3. 2 Rainfall during the cropping season of 2014 (INERA / Farako-Bâ)

### 3.1.3 The soil

There are two (2) soil types at Farako-Bâ: the Ferralsols in the northern part of the station and the Luvisols in the southern part (BUNASOL, 1990).

### **3.1.3.1 Characteristics of Ferralsols**

The WRBSR (2014) described Ferralsols as deeply weathered, red and yellow tropical soils with a high content of sesquioxides. These soils have diffuse horizon boundaries, a clay assemblage dominated by low-activity clays (mainly kaolinite). This mineralogy and the relatively low pH explain the stable microstructure (pseudosand) and yellowish (goethite) or reddish (hematite) soil colours.

Most Ferralsols have good physical properties: great soil depth, good permeability and stable microstructure. Moist Ferralsols are friable and easy to work. They are well drained but may in times be droughty because of their low available water storage capacity.

The chemical fertility of Ferralsols is poor; weatherable minerals are scarce or absent, and cation retention by the mineral soil fraction is weak. Strong retention (fixing) of P is a characteristic problem of Ferralsols. Ferralsols are normally also low in N, K, secondary nutrients (Ca, Mg and S), and some 20 micronutrients. Fertilizer selection and the mode and timing of fertilizer application determine to a great extent the success of agriculture for the Ferralsols (WRBSR, 2014).

### **3.1.3.2 Characteristics of Luvisols**

Luvisols are soils with a pedogenetic clay differentiation (especially clay migration) between a topsoil with a lower and a subsoil with a higher clay contents, highactivity clays and a high base saturation at some depth.

The parent material is a wide variety of unconsolidated materials including glacial till, and aeolian, alluvial and colluvial deposits. Luvisols have favourable physical properties; they have granular or crumb surface soils that are porous and well aerated. Their chemical properties vary with parent material and pedogenetic history.

Surface soils are normally wholly or partly de-calcified and slightly acid in reaction.

They contain a few percent organic matter but are generally mostly fertile soils and suitable for a wide range of agricultural uses.

Luvissols with a high silt contents are susceptible to structure deterioration when ploughed and harrowed under wet conditions or with heavy machinery. Luvissols on steep slopes require erosion control measures (WRBSR, 2014).

### 3.2 Experimental design and treatments

The experiment was a randomized complete block design arranged in split - plot with three replications. The main plot factor was the maize variety (Komsaya and SR21). The sub plot factor was application rate of mineral fertilizer. The main plots were 44 m x 20 m in dimensions while the sub plots were 6 m x 4 m. The treatments structure is given in Table 3.1.

Table 3.1 Mineral fertilizer treatments

Treatment	N-P-K (kg ha <sup>-1</sup> )	Treatment	N-P-K (kg ha <sup>-1</sup> )
T <sub>1</sub>	0-0-0	T <sub>5</sub>	90-22,5-0
T <sub>2</sub>	90-0-0	T <sub>6</sub>	90-15-10
T <sub>3</sub>	90-7.5-0	T <sub>7</sub>	90-15-20
T <sub>4</sub>	90-15-0	T <sub>8</sub>	90-15-30
T <sub>9</sub>	90-15-20-15S-10Mg-2.5Zn-0.5B		

Nitrogen, P, K, S, Mg, Zn and B fertilizers used were provided by single fertilizers (see section 3.5). The different treatments were selected based on the assumptions that the optimum rates of N, P and K are 90 kg ha<sup>-1</sup>, 15 kg ha<sup>-1</sup> and 20 kg ha<sup>-1</sup> respectively. Therefore, mineral fertilizer rates below the optimum P and K rates were added to test their performance against the optimum rates.

### **3.3 Soil sampling**

Prior to implementation of the trials, representative soil samples were taken at the four corners and central portions of the field on both soils. The soil samples were collected at a depth of 0 - 20 cm, mixed thoroughly and a subsample was brought to the laboratory to determine both physical and chemical properties.

### **3.4 Land preparation and sowing**

Conventional tillage (disc ploughing and harrowing) was used to clear the land. Later, the field was levelled manually where needed. Two (2) varieties of maize; Komsaya and SR21 were used. The first variety Komsaya is a hybrid while the SR21 is an open pollinated variety (OPV). Komsaya (colour orange-yellow) has a growth cycle of 85 to 90 days and the yield potential is about 8 to 9.5 tons ha<sup>-1</sup>. The SR21 has a growth cycle of 97 days with a yield potential of 5.1 tons ha<sup>-1</sup>.

Three (3) seeds were sown per stand on 15<sup>th</sup> July, 2014 and later thinned to two seedlings per stand 10 days after sowing. The planting distance used was 80 cm between rows and 40 cm between plants.

### **3.5 Mineral fertilizer application**

The mineral fertilizers used to supply Nitrogen, Phosphorus, Potassium, Sulphur, Magnesium, Zinc and Boron were respectively: Urea (46 % N), Triple Super Phosphate (45 % P<sub>2</sub>O<sub>5</sub>), Potassium Chloride (60.8 % K<sub>2</sub>O), Kieserite (MgSO<sub>4</sub>): 15 % Mg and 22 % S, Zinc sulphate (36.8 % ZnSO<sub>4</sub>) and Borax pentahydrate (48 % B<sub>2</sub>O<sub>3</sub>). The mineral fertilizers were applied two weeks after seedling emergence by side placement to their respective treatment plots. Nitrogen was applied in two equal splits doses, the first dose was applied in combination with the others nutrients two weeks after planting and the second dose was applied 30 days after the first application.

### **3.6 Crop management**

Two hoe weeding was carried out at 4 and 9 weeks after seedlings emergence.

Harvesting was done at 17 and 18 weeks after sowing respectively for Komsaya and SR21 respectively. The plants were harvested at physiological maturity (observable drying of leaves and cobs). Yield components were taken from a quadrat of 1.6 m x 2 m (3.2 m<sup>2</sup>) in the middle of each treatment plot leaving the border rows.

### **3.7 Laboratory analysis**

#### **3.7.1 Soil analysis**

##### **3.7.1.1 Particle size distribution**

The particle size distribution of a soil expresses the proportions of the various size classes (clay < 0.002 mm; silt, 0.002 - 0.02 mm and sand, 0.02-2.0 mm particle size), commonly represented by weight percentages of the total soil. The proportions of these fractions were determined by Hydrometer method (Bouyoucos, 1962) using Robinson's pipette based on the Stoker's Law which states that the rate of fall of particles in a suspension is directly proportional to their size.

Twenty (20) grams of a prepared soil sample (sieved with 2 mm mesh and oven-dried at 105 °C) was weighted into a one-litre flask. Five hundred (500) millilitres of distilled water and 100 millilitres of H<sub>2</sub>O<sub>2</sub> (30 %) were added to destroy the organic matter. The mixture was gently stirred with a glass rod and the flask was left for a night. The flask was heated until the mixture was clear.

The mixture was then transferred into a 1000 millilitres sedimentation cylinder and 20 millilitres of 5 % sodium hexametaphosphate solution were added to free the individual soil particles and the volume was made up to 1000 millilitres with distilled water. The cylinder was

closed with a stopper tightly and shaken on a mechanical shaker 30 turns/minute for 4 hours to allow the soil particles to disperse completely.

The cylinder was then after shaking by hand for one minute to homogenize the solution by removing all the particles laid down at the bottom. The stopper was removed and the cylinder was left away from any source of heat or direct sunlight during the period. Clay and silt particles were collected first by collecting an aliquot of 20 millilitres. The rest of the suspension was poured into a set of sieves to collect the finer and the coarser sand. A blank without soil was run simultaneously.

Calculation.

$$\% \text{ Sand} = 100 - [H_1 + 0.2 (T_1 - 20) - 2.0] \times 2$$

$$\% \text{ Clay} = [H_2 + 0.2 (T_2 - 20) - 2.0] \times 2$$

$$\% \text{ Silt} = 100 - (\% \text{ sand} + \text{clay})$$

where:

$H_1$  = Hydrometer reading at 40 seconds

$T_1$  = Temperature at 40 seconds

$H_2$  = Hydrometer reading at 3 hours

$T_2$  = Temperature at 3 hours

$0.2 (T - 20)$  = Temperature correction to be added to hydrometer reading -

2.0 = Salt correction.

### 3.7.1.2 Bulk density

The bulk density was determined at 20 cm depth using the core method before planting. A 400 cm<sup>3</sup> cylinder was used in taking the core samples. Samples were dried at 105 °C to constant weight for 48 hours and weighed. The bulk density ( $\rho_b$ ) was calculated as:

$$\rho_b = \frac{M_s}{V_t}$$

where:

$M_s$  = Oven dry weight of soil (g)

$V_t$  = total volume of cylinder ( $\text{cm}^3$ )

### 3.7.1.3 Soil pH

Soil pH was measured in a 1:2.5 soil - water suspension. From a prepared soil sample (air dried, 2 mm sieved), twenty (20) grams was weighed into a 100 ml beaker. Fifty (50) millilitres of distilled water were added and the beaker was shaken for 30 minutes at 150 turns  $\text{minute}^{-1}$ . The suspension was allowed to stand for 30 minutes. Calibrated pH meter (Cyberscan 510, Singapore) with buffers at pH 4 and 7 respectively was used to determine the pH of the suspension.

### 3.7.1.4 Soil organic carbon

The modified Walkley and Black procedure as described by Nelson and Summers (1982) was used in the determination of organic carbon. A 0.5 gram of soil sample was weighed into an Erlenmeyer flask. A reference sample and a blank were included. Two and half (2.5) millilitres of 1.0  $N$  (0.1667  $M$ ) potassium dichromate solution were added to the sample and the blank. Concentrated sulphuric acid (5 ml) was carefully added to the soil from a measuring cylinder, swirled and allowed to stand for 30 minutes in a fume cupboard. Twenty-five (25) millilitres of distilled water and 10 millilitres concentrated orthophosphoric acid were added and allowed to cool. One millilitre of diphenylamine indicator was then added and titrated with

1.0  $M$  ferrous sulphate ( $\text{FeSO}_4$ ) solution.

Calculation:

$$\% \text{ organic C} = \frac{(\text{m. e. K}_2\text{CrO}_7 - \text{m. e. FeSO}_4) \times 1.32 \times 0.003}{\text{weight of soil sample}} \times 100$$

where:

m.e. = molarity of solution x ml of solution used

0.003 = m.e. wt of C in grams (12/4000)

1.32 = correction factor

### 3.7.1.5 Organic matter

The percentage of the organic carbon was multiplied by 1.724 (the van Bemmelen factor) Bernoux and Chevaller, (2013) to get the percentage of the organic matter.

### 3.7.1.6 Ammoniacal nitrogen ( $\text{NH}_4^+$ - N) concentration

The  $\text{NH}_4^+$ - N was extracted with 10 % NaCl solution. The  $\text{NH}_4^+$ - N in NaCl extract was determined by distillation using the Kjeldhal's distillation apparatus (Behrotest WD 40, Germany). To ten (10) grams of fresh soil in 100 millilitres conical flask, 20 millilitres of NaCl solution was added and shaken for 30 minutes. The material was transferred into Kjeldhal tube and 20 millilitres of 40 % NaOH was added and distilled. The distillate was collected in 2 % boric acid and titrated against 0.01 N of  $\text{H}_2\text{SO}_4$ .

Calculation

$$\text{NH}_4^+ \text{- N in soil (mg kg}^{-1}\text{)} = \frac{(S-B) \times N \times 14 \times 1000}{\text{Sample weight (g)}}$$

where:

S= Volume of acid used against sample.

B= Volume of acid used against blank.

N= Normality of acid.

### 3.7.1.7 Available phosphorus

Phosphate was extracted in an acidic ammonium fluoride solution (Bray and Kurtz 1945). After the extraction, the phosphate was determined colorimetrically with ammonium molybdate as the colouring reagent. Two (2) grams of soil sample (sieved

with 0.5 mm mesh) was weighed into a 50 millilitres shaking bottle and 14 millilitres of the extractant (1 M NH<sub>4</sub> - F + 0.5 M HCl) were added, shaken for one minute by hand and filtered immediately using Whatman number 42 filter paper. One millilitre of the sample, two millilitres of boric acid and three millilitres of the mixed reagent (50 millilitres 2.5 M Sulphuric acid, 15 ml 4 % Ammonium molybdate, 30 millilitres 1.75 % Ascorbic acid, 5 millilitres 0.275 % Potassium antimony tartrate and 200 ml water) were successively pipetted into a test tube. The solution was then shaken and allowed to stand for one hour for the blue colour development. The concentration of the solution was measured at 882 nm or 720 nm using spectrophotometer (Cecil 3021, England) initially standardized with a series of solutions of known phosphorus concentration. Calculation:

$$\text{Available P (mg kg}^{-1}\text{)} = \frac{(S-B) \times D \times (14 + W)}{W \text{ (g)}}$$

where:

S = P concentration in sample (mg l<sup>-1</sup>) read by spectrophotometer

B = P concentration in blank (mg l<sup>-1</sup>) read by spectrophotometer.

D = Dilution factor (standard 1 for undiluted samples).

W = Sample weight

14 = volume of extractant.

### 3.7.1.8 Exchangeable potassium

Potassium was determined by the Ammonium acetate method of Hanway and Heidel (1952). Five (5) grams of soil sample sieved with 0.5 mm was weighed in 100 ml conical flask. Twenty-five (25) millilitres of 1 N ammonium acetate solution were then added and shaken for 5 minutes. The material was filtered through Whatman filter paper and K concentration was measured in the filtrate using flame photometer

(Jenway PFP 7, UK).

Calculation:

$$\text{Exchangeable K (mg kg}^{-1}\text{)} = \frac{C \times 25}{\text{Sample weight (g)}}$$

where:

C = Concentration of potassium in filtrate.

25 = Volume of Ammonium acetate.

### **3.7.1.9 Exchangeable cations**

Exchangeable bases (calcium, magnesium, potassium and sodium) in the soil were determined in 1.0 M ammonium acetate extract (Black, 1986). A 5 grams soil sample was weighed into a leaching tube and leached with 100 millilitres buffered 1.0 M ammonium acetate solution at pH 7.

#### ***Determination of calcium and magnesium***

Calcium and magnesium were determined in a 25 millilitres aliquot of the extract transferred into an Erlenmeyer flask. To this were added 1 millilitre of Hydroxylamine hydrochloride, 1 millilitre of 2.0 % Potassium cyanide, 1 millilitre of

2.0 % Potassium ferrocyanide, 10 ml Ethanolamine buffer and 0.2 ml Eriochrome Black T solution. The solution was titrated (Titroline *easy*, Germany) with 0.01 M

EDTA (Ethylene Diamine Tetraacetic Acid).

#### ***Determination of calcium***

A 25 millilitres aliquot of the extract was transferred into a 250 ml Erlenmeyer flask and the volume was made up to 50 ml with distilled water. One millilitre of Hydroxylamine, 1 millilitre of 2.0 % Potassium cyanide and 1 millilitre of 2.0 % Potassium ferrocyanide were then added to the solution. After a few minutes, 5

millilitres of 8.0 M Potassium hydroxide solution and a murexide indicator were added.

The resultant solution was titrated with 0.01 M EDTA solution.

Calculation:

$$\text{Ca} + \text{Mg (or Ca)} \text{ (cmol kg}^{-1} \text{ soil)} = \frac{0.01 \times (V_a - V_b) \times 100}{w}$$

where:

w = weight (g) of air - dried soil used

V<sub>a</sub> = ml of 0.01 MEDTA used in sample titration

V<sub>b</sub> = ml of 0.01 MEDTA used in blank titration

0.01 = concentration of EDTA

#### ***Determination of exchangeable potassium and sodium***

Potassium (K) and sodium (Na) in the leachate were determined by flame photometry.

A standard series of potassium and sodium were prepared by diluting both 1000 mg l<sup>-1</sup> K and Na solutions to 100 mg l<sup>-1</sup>. In doing this, 25 millilitres portion of each solution was taken into 250 millilitres volumetric flask and made up to the volume with distilled water. Portions of 0, 5, 10, 15, 20 millilitres of the 100 mg l<sup>-1</sup> standard solution were put into 200 millilitres volumetric flasks. One hundred milliliters of 1.0 M NH<sub>4</sub>OAc solution was added to each flask and made to the volume with distilled water. This resulted in standard series of 0, 2.5, 5.0, 7.5, 10 mg l<sup>-1</sup> for K and Na. Potassium and sodium were measured directly in the leachate by flame photometry (Jenway PFP 7, UK) at wavelengths of 766.5 and 589.0 nm respectively.

Calculation:

$$\text{Exchangeable K (cmol kg}^{-1} \text{ soil)} = \frac{(a - b) \times 250 \times \text{mcf}}{10 \times 39.1 \times w}$$

$$\text{Exchangeable Na (cmol kg}^{-1}\text{ soil)} = \frac{(a - b) \times 250 \times \text{mcf}}{10 \times 23 \times w}$$

where:

a = mg l<sup>-1</sup> K or Na in the diluted sample

b = mg l<sup>-1</sup> K or Na in the diluted blank

w = weight (g) of air - dried sample

mcf = moisture correcting factor

### 3.7.1.10 Soil total nitrogen, phosphorus and potassium

To determine the total nitrogen (N), phosphorus (P) and potassium (K), samples were first mineralized using H<sub>2</sub>SO<sub>4</sub> - Se mixture. A 0.5 gram of oven dried (70 °C) soil (0.5 mm,) was put into a digestion tube. Five (5) millilitres of digestion mixture was added to each tube and the reagent blanks for each batch of samples. The samples were digested at 330 °C for 2 hours using mineralization blocks (Buchi K 428, Switzerland and Gerhardt, German). The mixture was removed, cooled and three successive 1 millilitre portion of hydrogen peroxide and heated at 100 °C. This was repeated 3 times. About 25 millilitres of distilled water was added and mixed well.

The digest was then allowed to cool and made up to 50 millilitres with distilled water.

The total N and total P contents in the digest solution were assessed using an automatic colorimeter (Skalarsanplus Segmented flow analyzer, Model 4000-02). Total N was determined using a modified Bethelot reaction (Krom, 1980), and total P following the Murphy and Riley method (Murphy and Riley, 1962). Total K was determined using a flame photometer (Jenway PFP 7, UK).

### **3.8 Data collection**

#### **3.8.1 Nutrient dynamics in soil**

Soil samples were collected at the depth of 0 – 20 cm at 45, 60 and 75 days after planting (DAP) to assess the dynamics of N, P and K during the 2014 cropping season.

The samples were subjected to chemical analysis to determine soil pH,  $\text{NH}_4^+$ - N, available P and exchangeable K. The methods described in sections 3.7.1.3,

3.7.1.6, 3.7.1.7 and 3.7.1.8 were used.

#### **3.8.2 Plant nutrient concentrations**

Maize plants were collected at harvest to assess N, P and K concentrations. To determine the total nitrogen (N), phosphorus (P) and potassium (K), plant samples were analyzed following the procedure used for soil total N, P and K as described in section 3.7.1.10.

#### **3.8.3 Yield components**

##### **3.8.3.1 Grain yield**

The grain yield from each plot harvested from the harvestable area was calculated and the yield extrapolated to  $\text{kg ha}^{-1}$  using the formula below:

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{10000 \text{ m}^2 \times Q \text{ grain (kg)}}{\text{Harvest area (m}^2\text{)}}$$

where:

Q is the weight of the grain.

##### **3.8.3.2. Stover yield**

The plants harvested from the net plot were weighed and the yield converted into  $\text{kg ha}^{-1}$ . The formula used in section 3.8.1 was used for the calculation.

### 3.8.4 Calculations

#### 3.8.4.1 Harvest index

In determining the harvest index, five plants were selected randomly from each plot and weighed. The cob was threshed and the grain weighed. The harvest index was taken as the ratio of the grain weight to the above ground dry matter.

$$HI = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}}$$

where:

Economic yield = grain yield

Biological yield = grain and stover yields

#### 3.8.4.2 Nutrient uptake

Nutrient uptake was calculated as product of nutrient concentration in grain or whole plant multiplied by the yield

Nutrient uptake = Nutrient concentration in grain/straw  $\times$  yield

#### 3.8.4.3 Value cost ratio

Value cost ratio (VCR) is the ratio between the value of the additional crop yield obtained from fertilizer use and the cost of fertilizer used.

Calculation:

$$VCR = \frac{x-y}{z}$$

where:

x = value of crop produced from fertilized plots

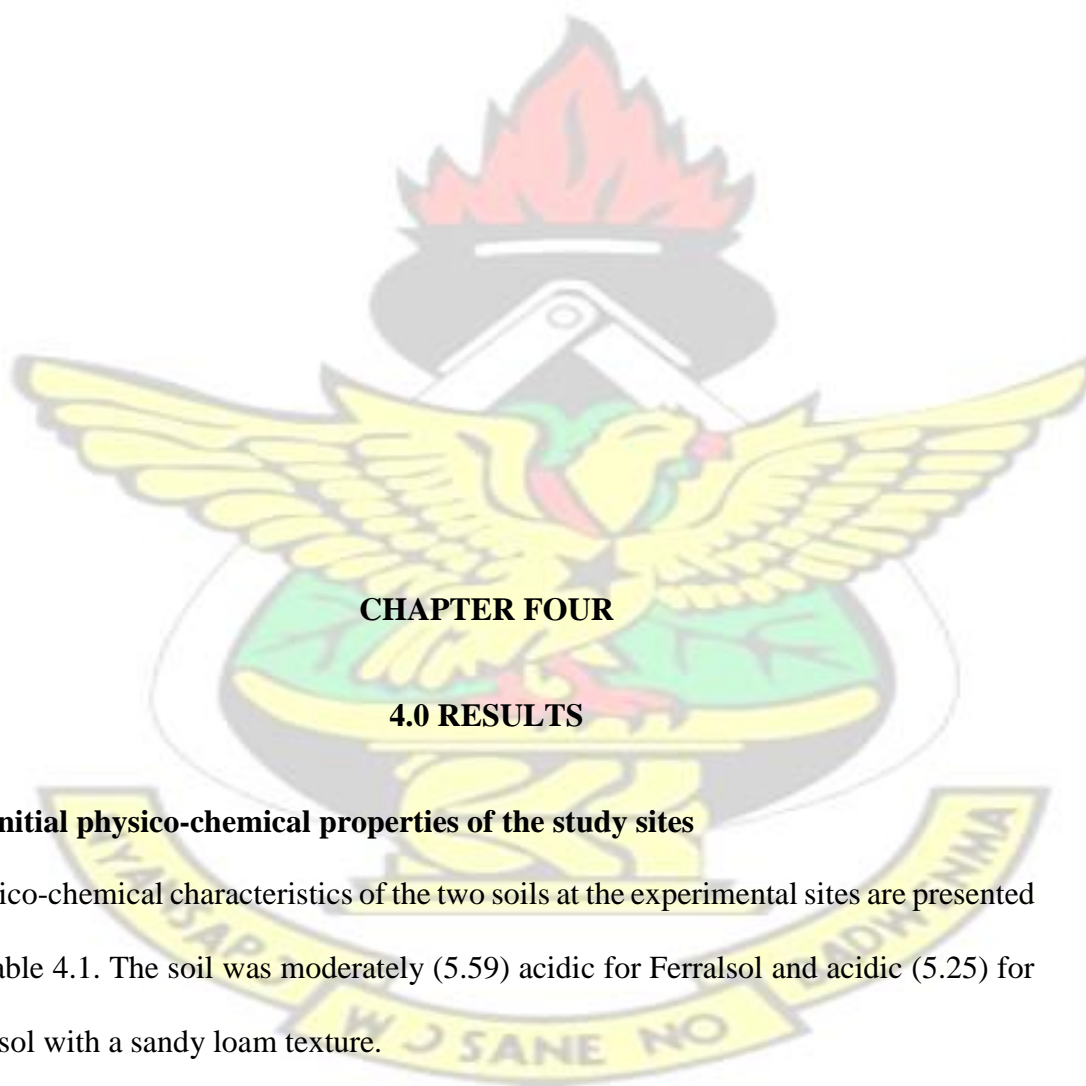
y = value of crop produced from unfertilized plots

z = cost of fertilizer

### 3.9 Data analysis

The data collected were subjected to analysis of variance (ANOVA) using GenStat statistical package. The means were compared using Least Significant Difference (LSD) at 5 % level of probability. Statistical significance was determined at the probability of 0.05 for the effects of fertilization, cropping varieties, soil type and their interactions on yield.

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## CHAPTER FOUR

### 4.0 RESULTS

#### 4.1 Initial physico-chemical properties of the study sites

Physico-chemical characteristics of the two soils at the experimental sites are presented in Table 4.1. The soil was moderately (5.59) acidic for Ferralsol and acidic (5.25) for Luvisol with a sandy loam texture.

Soil parameter	Ferralsol	Luvisol
pH(1: 2.5 in H <sub>2</sub> O)	5.59	5.25

Clay (%)	9.75	10.75	Table 4.1
Silt (%)	18.65	28.95	
Sand (%)	71.60	60.30	
Texture	Sandy-loam	Sandy-loam	
Bulk density (0-10 cm) (g cm <sup>-3</sup> )	1.47	1.63	
Bulk density (10-20 cm) (g cm <sup>-3</sup> )	1.66	1.62	
Organic carbon (g kg <sup>-1</sup> )	2.67	3.60	
Total N (g kg <sup>-1</sup> )	0.28	0.35	
Available P (mg kg <sup>-1</sup> )	1.57	1.82	
Exchangeable cations (Cmol <sub>c</sub> kg <sup>-1</sup> )			
Ca <sup>2+</sup>	0.96	1.12	
Mg <sup>2+</sup>	0.52	0.48	
K <sup>+</sup>	0.27	0.22	
Na <sup>+</sup>	0.04	0.05	
<u>CEC</u>	<u>2.87</u>	<u>3.87</u>	

Characteristics of soils of experimental sites (0 – 20 cm) at planting

Bulk density was relatively greater on Luvisol than on Ferralsol. Both the Luvisol and Ferralsol were very low in chemical properties such as organic carbon, nitrogen, available phosphorus and CEC. Nonetheless, the chemical properties of the Luvisol were relatively better than that of the Ferralsol (Table 4.1).

## 4.2 Soil nutrient dynamics

### 4.2.1 Soil $\text{NH}_4^+$ - N

#### 4.2.1.1 Soil $\text{NH}_4^+$ - N changes on a Luvisol

Table 4.2 presents the  $\text{NH}_4^+$ - N contents of the soil as affected by mineral fertilizer application rates and maize variety during the crop cycle on the Luvisol.

Analysis of variance showed highly significant effect ( $P < 0.05$ ) of mineral fertilizer on soil  $\text{NH}_4^+$ - N contents with time (Table 4.2). During the first sampling period (45 DAP), mineral fertilizer at the rate of 90N-0P-0K gave the highest soil  $\text{NH}_4^+$ - N contents (40.78 mg  $\text{kg}^{-1}$  soil) which was significantly higher than those of all the other mineral fertilizer rates except for the 90N-15P-0K and 90N-15P-20K-15S10Mg-2.5Zn-0.5B rates. The lowest value (31.57 mg  $\text{kg}^{-1}$  soil) was recorded for the 90N-7.5P-0K which was not significantly different from those of 90N-22.5P-0K and the control treatments.

At 60 DAP, mineral fertilizer rate 90N-0P-0K gave the highest soil  $\text{NH}_4^+$ - N contents of 40.65 mg  $\text{kg}^{-1}$  soil. This was significantly higher than those of the 90N-15P-10K, 90N-7.5P-0K and the control while the 90N-15P-10K rate had the lowest value (37.42 mg  $\text{kg}^{-1}$  soil) which was significantly ( $P < 0.05$ ) lower than those of all the other mineral fertilizer rates.

The highest soil  $\text{NH}_4^+$ -N contents at 75 DAP (39.25 mg  $\text{kg}^{-1}$  soil) was given by 90N0N-0K rate which was significantly higher than that of all the other mineral fertilizer rates except those for the 90N-15P-10K and 90N-15P-20K-15S-10Mg-2.5Zn-0.5B rates, while the lowest value was recorded for the 90N-0N-0K (34.64 mg  $\text{kg}^{-1}$  soil) treatments (Table 4.2). Generally, the results showed an increase in soil  $\text{NH}_4^+$ -N contents in the plots with a peak at 60 DAP followed by a decrease during the last sampling period except for plots amended with 90N-15P-10K and 90N-0P-0K that showed a continuous increase and decrease, respectively in soil  $\text{NH}_4^+$ -N contents.

Soil  $\text{NH}_4^+$ -N contents was significantly ( $P < 0.05$ ) affected by the varieties only at 45 DAP. Soil  $\text{NH}_4^+$ -N contents on plots planted to SR21 were significantly ( $P < 0.05$ ) higher by 6 % over that of plots cultivated with Komsaya (Table 4.2).

The combined effect of mineral fertilizer and maize variety significantly affected soil  $\text{NH}_4^+$ -N throughout the crop cycle (Appendix 1). Plots planted with SR21 and supplied with 90N-0P-0K gave the highest  $\text{NH}_4^+$ -N concentration of 45.18 mg  $\text{kg}^{-1}$  soil at 45 DAP, while those supplied with 90N-15P-30K gave the highest value at 60 and 75 DAP.

Table 4.2 Effect of mineral fertilizer application rate and maize variety on soil  $\text{NH}_4^+$ -N on a Luvisol

Treatment (kg ha )	- N (mg kg <sup>-1</sup> soil)		
	45 DAP	60 DAP	75 DAP
<u>Fertilizer rate</u>			
Control	33.16	38.76	35.17
90N-0P-0K	40.78	40.65	34.64
90N-7.5P-0K	31.57	39.06	36.40
90N-15P-0K	37.88	39.77	37.05
90N-22.5P-0K	32.53	39.67	37.41
90N-15P-10K	35.93	37.42	37.80
90N-15P-20K	36.64	39.77	36.92
90N-15P-30K	35.49	40.49	39.25
90N-15P-20K-15S10Mg-2.5Zn-0.5B	38.62	40.29	38.11
LSD (0.05)	3.40	1.26	1.63
Fpr	< 0.001**	< 0.001**	< 0.001**
<u>Variety</u>			
Komsaya	34.84	39.72	36.61
SR21	36.85	39.37	37.34
LSD (0.05)	1.60	0.59	1.77
Fpr	0.015*	NS	NS
<u>Mineral fertilizer x Variety</u>			
LSD (0.05)	4.80	1.77	2.30
Fpr	< 0.001**	< 0.001**	< 0.001**
CV (%)	8.1	2.7	3.8

DAP =Days after planting; NS = not significant at  $P < 0.05$ ; \* = significant at  $P < 0.05$ ; \*\* = significant at  $P < 0.01$

#### 4.2.1.2 Soil $\text{NH}_4^+$ - N dynamics on a Ferralsol

The results of soil  $\text{NH}_4^+$  - N contents as influenced by rates of mineral fertilizer and maize variety on Ferralsol at two sampling times are presented in Table 4.3.

At 45 DAP, the diagnostic mineral fertilizer rate 90N-15P-20K-15S-10Mg-2.5Zn0.5B produced the highest (37.88 mg kg<sup>-1</sup> soil) soil  $\text{NH}_4^+$  - N contents which was statistically ( $P < 0.05$ ) similar to that of the 90N-0P-0K and 90N-7.5P-0K rates while the control gave the lowest value of 27.28 mg kg<sup>-1</sup> soil which was significantly lower than those of all the other mineral fertilizer application rates.

At 60 DAP, the soil  $\text{NH}_4^+$  - N contents ranged from 24.12 mg kg<sup>-1</sup> soil in the 90N-0P0N treatment to 27.32 mg kg<sup>-1</sup> soil of the 90N-7.5P-0K, with significant differences observed among the mineral fertilizer rates. The 90N-7.5P-0K treatment gave the highest soil  $\text{NH}_4^+$  - N content which was significantly higher than those of all the other mineral fertilizer rates except for the 90N-22.5P-0K and 90N-15P-20K treatments. The lowest soil  $\text{NH}_4^+$  - N value was recorded for the 90N-0P-0N treatment which was statistically similar to those of all the other rates except for the 90N-7.5P-0K, 90N-22.5P-0K and 90N-15P-20K treatments (Table 4.3).

Soil  $\text{NH}_4^+$  - N contents was similar ( $P > 0.05$ ) in the plots planted with both maize varieties at 45 DAP. At 60 DAP, its contents significantly ( $P < 0.05$ ) differed as shown in Table 4.3. Plots planted with SR21 gave a soil  $\text{NH}_4^+$  - N contents of 21 % over that of the plots planted with Komsaya.

Table 4.3 Effect of mineral fertilizer application rate and maize variety on soil  $\text{NH}_4^+$ -N on a Ferralsol

Treatment (kg ha ) <u>Fertilizer rate</u>	- N (mg kg <sup>-1</sup> )	
	45 DAP	60 DAP
Control	27.28	25.06
90N-0P-0K	36.76	24.12
90N-7.5P-0K	36.44	27.32
90N-15P-0K	35.90	25.64
90N-22.5P-0K	33.85	26.01
90N-15P-10K	31.01	24.66
90N-15P-20K	34.88	26.55
90N-15P-30K	32.82	25.11
90N-15P-20K-15S- 10Mg-2.5Zn-0.5B	37.88	24.72
LSD (0.05)	1.94	1.58
Fpr	< 0.001**	0.006*
<u>Variety</u>		
Komsaya	34.43	23.75
SR21	33.64	27.18
LSD (0.05)	0.92	0.75
Fpr	NS	< 0.001**
<u>Mineral fertilizer x Variety</u>		
LSD (0.05)	2.78	2.24
Fpr	< 0.001**	< 0.001**
CV (%)	4.9	5.3

---

DAP =Days after planting; NS = not significant at  $P < 0.05$ ; \* = significant at  $P < 0.05$ ; \*\* = significant at  $P < 0.01$

The interactive effect of mineral fertilizer and maize variety significantly affected soil  $\text{NH}_4^+$  - N (Appendix 2). Plots planted with Komsaya and supplied with the diagnostic treatment gave the highest  $\text{NH}_4^+$  - N concentration of 42.42 mg  $\text{kg}^{-1}$  soil at 45 DAP, while those planted with SR21 and amended with 90N-15P-0K gave the highest value of 29.36 mg  $\text{kg}^{-1}$  soil at 60 DAP.

#### **4.2.2 Soil available phosphorus**

##### **4.2.2.1 Soil available phosphorus dynamics on a Luvisol**

The effects of mineral fertilizer and maize variety on soil available phosphorus for the Luvisol are presented in Table 4.4. The results revealed that available phosphorus was affected significantly by mineral fertilizer application and maize variety throughout the three sampling periods.

During the first sampling period, soil available P was highest (18.47 mg  $\text{kg}^{-1}$  soil) for the plots treated with 90N-22.5P-0K and the lowest (8.37 mg  $\text{kg}^{-1}$  soil) for the plot treated with 90N-0P-0K. There was a net decrease from the first to the third sampling period in soil available P contents for most of the plots except for the control, diagnostic 90N-15P-20K-10Mg-2.5Zn-0.5B and the 90N-0P-0K treatments plots that an increase from the first to the second sampling period was observed. Soil available P was also increased from the second to the third sampling period for the 90N-15P30K treatment plots (Table 4.4).

The different maize varieties showed significant effect ( $P < 0.05$ ) on soil phosphorus contents. Komsaya treatments plots had soil phosphorus contents of 6, 24 and 11 % higher than plots planted with SR21 at all the sampling periods. However, soil

phosphorus contents gradually decreased as the season progressed (Table 4.4) for the two varieties.

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Table 4.4 Effect of mineral fertilizer application rate and maize variety on soil available phosphorus on a Luvisol

Treatment (kg ha <sup>-1</sup> )	Available phosphorus (mg kg <sup>-1</sup> )		
	45 DAP	60 DAP	75 DAP
<u>Fertilizer rate</u>			
Control	9.78	11.30	8.59
90N-0P-0K	8.37	8.39	8.07
90N-7.5P-0K	15.65	11.96	11.70
90N-15P-0K	12.50	10.60	9.78
90N-22.5P-0K	18.47	13.43	10.28
90N-15P-10K	13.54	10.72	10.53
90N-15P-20K	14.85	11.24	10.70
90N-15P-30K	13.55	8.11	10.57
90N-15P-20K-15S10Mg-2.5Zn-0.5B	10.09	11.18	9.22
LSD (0.05)	1.00	0.57	0.47
Fpr	< 0.001**	< 0.001**	< 0.001**
<u>Variety</u>			
Komsaya	13.33	11.92	10.48
SR21	12.62	9.62	9.40
LSD (0.05)	0.47	0.27	0.22
Fpr	0.005*	< 0.001**	< 0.001**
<u>Mineral fertilizer x Variety</u>			
LSD (0.05)	1.42	0.81	0.67

Days

Fpr	< 0.001**	< 0.001**	< 0.001**
CV (%)	6.6	4.5	4.1

DAP = after planting; \* = significant at  $P < 0.05$ ; \*\* = significant at  $P < 0.01$  The interactive effect of mineral fertilizer and maize variety significantly ( $P < 0.05$ ) affected soil available phosphorus over time (Appendix 3). Plots planted with SR21 and supplied with 90N-22.5P-0K gave the highest soil available phosphorus concentration of 21.04 mg kg<sup>-1</sup> soil at 45 DAP, while those planted with Komsaya and supplied with 90N-7.5P-0K and 90N-15P-10K gave the highest at 60 and 75 DAP.

#### 4.2.2.2 Soil available phosphorus on a Ferralsol

The effects of mineral fertilizer application and maize variety on soil available phosphorus for Ferralsol are presented in Table 4.5. Mineral fertilizer rates significantly ( $P < 0.05$ ) affected the soil available phosphorus concentration with time. There was a drastic decrease in the phosphorus concentration in all the plots throughout the sampling periods except in the control and the plots amended with 90N-0P-0K, 90N-15P-30K, and diagnostic (90N-15P-20K-15S-10Mg-2.5Zn-0.5B) that showed an increase in soil phosphorus contents with time (Table 4.5).

Maize varieties planted on the Ferralsol significantly ( $P < 0.05$ ) affected the soil available phosphorus concentration over time. Plots planted with maize variety SR21 plots gave the highest value of soil available phosphorus concentration and significantly ( $P < 0.05$ ) increased soil available phosphorus by 18, 57 and 49 % over those of Komsaya (Table 4.5). The soil available phosphorus concentration in general decreased with time for these varieties throughout the growing season.

The combined effect of mineral fertilizer and maize variety significantly affected soil available phosphorus throughout the crop cycle (Appendix 4). Plots planted with SR21 and supplied with 90N-15P-0K, 90N-22.5P-0K and 90N-15P-30K gave the highest soil available phosphorus concentration at 45, 60 and 75 DAP.

Table 4.5 Effect of mineral fertilizer application rate and maize variety on soil available phosphorus on a Ferralsol

Treatment (kg ha <sup>-1</sup> )	Available phosphorus (mg kg <sup>-1</sup> )		
	45 DAP	60 DAP	75 DAP
<u>Fertilizer rate</u>			
Control	3.07	2.88	3.59
90N-0P-0K	3.81	3.15	3.30
90N-7.5P-0K	14.12	8.46	5.29
90N-15P-0K	22.48	8.89	8.46
90N-22.5P-0K	22.31	20.00	15.64
90N-15P-10K	19.63	11.86	9.69
90N-15P-20K	18.36	7.19	7.07
90N-15P-30K	24.39	13.63	15.28
90N-15P-20K-15S10Mg-2.5Zn-0.5B	14.38	9.86	10.08
LSD (0.05)	0.69	0.47	0.62
Fpr	< 0.001**	< 0.001**	< 0.001**
<u>Variety</u>			
Komsaya	14.50	7.44	7.00
SR21	17.18	11.66	10.42

Days

LSD (0.05)	0.33	0.22	0.29
Fpr	< 0.001**	< 0.001**	< 0.001**

Mineral fertilizer x Variety

LSD (0.05)	0.98	0.66	0.88
Fpr	< 0.001**	< 0.001**	< 0.001**
CV (%)	3.7	4.2	6.1

---

DAP = after planting; \*\* = significant at  $P < 0.01$

### 4.2.3 Soil exchangeable potassium

#### 4.2.3.1 Exchangeable potassium changes on a Luvisol

The results of Luvisol soil exchangeable potassium dynamics with time are shown in Table 4.6.

The application of mineral fertilizer significantly ( $P < 0.05$ ) increased exchangeable potassium contents in the soil with time, during the study period. A constant increase of soil exchangeable potassium concentration was observed in all the plots throughout the season except in the plot treated with 90N-7.5P-0K where the potassium contents decreased at 60 DAP and later increased at 75 DAP (Table 4.6).

The effects of the maize varieties on the soil exchangeable potassium contents with time was significant ( $P < 0.05$ ) at 60 DAP and 75 DAP. Nonetheless, the plots planted with the variety Komsaya gave the highest value which was significantly ( $P < 0.05$ ) different from exchangeable K contents in plots planted with SR21 as shown in (Table 4.6).

The interaction between mineral fertilizer and maize variety significantly affected soil exchangeable K (Appendix 5). Plots planted with SR21 and treated with 90N7.5P-0K,

and 90N-0P-0K gave the highest soil exchangeable K concentration of 0.207 and 0.200 (Cmol<sub>c</sub> kg<sup>-1</sup> soil) at 45 and 75 DAP. Those planted with Komsaya and amended with 90N-7.5P-0K recorded the highest soil exchangeable K at 60 DAP.

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Table 4.6 Effect of mineral fertilizer application rate and maize variety on soil exchangeable potassium on a Luvisol

Treatment (kg ha <sup>-1</sup> )	Exchangeable potassium (Cmol <sub>c</sub> kg <sup>-1</sup> )		
	45 DAP	60 DAP	75 DAP
<u>Fertilizer rate</u>			
Control	0.142	0.150	0.162
90N-0P-0K	0.135	0.151	0.173
90N-7.5P-0K	0.177	0.153	0.154
90N-15P-0K	0.135	0.149	0.150
90N-22.5P-0K	0.125	0.139	0.144
90N-15P-10K	0.101	0.133	0.142
90N-15P-20K	0.138	0.143	0.161
90N-15P-30K	0.125	0.144	0.160
90N-15P-20K-15S10Mg-2.5Zn-0.5B	0.121	0.138	0.153
LSD (0.05)	0.009	0.003	0.004
Fpr	< 0.001**	< 0.001**	< 0.001**
<u>Variety</u>			
Komsaya	0.133	0.161	0.162
Days			

SR21	0.133	0.128	0.149
LSD (0.05)	0.007	0.002	0.011
Fpr	NS	< 0.001**	0.03*

Mineral fertilizer x Variety

LSD (0.05)	0.012	0.004	0.008
Fpr	< 0.001**	< 0.001**	< 0.001**
CV (%)	5.6	1.6	2.4

---

DAP = after planting; NS = not significant at  $P < 0.05$ ; \*\* = significant at  $P < 0.01$

#### 4.2.3.2 Exchangeable potassium dynamics on a Ferralsol

Soil exchangeable potassium contents on the Ferralsol showed significant ( $P < 0.05$ ) differences as a result of mineral fertilizer application of varying rate (Table 4.7.)

In general, as shown in Table 4.7, soil exchangeable potassium contents continuously increased throughout the sampling periods in all the plots except for the one amended with 90N-7.5P-0K where soil potassium concentration was decreased at 75 DAP.

The results further showed that the use of the maize varieties did not significantly influence exchangeable potassium contents in the soil at 45 and 60 DAP. However, significantly higher exchangeable potassium was found in the plots planted with SR21 than those of the plots planted with Komsaya at 75 DAP. On the average, SR21 plots had higher soil exchangeable potassium contents by 22 % over those of Komsaya plots.

The combined effect of mineral fertilizer and maize variety significantly affected soil exchangeable K throughout the crop cycle (Appendix 6). Pots planted with SR21 and supplied with 90N-15P-30K, 90N-7.5P-0K and 0N-0P-0K (control) gave the highest

soil exchangeable K concentration of 0.187, 0.203 and 0.188  $\text{Cmol}_c \text{kg}^{-1}$  soil at 45, 60 and 75 DAP.

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Table 4.7 Effect of mineral fertilizer application rate and maize variety on soil exchangeable potassium on a Ferralsol

Treatment ( $\text{kg ha}^{-1}$ )	Exchangeable potassium ( $\text{Cmol}_c \text{kg}^{-1}$ )		
	45 DAP	60 DAP	75 DAP
<u>Fertilizer rate</u>			
Control	0.133	0.150	0.168
90N-0P-0K	0.101	0.117	0.145
90N-7.5P-0K	0.095	0.156	0.138
90N-15P-0K	0.090	0.127	0.134
90N-22.5P-0K	0.091	0.117	0.122
90N-15P-10K	0.088	0.126	0.126
90N-15P-20K	0.117	0.127	0.148
90N-15P-30K	0.166	0.147	0.148
90N-15P-20K-15S10Mg-2.5Zn-0.5B	0.106	0.115	0.146
LSD (0.05)	0.010	0.006	0.004

Days

Fpr	< 0.001**	< 0.001**	< 0.001**
<u>Variety</u>			
Komsaya	0.110	0.132	0.128
SR21	0.110	0.131	0.156
LSD (0.05)	0.005	0.003	0.002
Fpr	NS	NS	< 0.001**
<u>Mineral fertilizer x Variety</u>			
LSD (0.05)	0.014	0.008	0.006
Fpr	< 0.001**	< 0.001**	< 0.001**
CV (%)	7.4	3.8	2.6

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DAP = after planting; NS = not significant at  $P < 0.05$ ; \*\* = significant at  $P < 0.01$

#### 4.2.4 Soil pH

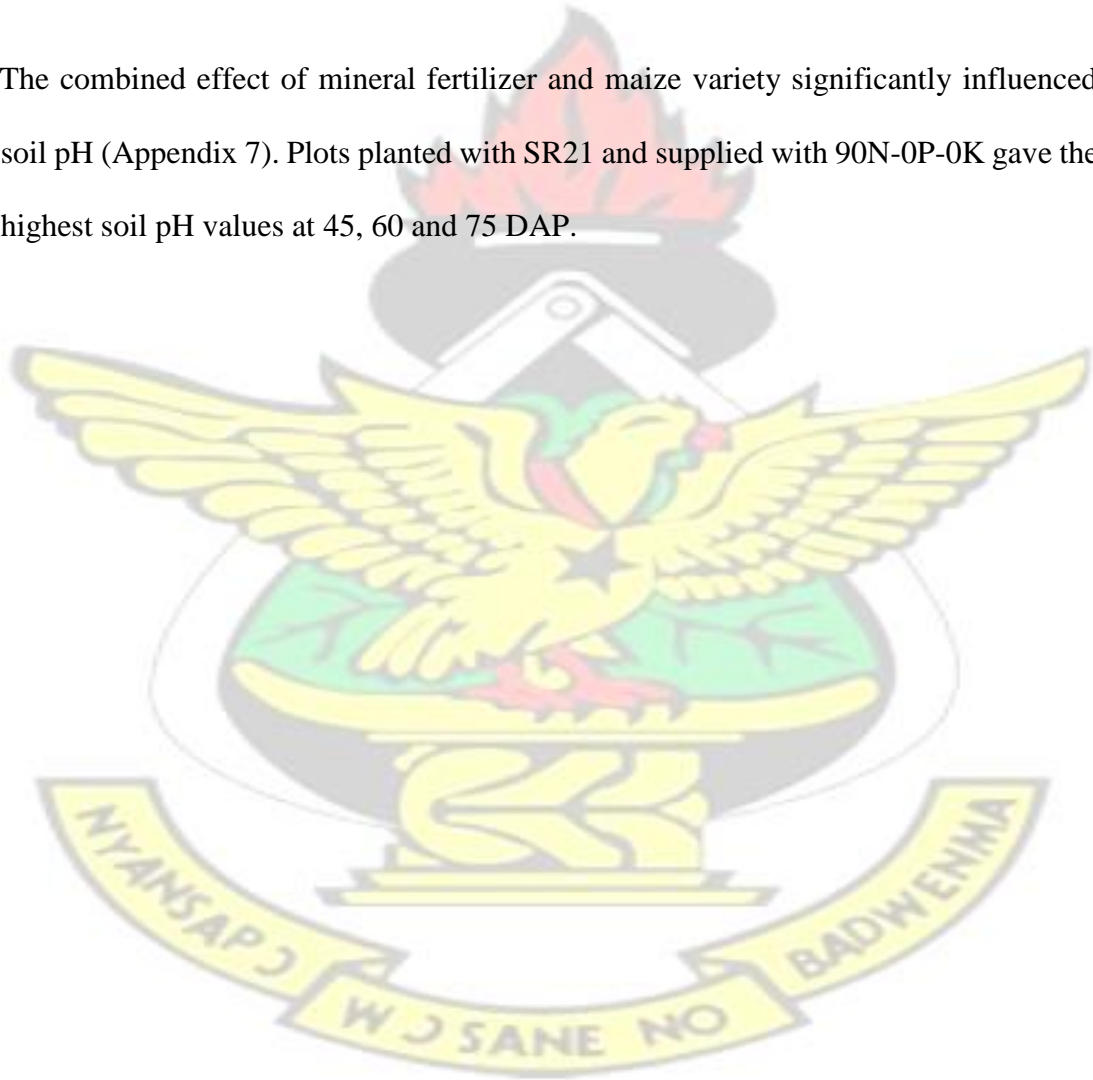
##### 4.2.4.1 Changes in soil pH on a Luvisol

The effects of mineral fertilizer application on soil pH over time for the Luvisol site are presented in Table 4.8.

The application of mineral fertilizer significantly ( $P < 0.05$ ) affected the soil pH with time. A continuous increase in pH value was observed from the first sampling period (45 DAP) to the last sampling period (75 DAP) in all the plots. Soil pH value was higher in plot amended with the mineral fertilizer rates of 90N-0P-0K and lower in the plot treated with 90N-22.5P-0K at the first two sampling periods. However, at 75 DAP, 90N-0P-0K recorded the highest pH value while the control recorded the lowest (Table 4.8).

The maize varieties also significantly ( $P < 0.05$ ) influenced the status on soil pH with time (Table 4.8). The soil pH values increased irrespective of the varieties throughout the season. Plots planted with SR21 gave the highest soil pH values during the three sampling periods and differed significantly from those of Komsaya. Though there was an increase in the pH values with time, the soil remains acidic, but could generally be said that it moved from low to medium in acidity.

The combined effect of mineral fertilizer and maize variety significantly influenced soil pH (Appendix 7). Plots planted with SR21 and supplied with 90N-0P-0K gave the highest soil pH values at 45, 60 and 75 DAP.



Days

Table 4.8 Effect of mineral fertilizer application rate and maize variety on soil pH on a Luvisol

Treatment (kg ha <sup>-1</sup> )	pH		
	45 DAP	60 DAP	75 DAP
<u>Mineral fertilizer</u>			
Control	5.28	5.36	5.47
90N-0P-0K	5.58	5.65	5.84
90N-7.5P-0K	5.42	5.58	5.72
90N-15P-0K	5.41	5.55	5.73
90N-22.5P-0K	5.27	5.35	5.62
90N-15P-10K	5.35	5.38	5.59
90N-15P-20K	5.37	5.42	5.65
90N-15P-30K	5.53	5.56	5.78
90N-15P-20K-15S10Mg-2.5Zn-0.5B	5.35	5.39	5.60
LSD (0.05)	0.02	0.02	0.02
Fpr	< 0.001**	< 0.001**	< 0.001**
<u>Variety</u>			
Komsaya	5.32	5.35	5.56
SR21	5.47	5.59	5.78
LSD (0.05)	0.01	0.01	0.01
Fpr	< 0.001**	< 0.001**	< 0.001**
<u>Mineral fertilizer x Variety</u>			
LSD (0.05)	0.02	0.03	0.02
Fpr	< 0.001**	< 0.001**	< 0.001**
CV (%)	0.3	0.3	0.3

---

DAP =Days after planting; \*\* = significant at  $P < 0.01$

#### 4.2.4.2 Soil pH dynamics on a Ferralsol

Table 4.9 presents the result of changes in soil pH on the Ferralsol with time. Soil pH was significantly ( $P < 0.05$ ) affected by mineral fertilizer application.

The soil pH increased throughout the growing season in all the plots. At 45 DAP, the control and the plot treated with 90N-0P-0K recorded the highest (4.82) and the lowest soil pH values (4.29) respectively. At 60 DAP, the control gave the highest (5.07) and the plot amended with 90N-7.5P-0K, the lowest value (4.54). At 75 DAP, the diagnostic plot (90N-15P-20K-15S-10Mg-2.5Zn-0.5B) and the plot amended with 90N-22.5P-0K recorded the highest (5.24) and the lowest (4.67) values respectively (Table 4.9). The diagnostic treatment was referring to a mineral fertilizer whose formulation encompass primary (N, P, K), secondary (S, Mg) and micronutrients (Zn, B).

The Table 4.9 further showed a significant effect of maize varieties on soil pH ( $P < 0.05$ ). In general, pH values increased with time except for plots planted with Komsaya that showed a slight decreased in pH value at 75 DAP. Higher pH values were found on in the plots cultivated with variety SR21 throughout the season than those planted with variety Komsaya (Table 4.9).

The interactive effect between mineral fertilizer and maize variety significantly affected soil pH (Appendix 8). Plots planted with SR21 and supplied with the control treatment gave the highest soil pH values of 4.88 and 5.11 at 45 and 60 while those treated with the diagnostic treatment gave higher soil pH value of 5.46 at 75 DAP.

Table 4.9 Effect of mineral fertilizer application rate and maize variety on soil pH on a Ferralsol

Treatment (kg ha <sup>-1</sup> )	pH		
	45 DAP	60 DAP	75 DAP
<u>Fertilizer rate</u>			
Control	4.82	5.07	5.22
90N-0P-0K	4.26	4.71	4.88
90N-7.5P-0K	4.33	4.54	4.70
90N-15P-0K	4.31	4.74	4.89
90N-22.5P-0K	4.29	4.61	4.67
90N-15P-10K	4.30	4.84	4.89
90N-15P-20K	4.41	4.82	5.04
90N-15P-30K	4.57	4.78	5.00
90N-15P-20K-15S10Mg-2.5Zn-0.5B	4.44	4.88	5.24
LSD (0.05)	0.01	0.02	0.02
Fpr	< 0.001**	< 0.001**	< 0.001**
<u>Variety</u>			
Komsaya	4.39	4.78	4.75
SR21	4.44	4.88	5.15
LSD (0.05)	0.01	0.01	0.01
Fpr	< 0.001**	< 0.001**	< 0.001**
<u>Mineral fertilizer x Variety</u>			
LSD (0.05)	0.02	0.03	0.02
Fpr	< 0.001**	< 0.001**	< 0.001**
CV (%)	0.3	0.3	0.3

---

DAP = Days after planting; NS = not significant at  $P < 0.05$ ; \* = significant at  $P < 0.05$ ; \*\* = significant at  $P < 0.01$

#### **4.2.5 Soil $\text{NH}_4^+$ - N, available P, exchangeable K and pH dynamics on a Luvisol and on a Ferralsol**

Soil type significantly ( $P < 0.05$ ) affected the patterns of soil ammonium - nitrogen, phosphorus, potassium and pH changes during the crop cycles (Figures 4.1 – 4.3).

On the Luvisol, soil nitrogen, phosphorus, potassium concentrations and pH value during the growing season were higher than their respective concentrations or values on the Ferralsol (Figures 4.1 – 4.3).

Soil nitrogen concentrations were increased in Luvisol by 5 and 55 % at 45 DAP and 60 DAP, respectively over those obtained from the Ferralsol. Soil phosphorus concentrations increased in Ferralsol by 18 % over those of the Luvisol at 45 DAP but the trend was reversed for the rest of the season on the Luvisol where increases in phosphorus concentrations of 13 and 14 % at 60 DAP and 75 DAP, respectively were recorded. Soil potassium concentrations in the Luvisol throughout the growing season were higher by 21, 10 and 10 % over those of the Ferralsol at the 45, 60 and 75 DAP sampling times respectively.

Changes in soil pH followed the same trend as the nutrients in the Luvisol. Soil pH increased by 22, 15 and 15 % over the corresponding values recorded for the Ferralsol. Though there was an increase in pH values on Luvisol, it remained low in acidity on Ferralsol except at the last sampling period where it moved from low to medium (Figure 4.3).

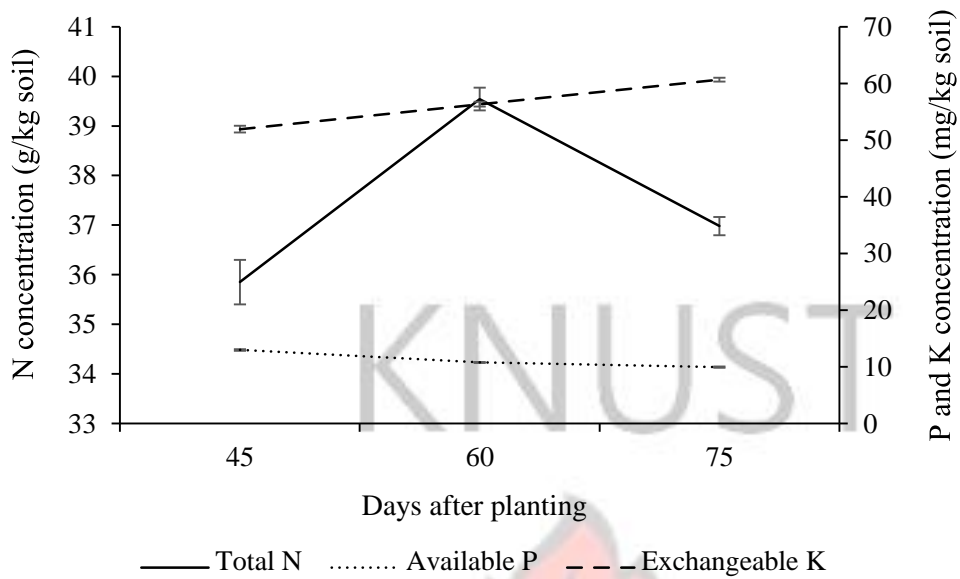


Figure 4. 1 Nitrogen, available P and exchangeable K dynamics over time on a Luvisol. Error bars indicate SED (0.05) for the various sampling stages.

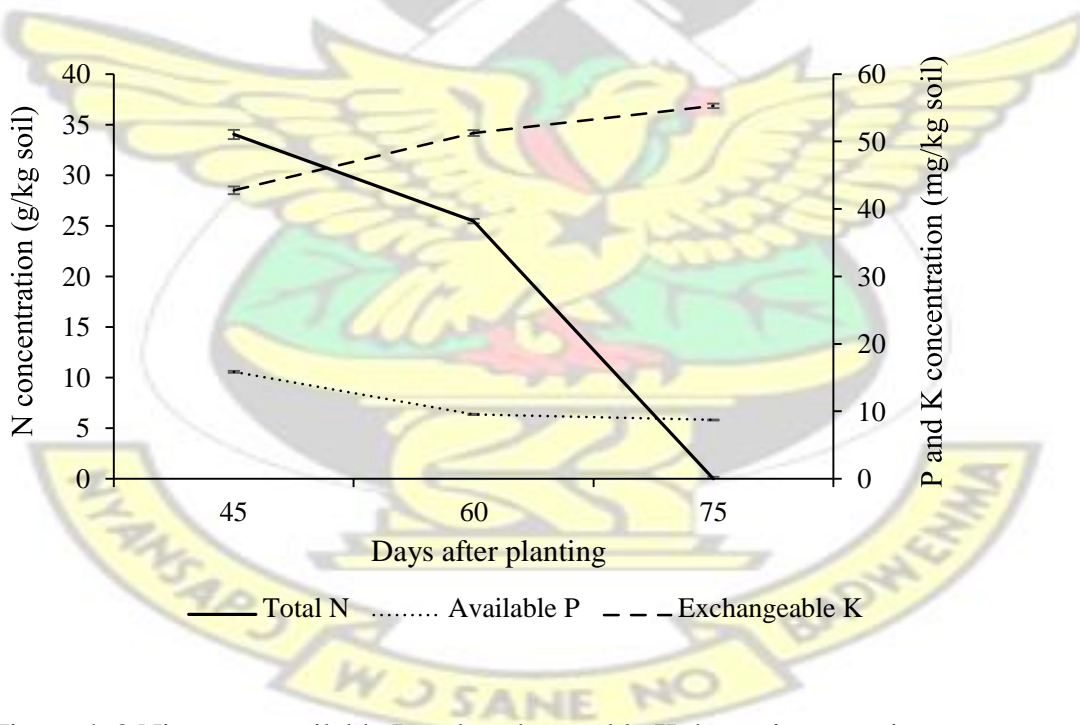


Figure 4. 2 Nitrogen, available P and exchangeable K dynamics over time on a Ferralsol. Error bars indicate SED (0.05) for the various sampling stages

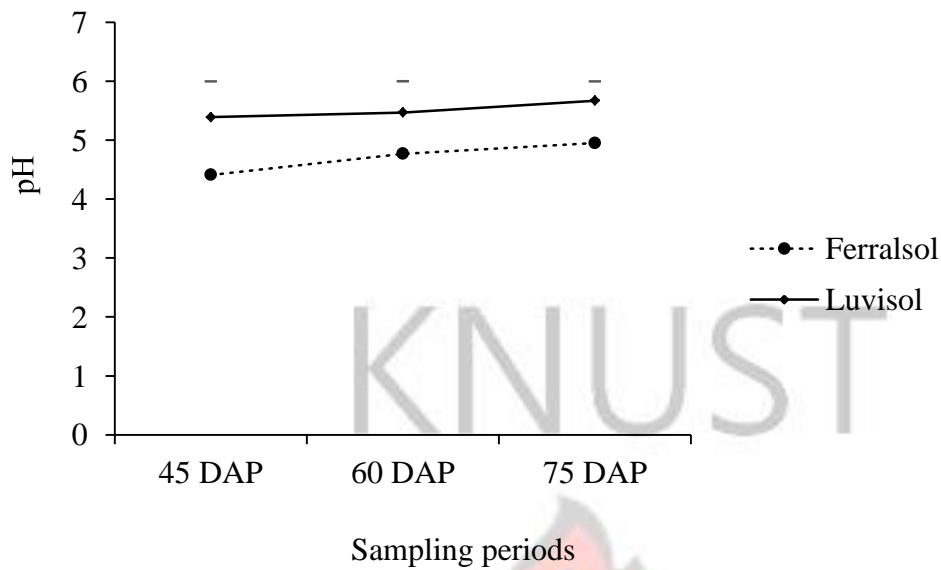


Figure 4.3 Changes in soil pH during the crop growth cycle. Error bars indicate the SED (0.05) for the various sampling stages

#### 4.3 Plant nutrient uptake at harvest

##### 4.3.1 Plant nitrogen uptake

##### 4.3.1.1 Nitrogen uptake on a Luvisol

Nitrogen uptake in maize plant at harvest as affected by mineral fertilizer application is illustrated in Table 4.10. The application of 90N-7.5P-0K resulted in the highest N uptake value at harvest but was not significantly ( $P < 0.05$ ) different from the rest of the treatments except that of the 90N-15P-10K and the control treatments.

Differences in N uptake of maize varieties are presented in Table 4.10. Maize varieties significantly ( $P < 0.05$ ) differed in N uptake. Variety SR21 recorded the higher value of nitrogen uptake; its N uptake was increased by 22 % over those of Komsaya.

#### **4.3.1.2 Nitrogen uptake of maize varieties grown on a Ferralsol**

Table 4.10 illustrates the effect of mineral fertilizer application on nitrogen uptake of maize varieties grown on a Ferralsol. Mineral fertilizer application significantly ( $P < 0.05$ ) affected nitrogen uptake by maize plant. The mineral fertilizer of 90N-22.5P0K treatment led to the highest value of nitrogen uptake and which was significantly ( $P < 0.05$ ) different from N uptake from the plots amended with 90N-0P-0K and the control gave the lowest N uptake.

Maize varieties did not show any significant ( $P > 0.05$ ) difference in nitrogen uptake (Table 4.10); nonetheless, maize variety SR21 gave N uptake value of  $2.9 \text{ kg ha}^{-1}$  higher than those of Komsaya.

#### **4.3.2 Plant phosphorus uptake**

##### **4.3.2.1 Phosphorus uptake on a Luvisol**

Phosphorus uptake as affected by mineral fertilizer application is shown in Table 4.10. Phosphorus uptake values at harvest ranged from  $2.96$  to  $9.42 \text{ kg ha}^{-1}$ . The NPK supplemented with micronutrients, supported the highest P uptake value. However, this was not statistically different from those of the other plots except the plots treated with 90N-15P-10K, 90N-0P-0K and the control (Table 4.10).

The differences in phosphorus uptake by the two varieties of maize are shown in Figure 4.8. Maize variety SR21 generally had higher phosphorus uptake of 9 % over those of Komsaya at harvest.

The statistics further showed a significant ( $P < 0.05$ ) interactive effect between mineral fertilizer rates and maize variety (Appendix 9). Plots planted with SR21 and amended to the diagnostic treatment gave phosphorus uptake values of  $13.69 \text{ kg ha}^{-1}$ .

#### **4.3.2.2 Phosphorus uptake on a Ferralsol**

Maize phosphorus uptake as influenced by mineral fertilizer application is illustrated in Table 4.10. The 90N-22.5P-0K treatment plots gave the highest value of phosphorus uptake at harvest while the control gave the lowest (Table 4.10).

Phosphorus uptake by maize was significantly ( $P < 0.05$ ) affected by maize varieties (Table 4.10). Variety SR21, phosphorus uptake gave values of 71 % higher than those of Komsaya at harvest.

#### **4.3.3 Plant potassium uptake**

##### **4.3.3.1 Potassium uptake on a Luvisol**

The effect of mineral fertilizer application on maize potassium uptake is presented in Table 4.10. At harvest, potassium uptake values ranged from 24.8 to 120.4 kg ha<sup>-1</sup>, the 90N-15P-30K treatment plots gave the highest and the control the lowest. The 90N-15P-30K treatment plots gave mean value that was similar to those from 90N15P-20K, 90N-0P-0K, 90N-7.5P-0K and 90N-15P-0K treatments plots but significantly different from those obtained from the remaining plots (Table 4.10).

Potassium uptake was significantly ( $P < 0.05$ ) affected by maize variety (Table 4.10). Maize variety SR21 gave the highest potassium uptake values and was significantly ( $P < 0.05$ ) different from those obtained for Komsaya.

##### **4.3.3.2 Potassium uptake in maize grown on a Ferralsol**

Table 4.10 illustrates the effect of mineral fertilizer on potassium uptake in maize plants. At harvest, potassium uptake in maize ranged between 16.9 and 80 kg ha<sup>-1</sup>. The highest value was obtained from 90N-15P-20K-15S-10Mg-2.5Zn-0.5B but this was not significantly different from those of the other plots in general except those from the 90N-15P-0K and control treatments.

Table 4.10 Effect of mineral fertilizer application rate and maize variety on stover nitrogen, phosphorus and potassium uptake at harvest

Treatment (kg ha <sup>-1</sup> )	Luvisol			Ferralsol		
	N uptake (kg ha <sup>-1</sup> )	P uptake (kg ha <sup>-1</sup> )	K uptake (kg ha <sup>-1</sup> )	N uptake (kg ha <sup>-1</sup> )	P uptake (kg ha <sup>-1</sup> )	K uptake (kg ha <sup>-1</sup> )
<u>Fertilizer rate</u>						
Control	12.2	2.96	24.8	6.8	0.4	16.9
90N-0P-0K	48.8	4.75	92.6	19.7	1.11	50.1
90N-7.5P-0K	60.7	7.87	92.3	38.8	1.55	59.8
90N-15P-0K	52.1	7.97	91.9	29.7	1.94	45.5
90N-22.5P-0K	48.8	8.49	77.4	45.4	3.40	75.5
90N-15P-10K	36.5	5.68	67.3	35.1	2.67	60.7
90N-15P-20K	46.0	9.13	119.7	35.9	1.93	70.2
90N-15P-30K	59.2	8.74	120.4	37.9	1.88	67.6
90N-15P-20K-15S-10Mg2.5Zn-0.5B	58.0	9.42	84.7	30.3	1.68	80.0
LSD (0.05)	13.26	2.74	28.81	16.02	1.13	31.69
Fpr	< 0.001**	< 0.001**	< 0.001**	0.001*	< 0.001**	0.01*
<u>Maize variety</u>						
Komsaya	42.3	6.91	78.3	29.6	1.36	52.9
SR21	51.6	7.53	93.1	32.5	2.33	64.1
LSD (0.05)	7.66	1.29	13.58	7.55	0.53	14.94
Fpr	0.02*	NS	0.03*	NS	< 0.001**	NS

CV (%)	29.5	32.2	28.7	44	52.4	46.2
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NS = non - significant at  $P < 0.05$ ; \* = significant at  $P < 0.05$ ; \*\* = significant at  $P < 0.01$

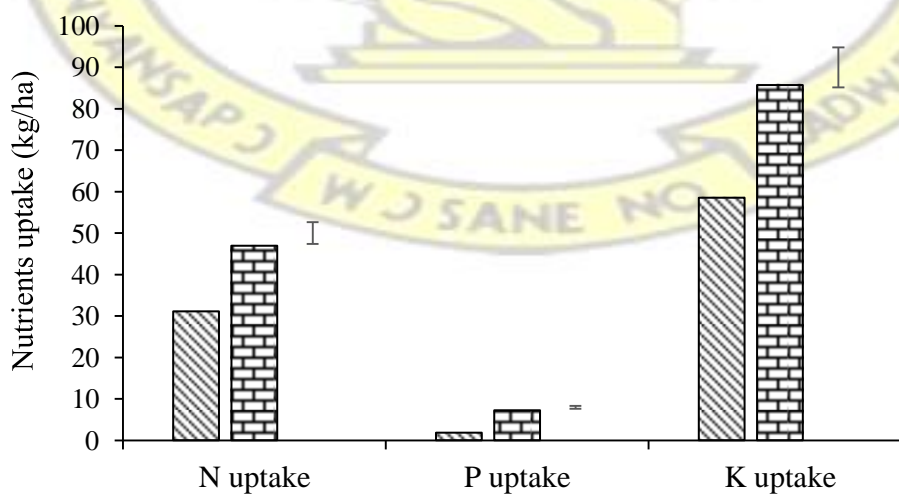
Differences in potassium uptake by maize varieties are presented in Table 4.10. At harvest, the varieties did not show any significant differences in potassium uptake; nonetheless, maize variety SR21 had accumulated potassium by  $11.2 \text{ kg ha}^{-1}$  higher than that of Komsaya.

#### 4.3.4 Effect of soil type on maize plant nitrogen, phosphorus and potassium uptake

Maize nitrogen, phosphorus and potassium uptake were significantly ( $P < 0.05$ ) affected by soil type (Figure 4.4). Maize varieties grown in the Luvisol generally had higher nutrient accumulation than on the Ferralsol. At harvest, N uptake for the Luvisol 51 % higher than the value obtained from the Ferralsol.

Similarly, maize grown in the Luvisol had phosphorus uptake values of 292 % higher than those obtained from the Ferralsol at harvest.

There was a significant ( $P < 0.05$ ) difference in potassium uptake between the two soil types. Luvisol increased potassium uptake by 47 % over Ferralsol.



■ Ferralsol ■ Luvisol

Figure 4.4 Maize nitrogen, phosphorus and potassium uptake as affected by soil type.

Error bars indicate SED (0.05).

#### 4.4 Yield data

##### 4.4.1 Grain and stover yield

###### 4.4.1.1 Grain yield on a Luvisol

The application of mineral fertilizer significantly ( $P < 0.05$ ) increased the yield of maize. The yield ranges from 395 kg ha<sup>-1</sup> to 5437 kg ha<sup>-1</sup> (Table 4.11). The plot amended with the mineral fertilizer at the rate of 90N-15P-30K gave the highest grain yield corresponding to over 1276 % in excess grain yield from the control plots.

The percentage increase in grain yield due to the application of mineral fertilizer ranged from 690 to 1276 % representing gains made from the application of 90N15P-30K and 90N-15P-10K respectively. The NPK mineral fertilizer supplemented with sulphur, magnesium, zinc and boron (90N-15P-20K-15S-10Mg-2.5Zn-0.5B) increased grain yield by 7 % over that of the 90N-15P-20K (without the micronutrients) treatment.

There was no significant difference ( $P > 0.05$ ) in grain yield between the two varieties of maize. However grain yield of Komsaya was generally higher than that SR21 (Table 4.11).

###### 4.4.1.2 Stover yield on a Luvisol

The maize stover yield as affected by the application of mineral fertilizer is presented in Table 4.11. The highest yield (8193 kg ha<sup>-1</sup>) was obtained from the 90N-15P-30K treatment plots and the lowest yield of 1822 kg ha<sup>-1</sup> was obtained from the control

plots. The percentage increase in stover yield due to the application of mineral fertilizer ranged from 201 to 349 %.

Table 4.11 Effect of mineral fertilizer application rate and maize variety on grain and stover yield on a Luvisol

Treatment (kg ha <sup>-1</sup> )	Luvisol			
	Grain yield (kg ha <sup>-1</sup> )	Increase over control (%)	Stover yield (kg ha <sup>-1</sup> )	Increase over control (%)
<u>Fertilizer rate</u>				
Control	395	-	1822	-
90N-0P-0K	4391	1011.64	6311	246.38
90N-7.5P-0K	4855	1129.11	6609	262.73
90N-15P-0K	4591	1062.27	6563	260.20
90N-22.5P-0K	4141	948.35	6410	251.81
90N-15P-10K	3119	689.62	5477	200.60
90N-15P-20K	4696	1088.86	7507	312.02
90N-15P-30K	5437	1276.46	8193	349.67
90N-15P-20K- 15S-10Mg2.5Zn- 0.5B	5029	1173.16	7269	298.96
LSD (0.05)	1559.9		2065.1	
Fpr	< 0.001**		< 0.001**	
<u>Maize variety</u>				
Komsaya	4275		6084	
SR21	3871		6396	
LSD (0.05)	735.3		973.5	
Fpr	NS		NS	

#### Mineral fertilizer x Maize variety

LSD (0.05)	2206	2920.5
Fpr	NS	NS
CV (%)	32.6	28.2

NS = not significant at  $P < 0.05$ ; \*\* = significant at  $P < 0.01$

The highest gain was recorded for 90N-15P-30K treatment but this was not significantly different from those of the remaining plots except that of plot treated with 90N-15P-10K treatment plots.

In terms of stover yield, the varieties did not show significant difference ( $P > 0.05$ ) even though maize variety SR21 generally gave a higher stover yield than Komsaya.

#### **4.4.1.3 Grain yield of maize grown on a Ferralsol**

The yield of maize was significantly ( $P < 0.05$ ) affected by the application of mineral fertilizer. The maize yield ranged from 121 to 3899 kg ha<sup>-1</sup> (Table 4.12). The plot amended with the mineral fertilizer at the rate of 90N-15P-20K-15S-10Mg-2.5Zn0.5B gave the highest grain yield representing 3122 % in excess of that of the control plots. This was significantly different from mean values from all the plots amended with mineral fertilizer except that of 90N-15P-20K treatment plots.

The percentage increase in grain yield over the control ranged from 606 to 3122 % representing percentage increases from 90N-15P-20K-15S-10Mg-2.5Zn-0.5B and 90N-0P-0K treatments respectively.

The NPK mineral fertilizer supplemented with sulphur, magnesium, zinc and boron (90N-15P-20K-15S-10Mg-2.5Zn-0.5B) significantly ( $P < 0.05$ ) increased grain yield by 1173 %, however the difference between the same formulation (90N-15P-20K) without the micronutrients was not significant at  $P < 0.05$ .

There was no significant ( $P > 0.05$ ) difference in grain yield between the two varieties of maize. Nonetheless the highest grain yield was associated with Komsaya which was  $538 \text{ kg ha}^{-1}$  higher than that of SR21.

#### **4.4.1.4 Maize stover yield on a Ferralsol**

The stover yield of maize as affected by fertilizer formulation and the maize variety is illustrated in Table 4.12. The highest maize stover yield value was obtained from 90N-15P-30K treatment plots and the lowest yield was from the control plots.

The percentage increase in stover yield due to the application of mineral fertilizer ranged from 146 to 349 % representing gains from 90N-0P-30K and 90N-0P-0K respectively. However the highest stover yield was not significantly different from the other rates except that from the plot amended with 90N-0P-0K.

In general, the varieties did not show significant ( $P > 0.05$ ) differences in stover yield even though SR21 gave maize stover  $312 \text{ kg ha}^{-1}$  higher than that of Komsaya.

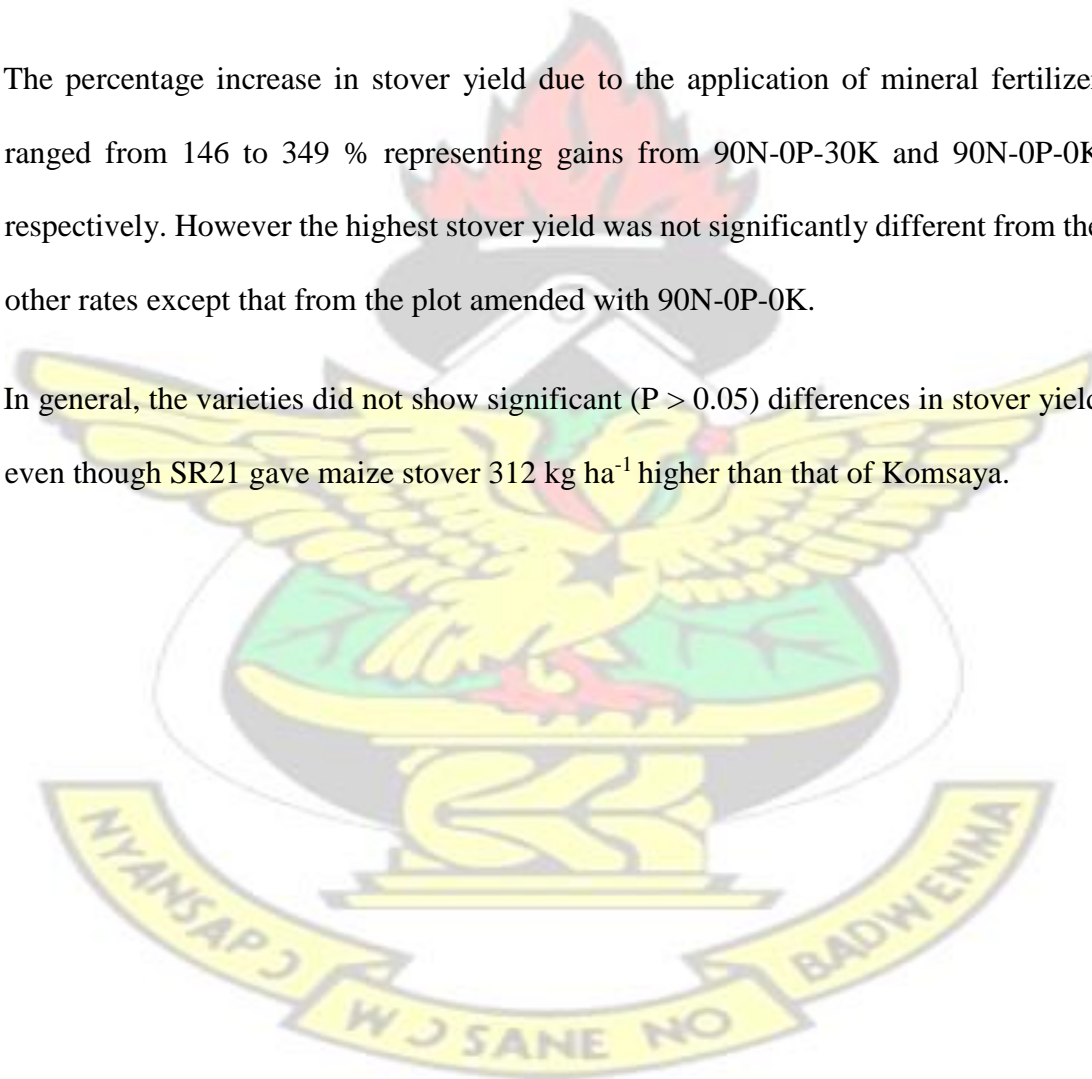


Table 4.12 Effect of mineral fertilizer application rate and maize variety on grain and stover yield on a Ferralsol

Treatment (kg ha <sup>-1</sup> )	Ferralsol			
	Grain yield (kg ha <sup>-1</sup> )	Increase over control (%)	Stover yield (kg ha <sup>-1</sup> )	Increase over control (%)
<u>Fertilizer rate</u>				
Control	121	-	1418	-
90N-0P-0K	854	605.78	3498	146.69
90N-7.5P-0K	1744	1341.32	4621	225.88
90N-15P-0K	1630	1247.11	3939	177.79
90N-22.5P-0K	2464	1936.36	5869	313.89
90N-15P-10K	2097	1633.06	4415	211.35
90N-15P-20K	2839	2246.28	5632	297.18
90N-15P-30K	1545	1176.86	5299	273.70
90N-15P-20K-15S-10Mg-2.5Zn-0.5B	3899	3122.31	5827	310.93
LSD (0.05)	1207		2301.7	
Fpr	< 0.001**		0.008*	
<u>Maize variety</u>				
Komsaya	2179		4102	
SR21	1641		4902	
LSD (0.05)	569		1085.0	
Fpr	NS		NS	

#### Mineral fertilizer x Maize variety

LSD (0.05)	1707	3255.1
Fpr	NS	NS
CV (%)	53.9	46.8

NS = not significant at  $P < 0.05$ ; \* = significant at  $P < 0.05$ ; \*\* = significant at  $P < 0.01$

#### **4.4.1.5 Effect of soil type on maize grain and stover yield**

Maize grain and stover yield as affected by soil type is illustrated in Figure 4.5. Soil type significantly ( $P < 0.05$ ) influenced grain and stover yield. On the average, grain and stover yield were 113 and 39 % respectively higher than the corresponding yield on the Ferralsol.

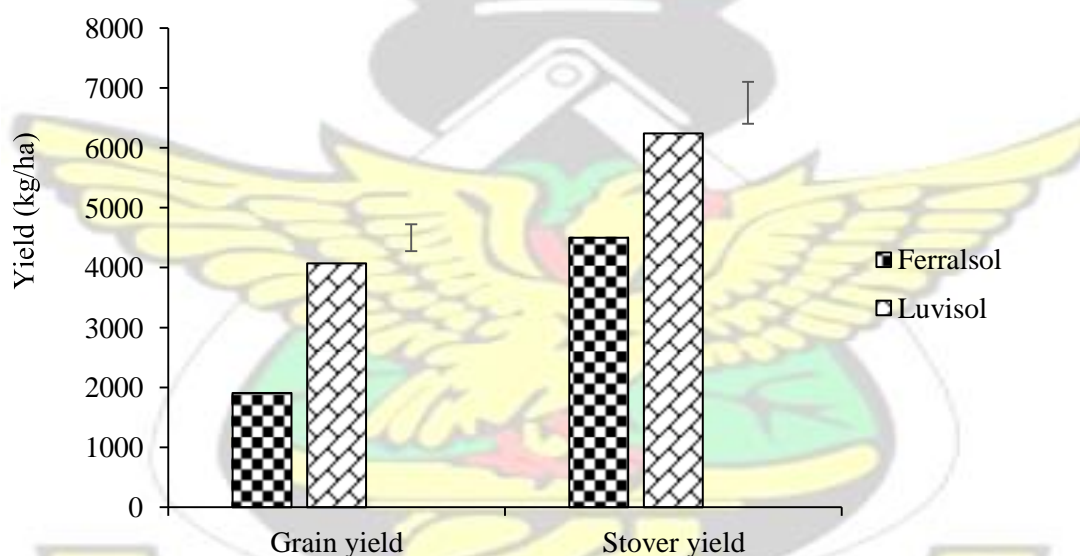


Figure 4. 5 Effect of soil type on maize grain and stover yield. Error bars represent SED (0.05)

#### **4.4.1.6 Effect of soil type and maize varieties on grain yield**

Figure 4.6 presents the mean grain yield of maize as influenced by variety and soil type. Maize varieties did vary significantly ( $P > 0.05$ ) in grain yield when grown on the two soils. Nevertheless, Komsaya in general gave the highest grain yield on both

soil.

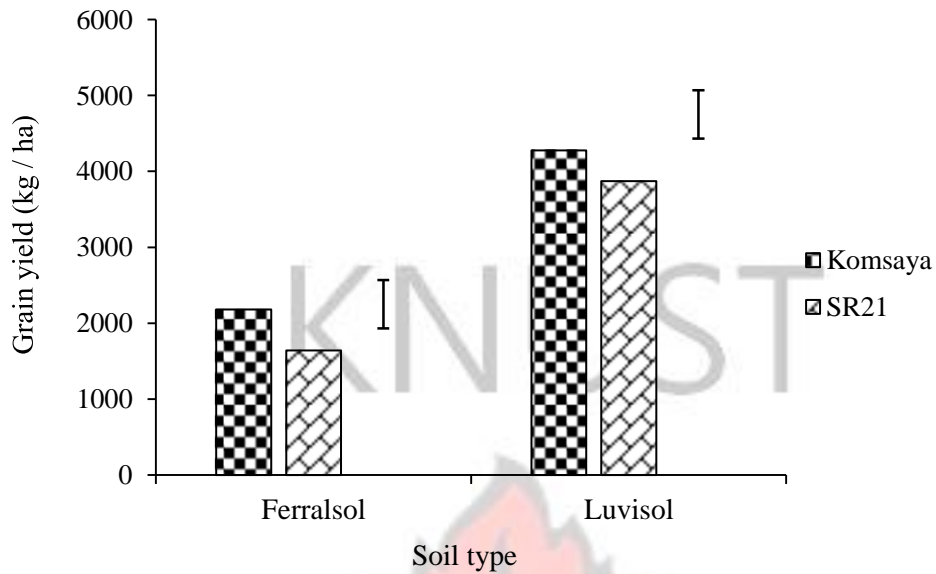


Figure 4. 6 Grain yield of two maize varieties in response to mineral fertilizer application on two soil types. Error bars represent the SED (0.05)

#### 4.4.2 Harvest index

The results of harvest index (HI) on Luvisol and Ferralsol are presented in Table 4.13. The harvest index was significantly ( $P < 0.05$ ) affected by the application of mineral fertilizer. It ranged from 37.84 to 48.85 % on Luvisol representing values obtained for the control and 90N-0P-0K treatments plots, respectively. The HI of variety was significantly ( $P < 0.05$ ) increased when grown on the Luvisol with Komsaya variety giving higher HI values than that of SR21 (Table 4.13).

13 Effect of mineral fertilizer application rate and maize variety on harvest index on a Luvisol and a Ferralsol

Treatment (kg ha <sup>-1</sup> )	Harvest index (%)	
	Luvisol	Ferralsol
<u>Fertilizer rate</u>		
Control	37.84	32.37
90N-0P-0K	48.85	47.61
90N-7.5P-0K	44.85	38.46
90N-15P-0K	43.03	39.19
90N-22.5P-0K	44.48	35.45
90N-15P-10K	43.79	42.59
90N-15P-20K	46.10	38.95
90N-15P-30K	45.72	40.71
90N-15P-20K-15S-10Mg-2.5Zn-0.5B	43.48	32.67
LSD (0.05)	5.38	6.73
Fpr	0.029*	0.001**
<u>Variety</u>		
Komsaya	48.59	40.83
SR21	39.99	36.50
LSD (0.05)	2.537	3.172
Fpr	< 0.001**	0.009*
<u>Mineral fertilizer x Variety</u>		
LSD (0.05)	7.611	9.517
Fpr	NS	0.019*

Table 4.

CV (%)	10.4	14.8
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NS = not significant at  $P < 0.05$ ; \* = significant at  $P < 0.05$ ; \*\* = significant at  $P < 0.01$

On the Ferralsol, HI was also significantly ( $P < 0.05$ ) affected by mineral fertilizer rates as shown in Table 4.13. The control and the 90N-0P-0K treatments gave HI values 32.37 and 47.61 %, respectively. The highest harvest index was obtained from 90N-0P-0K treatment but this was not significantly different from that of 90N-15P10K but different from those of all the other treatments. The control treatment gave the lowest HI but this was not significantly different from HI obtained from 90N7.5P-0K, 90N-22.5P-0K, 90N-15P-30K and 90N-15P-20K-10Mg-2.5Zn-0.5B. The varieties also significantly ( $P < 0.05$ ) varied in HI. The highest HI value was obtained for Komsaya variety and was 4.33 % higher than that of SR21 (Table 4.13).

Plots planted with variety Komsaya and amended to the control and the 90N-0P-0K gave lower and higher values of HI of 29 and 58.02 % respectively (Appendix 10), while those planted with SR21 gave lowest and highest values of HI as 33.21 and 38.97 % which were obtained from the diagnostic and the 90N-15P-0K treatments plots, respectively. No significant ( $P > 0.05$ ) interactive effect between the mineral fertilizer and maize variety on HI was observed on the Luvisol.

#### **4.4.3 Grain nitrogen and phosphorus uptake**

##### **4.4.3.1 Grain nitrogen and phosphorus uptake on Luvisol**

Grain N and P uptake as influenced by mineral fertilizer amendments and different maize varieties are presented in Table 4.14.

The use of mineral fertilizer significantly ( $P < 0.05$ ) increased grain N and P uptake (Table 4.14). N uptake values ranged from 6.0 to 83.1 kg ha<sup>-1</sup>. The highest N uptake

was obtained from the 90N-15P-30K treatment which was significantly different from those of the control and 90N-15P-10K treatments (Table 4.14).

14 Effect of mineral fertilizer application rate and maize variety on grain nitrogen and phosphorus uptake on a Luvisol

Treatment (kg ha <sup>-1</sup> )	Luvisol			
	N uptake (kg ha <sup>-1</sup> )	Increase over control (%)	P uptake (kg ha <sup>-1</sup> )	Increase over control (%)
<u>Fertilizer rate</u>				
Control	6.0	-	1.28	-
90N-0P-0K	67.8	1030.00	12.27	858.59
90N-7.5P-0K	69.4	1056.67	17.61	1275.78
90N-15P-0K	69.2	1053.33	18.36	1334.38
90N-22.5P-0K	61.1	918.33	18.41	1338.28
90N-15P-10K	47.0	683.33	14.09	1000.78
90N-15P-20K	65.2	986.67	16.94	1223.44
90N-15P-30K	83.1	1285.00	23.03	1699.22
90N-15P-20K15S-10Mg-2.5Zn0.5B	69.3	1055.00	17.86	1295.31
LSD (0.05)	22.79		6.212	
Fpr	< 0.001**		< 0.001**	
<u>Maize variety</u>				
Komsaya	83.1		23.03	
SR21	69.3		17.86	
LSD (0.05)	10.75		2.928	
Fpr	NS		NS	

Table 4.

Mineral fertilizer x Maize variety

LSD (0.05)	32.24	8.785
Fpr	NS	NS
CV (%)	32.5	34.1

NS = not significant at  $P < 0.05$ ; \*\* = significant at  $P < 0.01$

The highest P uptake was obtained from the 90N-15P-30K treatment and the lowest was obtained from the control treatment. Statistically, the values of P uptake in all the treatments were similar except the plots amended with 90N-0P-0K, 90N-15P10K and the control which were significantly lower than those from the other treatments.

Though the different maize varieties did not show a significant effect on grain N and P uptake ( $P > 0.05$ ), Komsaya generally had values that were 13.8 kg N ha<sup>-1</sup> and 5.17 kg P ha<sup>-1</sup> higher than those recorded for SR21.

#### 4.4.3.2 Grain N and P uptake on Ferralsol

Table 4.15 presents the effect of mineral fertilizer application and maize variety on maize grain N and P uptake from the Ferralsol.

Mineral fertilizer significantly ( $P < 0.05$ ) increased grain N and P uptake on the Ferralsol. The N uptake ranged from 2.0 to 62.1 kg ha<sup>-1</sup> while the P uptake ranged from 0.33 kg ha<sup>-1</sup> to 10.17 kg ha<sup>-1</sup> (Table 4.15). Maize plants supplied with the mineral fertilizer 90N-15P-20K-15S-10Mg-2.5Zn-0.5B gave the highest N and P uptake values relative to that of the control. The NPK mineral fertilizer supplemented with sulphur, magnesium, zinc and boron (90N-15P-20K-15S-10Mg-2.5Zn-0.5B) gave the highest grain N and P uptake values but these values were not significantly different from those of 90N-15P-20K treatment.

There was no significant ( $P > 0.05$ ) difference in grain N and P uptake between the two varieties of maize. However the higher grain N and P uptake values were obtained for Komsaya.

15 Effect of mineral fertilizer application rate and maize variety on grain nitrogen and phosphorus uptake on a Ferralsol

Treatment (kg ha <sup>-1</sup> )	Ferralsol			
	N uptake (kg ha <sup>-1</sup> )	Increase over control (%)	P uptake (kg ha <sup>-1</sup> )	Increase over control (%)
<u>Fertilizer rate</u>				
Control				
	2.0	-	0.33	-
90N-0P-0K	13.7	585	2.12	542.42
90N-7.5P-0K	26.4	1220	4.50	1263.63
90N-15P-0K	24.4	1120	4.26	1190.90
90N-22.5P-0K	39.5	1875	7.17	2072.72
90N-15P-10K	33.9	1595	5.95	1703.03
90N-15P-20K	45.9	2195	7.57	2193.93
90N-15P-30K	24.8	1140	4.28	1196.97
90N-15P-20K- 15S-10Mg2.5Zn- 0.5B	62.1	3005	10.17	2981.81
LSD (0.05)	19		3.488	
Fpr	< 0.001**		< 0.001**	
<u>Maize variety</u>				
Komsaya	34.7		5.40	
SR21	25.9		4.90	

Table 4.

LSD (0.05)	8.96	1.644
Fpr	NS	NS
<u>Mineral fertilizer x maize variety</u>		
LSD (0.05)	26.87	4.932
Fpr	NS	NS
CV (%)	53.5	57.7

NS = not significant at  $P < 0.05$ ; \*\* = significant at  $P < 0.01$

#### 4.4.3.3. Effect of soil type on maize grain nitrogen and phosphorus uptake

Soil type greatly ( $P < 0.05$ ) affected maize grain N and P uptake as illustrated in Figure 4.7. Maize N and P uptake values were high on the Luvisol by 97 and 202 % respectively over their respective values on the Ferralsol.

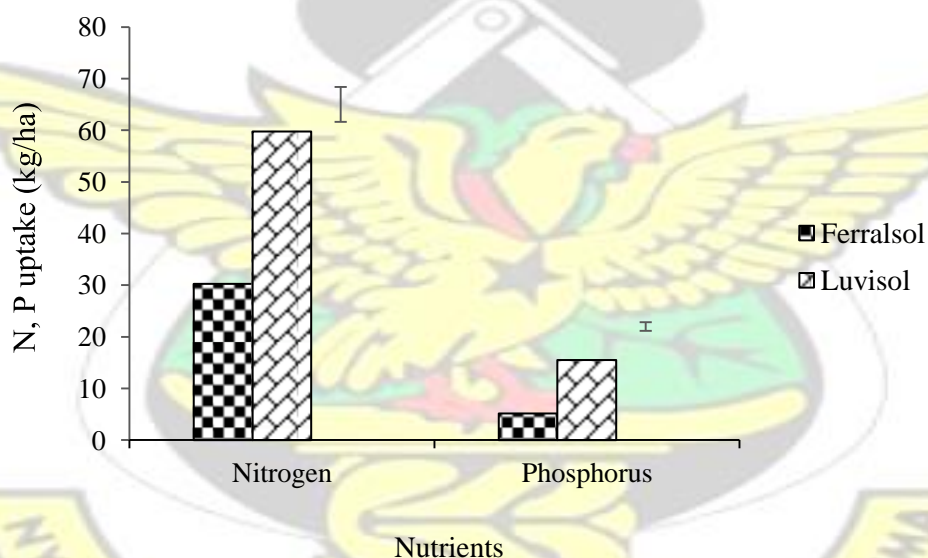


Figure 4. 7 Grain N and P uptake as affected by the type of soil. Error bars represent SED (0.05)

#### 4.4.4 Value cost ratio

The economic analysis for maize grain on Luvisol indicates that all the mineral fertilizer amendments were profitable ( $VCR > 2$ ) (Table 4.16). While the VCR of Komsaya variety ranged from 2.6 to 8.0 that of SR21 ranged from 2.9 to 4.6. The rates

of mineral fertilizer that gave the highest VCR were 90N-0P-0K and 90N-7.5P0K treatments for Komsaya variety while the rates of 90N-15P-20K and 90N-0P-0K treatments gave the highest VCR for SR21 variety.

On the Ferralsol, the VCR values ranged from 0.5 to 3.5 for Komsaya variety and from 0.7 to 2.2 for SR21 variety. The rate of mineral fertilizer that gave profitable benefit for planting Komsaya was 90N-15P-20K-15S-10Mg-2.5Zn-0.5B. For SR21,



the best fertilizer treatment was 90N-15P-20K while the rest of the treatments were not profitable (Table 4.17).

Table 4.16 Economic viability of maize varieties cultivated under varied fertilizer regimes on a Luvisol

Maize variety	Mineral fertilizer rate (kg ha <sup>-1</sup> )	Total revenue (F CFA)	Net return (F CFA)	Fertilizer cost (F CFA)	VCR
<b>Komsaya</b>					
	90N-0P-0K	787950	721200	90000	8.0
	90N-7.5P-0K	876900	810150	107202	7.6
	90N-15P-0K	721950	655200	124404	5.3
	90N-22.5P-0K	643350	576600	141605	4.1
	90N-15P-10K	410400	343650	132628	2.6
	90N-15P-20K	539850	473100	140851	3.4
	90N-15P-30K	919500	852750	149075	5.7
	90N-15P-20K- 15S10Mg-2.5Zn-0.5B	804000	737250	190688	3.9
<b>SR21</b>					
	90N-0P-0K	423600	382200	90000	4.2
	90N-7.5P-0K	463800	422400	107202	3.9
	90N-15P-0K	524280	482880	124404	3.9
	90N-22.5P-0K	479040	437640	141605	3.1
	90N-15P-10K	420240	378840	132628	2.9
	90N-15P-20K	695280	653880	140851	4.6
	90N-15P-30K	569280	527880	149075	3.5

90N-15P-20K- 15S10Mg-2.5Zn-0.5B	563760	522360	190688	2.7
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Table 4.17 Economic viability of maize varieties cultivated under varied fertilizer regimes on a Ferralsol

Variety	Mineral fertilizer	Total Net Fertilizer (F CFA)	VCR rate (kg ha <sup>-1</sup> ) (F CFA)	revenue (F CFA)	return cost
<b>Komsaya</b>					
	90N-0P-0K	65100	46500	90000	0.5
	90N-7.5P-0K	312300	293700	107202	2.7
	90N-15P-0K	282000	263400	124404	2.1
	90N-22.5P-0K	475650	457050	141605	3.2
	90N-15P-10K	336300	317700	132628	2.4
	90N-15P-20K	441150	422550	140851	3.0
	90N-15P-30K	322200	303600	149075	2.0
	90N-15P-20K-15S- 10Mg-2.5Zn-0.5B	688650	670050	190688	3.5
<b>SR21</b>					
	90N-0P-0K	152880	138600	90000	1.5
	90N-7.5P-0K	168600	154320	107202	1.4
	90N-15P-0K	165600	151320	124404	1.2
	90N-22.5P-0K	210720	196440	141605	1.4
	90N-15P-10K	234360	220080	132628	1.7
	90N-15P-20K	328320	314040	140851	2.2
	90N-15P-30K	113160	98880	149075	0.7

## CHAPTER FIVE

### 5.0 DISCUSSION

#### 5.1 Effect of mineral fertilizer and soil type on soil nutrient dynamics

##### 5.1.1 Soil $\text{NH}_4^+$ - N

Fertilizer application is crucial for maintaining available nutrient contents of the soil, because it ensures the largely constant presence of active microorganisms and the regular dynamic of biomass carbon (Nardi *et al.*, 2004). There was a fluctuation in the trend of soil  $\text{NH}_4^+$ - N with time following mineral fertilizer application on the Luvisol while a decrease in soil  $\text{NH}_4^+$ - N was observed on the Ferralsol (Table 4.3). The decrease in soil  $\text{NH}_4^+$ - N contradicted with the results of Snapp and Borden (2005) that soil  $\text{NH}_4^+$ - N remained constant throughout the study. The changes in soil  $\text{NH}_4^+$ - N may largely be attributed to nitrification and crop uptake at different stages of growth (Logah, 2009).

Generally, higher soil  $\text{NH}_4^+$ - N values were found for mineral fertilizer amended plots than the control treatment (Tables 4.2 – 4.3). The highest soil  $\text{NH}_4^+$ - N level observed in mineral fertilizer plots on both soil type was as result of the N fertilizer imposed on these plots. Wu *et al.* (2008) reported higher available N in NPK treatment that was 1.2 times higher than that in the control treatment. Mineral fertilizer plots that recorded

lower soil  $\text{NH}_4^+$ - N than the control (Table 4.2) could be due to rapid N losses through volatilization.

Soil  $\text{NH}_4^+$ - N contents was significantly ( $P < 0.05$ ) affected by the varieties only at 45 DAP on the Luvisol and at 60 DAP on the Ferralsol. Soils planted with SR21 had higher  $\text{NH}_4^+$ - N than those planted with variety Komsaya on both soil types (Tables 4.2 - 4.3).

The observed differences in the  $\text{NH}_4^+$ - N contents of the soils grown with the two varieties may be due to differences in genetic makeup of the varieties. Different varieties differ in their genetic makeups and therefore have the tendency of being influenced differently by the soil environment. Komsaya as hybrid is a heavy feeder than SR21 (OPV) (Chilimba, 1989; Mphande, 1994), hence Komsaya might have utilized more effectively most of the mineral nutrients applied than SR21. These could have accounted for the lower soil  $\text{NH}_4^+$ - N contents in plots planted with Komsaya.

The interactive effects of both maize varieties, Komsaya and SR21 with the mineral fertilizer were significant ( $P < 0.05$ ) across soil types. At each sampling time, both varieties interacted differently with mineral fertilizer application to induce the highest soil  $\text{NH}_4^+$ - N contents left in the soil (Appendices 1 – 2). This may be due to the inherent difference between the two varieties in their needs in terms of nutrients uptake.

### **5.1.2 Soil available phosphorus**

There was a net decline in soil available P contents between the first and the final sampling period for all the treatments for both soil types (Tables 4.4 – 4.5). Unlike the marginal decline observed in plot without mineral fertilizer, a sharp decline was found in plots amended with mineral fertilizer. This might be due to the “A” value concept stated by Fried and Dean (1952). The concept explained that the quantities of P

absorbed from the soil and mineral fertilizer is proportional to the amounts available. Therefore more P would be expected to be taken by crops supplied with P fertilizer, hence the sharp decline. Despite the decline with time, mineral fertilizer treatments generally induced soil available P levels that were higher than the available P in the unfertilized soil. The observed higher available P was by virtue of P solubilization from the mineral fertilizer applied. The bulk of applied P remains in soils due to very slow diffusion and immobilization (Prasad and Power, 1997). This result was consistent with the assertion of Dong *et al.* (2012) that higher available P levels in mineral fertilizer treated plots relative to the control were derived from the P inputs from the fertilizer. The application of mineral fertilizer has been reported to significantly alter the amounts and proportion of labile and stable soil P pools (Qu *et al.*, 2009; Motavalli and Miles, 2002).

Plots planted with Komsaya and grown on a Luvisol gave the highest soil available P values during the three sampling periods and differed significantly from those of SR21. However on the Ferralsol, the reverse trend was observed. Differences in the genetic constituent of the varieties could have accounted for their varying influence on the soil available P levels with time.

It was evident from the results that the combined effect of varieties and the mineral fertilizer significantly affected the available P contents of both soils (Appendices 3 – 4). On the Luvisol, the application of mineral fertilizer at the rates of 90N-15P-10K, 90N-7.5P-0K and 90N-15P-10K to the Komsaya and rates of 90N-22.5P-0K, 90N-22.5P-0K and 90N-7.5P-0K to the SR21 led to higher soil available P. On the Ferralsol, the application of 90N-15P-30K, 90N-15P-10K and 90N-22.5P-0K to Komsaya and 90N-15P-20K, 90N-15P-0K and 90N-15P-30K to SR21 induced

higher soil available P. Perhaps the SR21 variety was more P efficient than Komsaya as the application of 15 kg ha<sup>-1</sup> P led to the highest available P while the application of 15 to 22.5 kg ha<sup>-1</sup> P was required by Komsaya to obtain the highest available P. Furthermore, the Komsaya variety as hybrid had higher P requirement (Chilimba, 1989; Mphande, 1994) and consequently utilized more of the available P from both the mineral fertilizer and the soil stock.

### **5.1.3 Soil exchangeable K**

The results of the exchangeable K in both soil types (Tables 4.6 – 4.7), showed a general increase following the application of mineral fertilizer suggesting that applying mineral fertilizer containing K could improve the exchangeable K levels of soil. This result agrees with findings of Danso *et al.* (2010) and Dong *et al.* (2012) that exchangeable K increased in soils with time following mineral fertilizer application. Another possible explanation for the increase in exchangeable K over time with mineral fertilizer application could be due to a greater portion of available K released into the soil solution from exchange sites.

On the Luvisol, the plots planted with variety Komsaya gave the highest values of soil exchangeable K over time which was significantly ( $P < 0.05$ ) different from SR21. On the Ferralsol, plots planted with variety SR21 gave the highest values of soil exchangeable K at 75 DAP which was significantly ( $P < 0.05$ ) different from Komsaya. Differences in the genetic constituent of the varieties could have accounted for their varying influence on the soil exchangeable K levels with time.

The combined effects between maize varieties and mineral fertilizer rates were significant (Appendices 5 – 6). In general, the plots cultivated with SR21 gave higher exchangeable K in the soil than Komsaya. This could be due to the fact that

Komsaya known as a heavy feeder had utilized more exchangeable K.

#### **5.1.4 Soil pH**

The relationship between fertilization and soil pH has been widely studied (Daugelene and Butkute, 2008; Zhang *et al.*, 2009). It has been reported that the soil pH was decreased to a certain extent with different fertilizer treatments (Wang *et al.*, 2010). In the present study, the soil pH tends to increase in the different treatments with time on both soil types (Tables 4.8 – 4.9). On the Luvisol, soil pH values were relatively higher in the plots amended with the mineral fertilizer treatments over the unfertilized plots throughout the sampling periods. This suggests that mineral fertilizer could reduce soil acidification to some extent. This result was in line with the report of Wu *et al.* (2008) that mineral fertilizer application increased soil pH significantly over the control. On the Ferralsol, increase in soil pH was pronounced in the control which produced significantly higher soil pH than those of the mineral fertilizer treated plots. This result is in agreement with Olusegun (2014) who reported higher soil pH for control treatment plots than plots that received inorganic fertilizer, but contradict report of Wu *et al.* (2008). The lower soil pH of the plots treated with mineral fertilizer compared to the control treatment in this study could be attributed to their rapid rates of release of nutrient, which are immediately used up by plants, leading to poor accumulation of exchangeable bases that neutralizes soil acidity (Olusegun, 2014).

Soil pH with time was affected by the maize varieties evaluated at the various sampling periods. On the Luvisol, plots planted with SR21 gave the highest soil pH values during the three sampling periods and differed significantly from those of Komsaya. The higher nutrient requirements of hybrid maize over composite varieties might have triggered the utilization of most of the available nutrients in the soil by

Komsaya than SR21 leading to poor accumulation of exchangeable bases that neutralizes soil acidity (Olusegun, 2014) and thus the low pH in plots planted with Komsaya. Elsewhere, Smith and Read (2008) reported that when more nutrients such as  $\text{NH}_4^+$  ions are absorbed by plant roots, more  $\text{H}^+$  ions will be released into soil solutions and cause soil acidification.

Maize varieties grown on both Luvisol and Ferralsol significantly ( $P < 0.05$ ) influenced soil pH (Tables 4.8 – 4.9). The plots planted with variety SR21 gave higher pH values throughout the season than those planted with variety Komsaya on both soil type. The statistically significant differences observed between the varieties in influencing soil pH at all the sampling times might have been due to the differences in their genetic makeup. Different varieties have different genetic makeup and thus have the tendency of influencing or to be influenced differently by the soil environment. Komsaya being a hybrid is a heavy feeder than SR21 (OPV) (Chilimba, 1989; Mphande, 1994), hence Komsaya can utilize soil nutrients more effectively than variety SR21 thereby leading to poor accumulation of exchangeable bases that neutralizes soil acidity and thus the low pH in plots planted with Komsaya.

On the Luvisol, the application of mineral fertilizer on both maize varieties produced higher soil pH values than that of the unfertilized treatment plots (Table 4.8). Mineral fertilizer application has been reported to increase soil pH levels (Wu *et al.*, 2008). On the Ferralsol, the result showed that the control treatment under both maize varieties SR21 and Komsaya produced generally higher soil pH values (Table 4.9) confirming the positive effects of no mineral fertilizer application in increasing the soil pH. The application of no mineral fertilizer has been reported to increase soil pH in plots more than the fertilized plots (Olusegun, 2014).

## 5.2 Effect of mineral fertilizer, soil type and maize varieties on plant nutrient uptake

The nutrients uptake of plants grown on both soil types were significantly ( $P < 0.05$ ) increased with the application of mineral fertilizer. On Ferralsol, the result indicated that all the combination of NPK led to more N uptake than when N is applied solely (Table 4.10). Again, the highest N uptake was associated with the mineral fertilizer which contains the highest level of P. This can be as a result of the fact that N is related to P as reported by Bélanger *et al.* (2011), Yoseftabar (2012). On Luvisol, the highest N uptakes were generally recorded by the mineral fertilizer formulation of 90N-7.5P-0K. This could be explained by the fact N uptake is enhanced when P is present as reported by Bélanger *et al.* (2011), Yoseftabar (2012).

On Ferralsol, higher P uptake was observed with mineral fertilizer rates that had high P levels (90N-22.5P-0K) (Table 4.10). Similar results were reported by Mallarino *et al.* (1999), Wasonga *et al.* (2008). On Luvisol, the highest P uptake was obtained from the 90N-15P-20K-15S-10Mg-2.5Zn-0.5B. These results showed that P uptake is enhanced by a positive interaction between P and the secondary macronutrients and the micronutrients which contradicted the findings of Mallarino *et al.* (1999).

On Luvisol, the highest K uptake was associated with the application of high K levels (90N-15P-30K). On Ferralsol, the highest K uptake values were associated with highest mineral fertilizer rate of 90N-15P-20K-15S-10Mg-0.5B. These results agreed with the findings of Mallarino *et al.* (1999) that the application of higher rate of K led to an increase in K uptake by maize. The general low values in maize plant

N, P and K uptake on both soil at harvest could be due to the migration of the nutrient from the stover to the reproductive parts of the plants as reported earlier by Djaman *et al.* (2013).

Plant N, P and K uptake at harvest was affected by maize varieties on Ferralsol and Luvisol. Generally, SR21 recorded statistically or numerically the highest N, P and K uptake, while Komsaya recorded the lowest (Table 4.10). This may be due to a greater translocation capacity of photosynthates to the growing sinks for Komsaya and a poor distribution of nutrients for SR21 which led to a greater grain yield for Komsaya variety (Figure 4.4). Earlier reports by Spiertz and Vos (1985) alluded to the ability of the plant to accumulate and distribute dry mass into its organs during the whole period of vegetation is one of the major factors that determine cereal yield. Another possible explanation for this could have been due to differences in the growth cycle of Komsaya and SR21. Komsaya is an early maturing maize variety and it occurred that the sampling periods coincided with the period between maize silking and physiological maturity for Komsaya but not for SR21 and at this stage most of the nutrients in the vegetative part are translocated (remobilized) to the economic sinks.

N, P and K uptake were significantly affected by soil type. Plants grown on Luvisol recorded the highest values of nutrients uptake than plants on Ferralsol (Figure 4.4). The significant effect might be due to the differences in fertility status between the Luvisol and the Ferralsol (Table 4.1). According to WRBSR (2014), Luvisol are reported to be suitable for agricultural purposes and thus is expected to make available more plant nutrients for uptake than Ferralsol.

### **5.3 Effect of mineral fertilizer and maize varieties on grain and stover yield**

Judicious application of mineral fertilizer improves yield of crops (Sharma *et al.*, 1996). Consequently, the mineral fertilizer application significantly increased grain

and stover yield on Luvisol and Ferralsol as presented in Tables 4.11 and 4.12. All the mineral fertilizer rates produced grain and stover yield higher than the control. The 90N-15P-30K and 90N-15P-20K-15S-10Mg-2.5Zn-0.5B treatments produced the highest grain and stover yield for Luvisol and Ferralsol respectively. The difference in the optimal rates of mineral fertilizer required to obtain highest yield maybe due to the inherent fertility status of these soils. Luvisol has been reported to be a fertile soil while Ferralsol is known to be deficient in some macronutrients and some micronutrients (WRBSR, 2014). The significant response of maize to mineral fertilizer application observed in this study in terms of grain and stover yield in both soils may be due to increased availability of essential nutrient in the soil for plant use.

There was no significant difference ( $P > 0.05$ ) in grain and stover yield among the maize varieties on both the Luvisol and Ferralsol (Tables 4.11 and 4.12). However, Komsaya produced numerically higher grain yield over SR21. Generally, it has been reported that hybrids are better users of both soil and applied nutrients (Chilimba, 1989; Mphande, 1994) with high yielding attributes (Odendo *et al.*, 2001) than the composite and local maize varieties.

On the other hand, SR21 produced numerically higher stover yield than Komsaya (the hybrid). The numerically higher stover yield but lesser grain yield obtained by SR21 over Komsaya is an indication that most of the dry matter accumulated by SR21 were partitioned into the vegetative sink instead of being translocated to the economic part (grains). Indeed, the harvest index, which reflects the efficiency of dry matter partitioning to the grain, showed that Komsaya partitioned more of its dry matter into to the grains than SR21 on both soils (Table 4.13). Improvements in maize grain yield have been accompanied by increased total biomass yield (Hay, 1995; Lorenz *et al.*, 2010), and it efficiency to be partitioned to the grains.

#### **5.4 Effect of soil type on maize grain and stover yield**

The observation that plants grown on Luvisol produced significantly ( $P < 0.05$ ) higher grain and stover yield than plants grown on the Ferralsol (Figure 4.5), suggest that the Luvisol was more fertile than the Ferralsol. This result was similar to the findings of Gao *et al.* (2007), who reported differences in maize yield when grown in two different types of soil but contradicts report of Li *et al.* (2012) who indicated that soil type had no significant effects on maize yield. Furthermore, it affirmed the assertion of van Waverson *et al.* (1993) that different type of soils are endowed with different physical and chemical properties which make them superior or inferior to other soils within a given locality.

#### **5.5 Effect of mineral fertilizer and maize varieties on harvest index**

Harvest index (HI) is the proportion of grain in the total aboveground biomass of the crop expressed in percentage. The results shown that harvest index was significantly ( $P < 0.05$ ) increased by the application of mineral fertilizer rates (Table 4.13). This was in line with the findings of Wasonga *et al.* (2008). The significant increase in HI following mineral fertilizer application might be due to good growth and biomass production thus the tendency for more dry matter to be translocated to the economic part of the plant. The result was in line with the report of Malagi (2005) that there were significant increases in HI following mineral fertilizer application but contradicted with the report of Singh *et al.* (2003).

The Komsaya variety produced significantly higher harvest index than SR21 for both of the soils. The significant difference observed in harvest index among the varieties might possibly be due to differences in their genetic makeup. This result agrees with

that of Singh *et al.* (2003) who reported that harvest index is a genetic trait and can be influenced by varietal differences.

There was a significant ( $P < 0.05$ ) interaction between mineral fertilizer application rate and maize varieties on HI on the Ferralsol (Appendix 10). The 90N-0P-0K gave the highest HI value of 58 % in variety Komsaya while the 90N-15P-0K gave the highest HI (39 %) in SR21. This may be due to the ability of the plants to take up the nitrogen supplied by the urea and use it efficiently during grain formation. The control (HI = 29 %) and the diagnostic (HI = 33 %) treatments gave lower harvest indices in Komsaya and SR21 respectively. These HI values are below 40 % might be because those plots suffered from either biotic or abiotic stress other than nutrients as explained earlier by Hay (1995).

#### **5.6 Effect of mineral fertilizer, soil type and maize varieties on grain nitrogen and phosphorus uptake**

Nutrient uptake is considered as an indicator of the availability and accessibility of soil nutrients in plants while grain nutrient uptake could be a proxy for both quantity and quality of the grain produced (Okebalama, 2014). Maize grain nitrogen concentration was high compared to phosphorus among the treatments and across both soil type. The increased N concentration might be due to synergistic effect of different levels of NPK than the sole application of nitrogen as reported by many studies.

The low P uptake of crops grown on the Ferralsol (Table 4.15) may be due to the low availability of soil P as a result of the low inherent fertility status and available P partly because of the strong P fixation of the Ferralsol (WRBSR, 2014). Moreover, Lake (2000) stated that under low pH, beneficial elements such as phosphorus, magnesium

and calcium become less available to plants. Consequently, the low available P concentrations in both soils could be due to the low pH (< 6).

The maize varieties did not show any significant difference in grain N and P uptake on both soil but Komsaya grain N and P contents were increased by 13.8 kg N ha<sup>-1</sup> N and 5.17 kg P ha<sup>-1</sup> over those of variety SR21 on Luvisol and by 8.8 kg N ha<sup>-1</sup> and 0.5 kg P ha<sup>-1</sup> over those of SR21 on Ferralsol. This is consistent with the observations of Chilimba (1989) and Mphande (1994) that hybrids were better users of both the soil and fertilizer applied nutrients than composite and local varieties.

Maize grain N and P uptake were significantly affected by the soil type. On Luvisol, the uptake was significantly higher than that on Ferralsol (Figure 4.7). This may be explained by the characteristics of the two soil types. It has been reported that Ferralsol were incapable of storing and supplying the nutrients to the plants when needed while Luvisol as known to be a fertile soil suitable for crop production (WRBSR, 2014). The highest N and P uptake was obtained with the rate of 90N15P-30K on Luvisol and 90N-15P-20K-15S-10Mg-2.5Zn-0.5B on Ferralsol translated into the highest grain yield (Tables 4.14 – 4.15) respectively.

### **5.7 Value cost ratio**

The returns on investments in applied mineral fertilizer were appraised by assessing the value cost ratio (VCR). The positive returns earned from the application of mineral fertilizer to maize varieties on both soils (Tables 4.16 – 4.17) highlighted the role of mineral fertilizer as the paramount key entry point for increased crop productivity in Sub-Saharan Africa (Sanginga and Woomer, 2009). On the Luvisol, the use of both maize varieties were profitable. In general, VCR declined with increase rate of mineral fertilizer for both varieties. This was in line with the findings of Sime and Aune (2014).

Cultivation of Komsaya gave the highest VCR value ( $VCR = 8.0$ ) which was obtained from the lower mineral fertilizer rate of 90N-0P0K; similar observation was made by Roy *et al.* (2006); Sime and Aune (2014) who attributed high VCR value to low fertilizer application owing low investment cost and high response. Moreover,  $VCR > 4$  was found with the plots planted with Komsaya and amended to the mineral fertilizer rates of 90N-15P-0K, 90N-7.5P-0K, 90N-22.5P-0K, 90N-15P-10K, 90N-15P-20K and 90N-15P-30K (Figure 4.9); variety SR21 recorded  $VCR > 4$  with the plots treated to 90N-0P-0K and 90N-15P-20K.  $VCR > 4$  implies positive returns on fertilizer investment that was economically viable. Guo *et al.*, (2009) suggested the  $VCR > 4$  could accommodate price and climatic risks and still remain profitable to farmers. The relative higher VCR ratio found with the lower mineral fertilizer rate of 90N-0P-0K for both varieties also supports that increase crop yield is made through lower fertilizer rate at low cost and with moderate risk to farmers in sub-Saharan region as reported earlier by Aune *et al.* (2007); Aune and Ousman (2011). The high yielding traits of Komsaya made the use of the variety more profitable than SR21.

On the Ferralsol, VCR values for both maize varieties increased with the increase rate of mineral fertilizer. This contradicted the findings of Sime and Aune (2014) that VCR declines with increasing fertilizer rates. The profitability of mineral fertilizer was found to be very low (Table 4.17). This may be due to the poor crop response and unfavourable fertilizer to maize price ratio as reported by Gerner and Harris (1993) and Dembélé and Savadogo (1996). Due to the general lack of higher response of SR21 (recording the lowest grain yield) to mineral fertilizer applied on Ferralsol, none of the applied rates were economically attractive. Similar findings were obtained by Opoku

(2011) at Maradi (Niger). Generally, cultivation of variety Komsaya on a Ferralsol is relatively profitable than cropping variety SR21.

# KNUST



## CHAPTER SIX

### 6.0 CONCLUSION AND RECOMMENDATIONS

#### 6.1 Conclusion

There were significant changes in soil  $\text{NH}_4^+$ - N, available P and exchangeable K concentration over time depending on the uptake by the plants. The SR21 variety was more P efficient than Komsaya. Stover and grain N, P and K uptake were significantly increased by the use of mineral fertilizer. Nutrient dynamics differed significantly across soil type; on Luvisol, soil  $\text{NH}_4^+$ - N, available P, exchangeable K concentration as well as stover and grain N, P and K uptake were higher relative to those of Ferralsol. These findings reject the null hypothesis of this study that the application of mineral fertilizer has no significant effect on soil and plant N, P and K dynamics.

On Luvisol, the rate of mineral fertilizer which gave higher grain and stover yield was 90N-15P-30K while on Ferralsol, the best rate was 90N-15P-20K-15S-10Mg-2.5Zn-0.5B. There was no significant difference between the two varieties in terms of grain and stover yield across the soil types. However, Komsaya produced the highest grain yield of 2179 and 4275  $\text{kg ha}^{-1}$  while SR21 gave the highest stover yield of 4902 and 6396  $\text{kg ha}^{-1}$  on Ferralsol and Luvisol respectively. Moreover, grain yield increases over the control on the Ferralsol and Luvisol ranged from 606 % (90N-0P-0K) to 3122 % (90N-15P-20K-15S-10Mg-2.5Zn-0.5B) and 690 % (90N15P-10K) and 1276 % (90N-15P-30K), respectively. The significant increases in grain yield following the application of mineral fertilizer refuted the second null hypothesis that the application of appropriate rates of mineral fertilizer does not lead to an increase in grain yield.

The returns on investments were economically viable by growing both maize varieties. Komsaya gave the highest VCR value (VCR = 8) under 90N-0P-0K while SR21 gave VCR > 4 on plots which received 90N-15P-20K and 90N-0P-0K confirming that the use of mineral fertilizer is profitable for farmers. This contradicts the third hypothesis of this study that the application of mineral fertilizer is not profitable for smallholder farmers.

## **6.2 Recommendation**

The outcome of this study is from one growing season; therefore further studies should be conducted in order to ascertain these findings.



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### APPENDICES

Appendix 1. Interactive effect between mineral fertilizer application rate and maize variety on soil  $\text{NH}_4^+$ - N on a Luvisol

Treatment (kg ha <sup>-1</sup> )	- N (mg kg <sup>-1</sup> )					
	45 DAP		60 DAP		75 DAP	
	Komsaya	SR21	Komsaya	SR21	Komsaya	SR21
<u>Fertilizer rate</u>						
Control	35.41	30.92	38.40	39.11	34.43	35.92
90N-0P-0K	36.39	45.18	40.66	40.65	34.08	35.21
90N-7.5P-0K	25.63	37.52	39.79	38.32	35.88	36.93
90N-15P-0K	37.05	38.71	40.61	38.93	38.33	35.77
90N-22.5P-0K	33.82	31.23	41.81	37.53	40.05	34.78
90N-15P-10K	36.54	35.31	39.73	35.10	37.76	37.84
90N-15P-20K	35.59	37.70	37.62	41.92	36.61	37.23
90N-15P-30K	34.93	36.04	37.12	43.87	34.41	44.09
90N-15P-20K- 15S10Mg-2.5Zn-0.5B	38.22	39.02	41.69	38.89	37.97	38.25
LSD (0.05)	4.80		1.77		2.3	

Fpr	< 0.001*	< 0.001*	< 0.001*
CV (%)	8.1	2.7	3.8

DAP = Days after planting; \* = significant at  $P < 0.01$

# KNUST



Appendix

2. Interactive effect between mineral fertilizer application rate and maize variety on soil  $\text{NH}_4^+$ -N on a Ferralsol

Treatment (kg ha <sup>-1</sup> )	- N (mg kg <sup>-1</sup> )			
	45 DAP		60 DAP	
	Komsaya	SR21	Komsaya	SR21
<u>Fertilizer rate</u>				
Control	30.07	24.49	22.11	28.02
90N-0P-0K	38.94	34.58	23.23	25.01
90N-7.5P-0K	33.95	38.93	24.63	30.01
90N-15P-0K	37.27	34.52	21.92	29.36
90N-22.5P-0K	31.91	34.78	24.01	28.00
90N-15P-10K	34.39	27.63	24.30	25.03
90N-15P-20K	30.11	39.66	25.14	27.97
90N-15P-30K	30.81	34.83	23.62	26.59
90N-15P-20K15S-10Mg-2.5Zn0.5B	42.42	33.33	24.79	24.66
LSD (0.05)	2.78		2.24	
Fpr	< 0.001*		< 0.001*	
CV (%)	4.9		5.3	

DAP = Days after planting; \* = significant at P < 0.01

Appendix

3. Interactive effect of mineral fertilizer application rate and maize variety on soil available phosphorus on a Luvisol

Treatment (kg ha <sup>-1</sup> ) 1	Available phosphorus (mg kg <sup>-1</sup> )					
	45 DAP		60 DAP		75 DAP	
	Komsaya	SR21	Komsaya	SR21	Komsaya	SR21
<u>Fertilizer rate</u>						
Control	9.27	10.29	10.40	12.19	7.22	9.97
90N-0P-0K	7.85	8.9	9.99	6.78	7.74	8.40
90N-7.5P-0K	16.79	14.5	14.48	9.44	11.51	11.88
90N-15P-0K	15.13	9.86	12.06	9.14	10.25	9.31
90N-22.5P-0K	15.90	21.04	12.89	13.98	11.62	8.94
90N-15P-10K	19.43	7.65	13.30	8.13	13.56	7.50
90N-15P-20K	14.92	14.79	12.93	9.55	11.97	9.42
90N-15P-30K	10.23	16.88	9.60	6.63	11.47	9.66
90N-15P-20K- 15S10Mg-2.5Zn-0.5B	10.47	9.7	11.62	10.73	8.94	9.51
LSD (0.05)	1.42		0.81		0.67	
Fpr	< 0.001*		< 0.001*		< 0.001*	
CV (%)	6.6		4.5		4.1	

DAP = Days after planting; \* = significant at P < 0.01

## Appendix

### 4. Interactive effect of mineral fertilizer application rate and maize variety on soil available phosphorus on a Ferralsol

Treatment (kg ha <sup>-1</sup> ) 1	Available phosphorus (mg kg <sup>-1</sup> )					
	45 DAP		60 DAP		75 DAP	
	Komsaya	SR21	Komsaya	SR21	Komsaya	SR21
<u>Fertilizer rate</u>						
Control	2.92	3.25	2.07	3.69	3.45	3.73
90N-0P-0K	3.14	4.47	2.38	3.93	2.75	3.86
90N-7.5P-0K	7.20	21.04	6.04	10.88	4.60	5.98
90N-15P-0K	16.75	28.22	3.10	14.68	8.09	8.83
90N-22.5P-0K	26.41	18.21	12.69	27.30	17.56	13.72
90N-15P-10K	18.86	20.39	17.75	5.98	6.74	12.65
90N-15P-20K	15.59	21.13	7.61	6.76	6.17	7.96
90N-15P-30K	28.07	20.72	11.47	15.79	9.57	20.98
90N-15P-20K- 15S10Mg-2.5Zn-0.5B	11.58	17.18	3.82	15.90	4.08	16.07
LSD (0.05)	0.98		0.66		0.88	
Fpr	< 0.001*		< 0.001*		< 0.001*	
CV (%)	3.7		4.2		6.1	

DAP = Days after planting; \* = significant at P < 0.01

Appendix

5. Interactive effect between mineral fertilizer application rate and maize variety on soil exchangeable potassium on a Luvisol

Treatment (kg ha <sup>-1</sup> ) 1	Exchangeable potassium (Cmol <sub>c</sub> kg <sup>-1</sup> )					
	45 DAP		60 DAP		75 DAP	
	Komsaya	SR21	Komsaya	SR21	Komsaya	SR21
<u>Fertilizer rate</u>						
Control	0.160	0.125	0.171	0.128	0.176	0.148
90N-0P-0K	0.122	0.148	0.137	0.165	0.146	0.200
90N-7.5P-0K	0.147	0.207	0.184	0.122	0.180	0.129
90N-15P-0K	0.152	0.117	0.177	0.122	0.155	0.145
90N-22.5P-0K	0.134	0.117	0.162	0.115	0.157	0.132
90N-15P-10K	0.107	0.094	0.161	0.106	0.151	0.133
90N-15P-20K	0.144	0.132	0.156	0.131	0.185	0.137
90N-15P-30K	0.122	0.128	0.153	0.135	0.158	0.162
90N-15P-20K- 15S10Mg-2.5Zn-0.5B	0.113	0.130	0.148	0.128	0.153	0.153
LSD (0.05)	0.012		0.004		0.008	
Fpr	< 0.001*		< 0.001*		< 0.001*	
CV (%)	5.6		1.6		2.4	

DAP = Days after planting; \* = significant at P < 0.01

Appendix

KNUST

6. Interactive effect of mineral fertilizer application rate and maize variety on soil exchangeable potassium on a Ferralsol

Treatment (kg ha <sup>-1</sup> ) 1	Exchangeable potassium (Cmol <sub>c</sub> kg <sup>-1</sup> )					
	45 DAP		60 DAP		75 DAP	
	Komsaya	SR21	Komsaya	SR21	Komsaya	SR21
<u>Fertilizer rate</u>						
Control	0.135	0.132	0.155	0.146	0.148	0.188
90N-0P-0K	0.108	0.094	0.124	0.110	0.156	0.134
90N-7.5P-0K	0.104	0.085	0.108	0.203	0.137	0.140
90N-15P-0K	0.094	0.087	0.135	0.118	0.117	0.152
90N-22.5P-0K	0.099	0.084	0.134	0.101	0.117	0.127
90N-15P-10K	0.089	0.087	0.130	0.122	0.112	0.141
90N-15P-20K	0.124	0.110	0.142	0.111	0.116	0.180
90N-15P-30K	0.144	0.187	0.149	0.146	0.139	0.157
90N-15P-20K- 15S10Mg-2.5Zn-0.5B	0.091	0.121	0.112	0.119	0.111	0.182
LSD (0.05)	0.014		0.008		0.006	
Fpr	< 0.001*		< 0.001*		< 0.001*	

Appendix

CV (%) 7.4 3.8 2.6

DAP = Days after planting; \* = significant at  $P < 0.01$

KNUST

7. Interactive effect of mineral fertilizer application rate and maize variety on soil pH on a Luvisol

Treatment (kg ha <sup>-1</sup> ) 1	pH					
	45 DAP		60 DAP		75 DAP	
	Komsaya	SR21	Komsaya	SR21	Komsaya	SR21
<u>Fertilizer rate</u>						
Control	5.14	5.41	5.08	5.64	5.29	5.65
90N-0P-0K	5.34	5.81	5.49	5.80	5.60	6.08
90N-7.5P-0K	5.40	5.45	5.62	5.54	5.67	5.77
90N-15P-0K	5.37	5.44	5.54	5.56	5.59	5.87
90N-22.5P-0K	5.31	5.24	5.25	5.45	5.59	5.66
90N-15P-10K	5.33	5.37	5.31	5.45	5.48	5.71
90N-15P-20K	5.26	5.47	5.26	5.58	5.73	5.57
90N-15P-30K	5.49	5.57	5.32	5.80	5.64	5.92

Appendix					
90N-15P-20K-15S10Mg-5.25 2.5Zn-0.5B	5.46	5.28	5.50	5.41	5.78
LSD (0.05)	0.02	0.03		0.02	
Fpr	< 0.001*	< 0.001*		< 0.001*	
CV (%)	0.3	0.3		0.3	

DAP = Days after planting; \* = significant at P < 0.01

8. Interactive effect between mineral fertilizer application rate and maize variety on soil pH on a Ferralsol

Treatment (kg ha <sup>-1</sup> ) 1	pH					
	45 DAP		60 DAP		75 DAP	
	Komsaya	SR21	Komsaya	SR21	Komsaya	SR21
<u>Fertilizer rate</u>						
Control	4.76	4.88	5.02	5.11	5.12	5.33
90N-0P-0K	4.17	4.36	4.62	4.81	4.73	5.03
90N-7.5P-0K	4.23	4.42	4.32	4.76	4.49	4.91
90N-15P-0K	4.34	4.28	4.70	4.78	4.55	5.24
90N-22.5P-0K	4.23	4.35	4.62	4.59	4.51	4.83
90N-15P-10K	4.24	4.36	4.86	4.81	4.74	5.03
90N-15P-20K	4.34	4.48	4.89	4.76	4.67	5.41

Appendix						
90N-15P-30K	4.61	4.53	4.88	4.67	4.88	5.11
90N-15P-20K- 15S10Mg-2.5Zn- 0.5B	4.57	4.30	4.93	4.82	5.03	5.46
LSD (0.05)	0.02		0.03		0.02	
Fpr	< 0.001*		< 0.001*		< 0.001*	
CV (%)	0.3		0.3		0.3	

DAP = Days after planting; \* = significant at P < 0.01

9. Interactive effect between mineral fertilizer application rate and maize variety on maize phosphorus uptake on a Luvisol at harvest.

Treatment (kg ha <sup>-1</sup> )	Phosphorus uptake (kg ha <sup>-1</sup> )	
	Komsaya	SR21
<u>Fertilizer rate</u>		
Control	2.42	3.50
90N-0P-0K	5.08	4.42
90N-7.5P-0K	7.50	8.25
90N-15P-0K	9.76	6.17
90N-22.5P-0K	8.03	8.96

Appendix		
90N-15P-10K	4.40	6.95
90N-15P-20K	8.64	9.63
90N-15P-30K	11.24	6.24
90N-15P-20K-15S-10Mg2.5Zn-0.5B	5.15	13.69
LSD (0.05)		3.87
Fpr		0.002*
CV (%)		32.2

\* = significant at  $P < 0.05$

### 10. Interactive effect between mineral fertilizer application rate and maize variety.

Harvest index (%)				
Treatment (kg ha <sup>-1</sup> )	Luvisol		Ferralsol	
	Komsaya	SR21	Komsaya	SR21
<u>Fertilizer rate</u>				
Control	36.98	38.70	29.31	35.43
90N-0P-0K	53.80	43.91	58.02	37.20

Appendix				
90N-7.5P-0K	48.21	41.50	39.53	37.39
90N-15P-0K	49.24	36.81	39.40	38.97
90N-22.5P-0K	46.89	42.06	35.62	35.28
90N-15P-10K	50.06	37.52	47.23	37.95
90N-15P-20K	53.17	39.03	41.90	35.99
90N-15P-30K	50.94	40.49	44.34	37.08
90N-15P-20K15S- 10Mg-2.5Zn0.5B	48.04	38.92	32.13	33.21
LSD (0.05)	9.52		7.61	
Fpr	NS		0.019*	
CV (%)	14.8		10.4	

NS = not significant at  $P < 0.05$ ; \* = significant at  $P < 0.05$

