EFFICACY OF ORGANIC N-FERTILIZER ON MAIZE GROWTH IN A VERTISOL AND AN ACRISOL IN THE ACCRA PLAINS

THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN
PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MPHIL
SOIL SCIENCE DEGREE

BY

EDEM BABA MUTALA

DEPARTMENT OF SOIL SCIENCE
SCHOOL OF AGRICULTURE, COLLEGE OF AGRICULTURE AND CONSUMER
SCIENCES, UNIVERSITY OF GHANA LEGON, GHANA

JULY, 2012.

EFFICACY OF ORGANIC N-FERTILIZER ON MAIZE GROWTH IN A VERTISOL AND AN ACRISOL IN THE ACCRA PLAINS

THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MPHIL SOIL SCIENCE DEGREE

BY

EDEM BABA MUTALA

DEPARTMENT OF SOIL SCIENCE

SCHOOL OF AGRICULTURE, COLLEGE OF AGRICULTURE AND CONSUMER SCIENCES, UNIVERSITY OF GHANA LEGON, GHANA

JULY, 2012.

DECLARATION

I do hereby declare that this thesis, “Efficacy of Organic N-Fertilizer on Maize Growth in a Vertisol and an Acrisol in the Accra Plains” herein presented for a degree of Master of Philosophy in Soil Science is the result of my own investigation and that this thesis has neither in whole nor part been presented elsewhere for another degree. References to other authors have been duly acknowledged.

………………………………
Edem Baba Mutala
(Student)

………………………………
Prof. G.N.N. Dowuona
(Major Supervisor)

………………………………
Dr. E.K. Nartey
(Co- Supervisor)

………………………………
Dr. T.A. Adjadeh
(Co- Supervisor)

DEDICATION

I dedicate this Thesis to the glory of the almighty God, Dr. E.K Nartey, my mother Miss Vivi Avotri, my father the late ALHAJI BABA MUSA, my grandmother, the late Selina, S. Kumadie, my benefactor ABU MANAF, Rev and Mrs. Larrie Davids, to Thelma Adzima and to all my friends and family.

ACKNOWLEDGEMENT

I express my profound gratitude to the Almighty God from whom all good things come, for the success of this thesis; I could not have come this far without his grace. I also express my sincerest gratitude to my supervisors, Prof. G.N.N. Dowuona, Dr. E.K. Nartey and Dr. T.A. Adjadeh for the support and guidance throughout the green house stage, laboratory phase and write up of this thesis.

My sincerest thanks go to my mother Miss Vivi Avotri for supporting my education even though she had every reason to give up on me as some parents would have done in her situation. Mum, I am most thankful. I am also very grateful to Abu Manaf, for sponsoring me through school, even though he had other responsibilities on his shoulder. My sincerest appreciations also go to Mad. Comfort Aborbor, and his son Rev. Larrie Davids for hosting me throughout my stay in Accra.

I say a big thank you to members of my family, especially Ms. Morny Adzo(Sister Adzo), Eva Kumadie (Funmilayo) who was a very great source of encouragement to me throughout my study. To Mr. Kenn Kafui, wife and children, I am most grateful for your support in diverse ways. To Miss Ethel Tsaku, Salisu Baba, Prof. S.G.K Adiku, and all my siblings, I say thank you for having been there for me..

My warmest thanks go to Thelma Adzima for being a pillar of support and a shoulder to lean on. You are a gift from God and I hope one day I will be able make you proud. To my friends Pastor John (John Gat), Pastor Wilson, Pastor Gideon, Pastor Gershon, Godwin Kujo, Henry Ametefe (Bartiboy), Kulley Ali, Mutala Mohammed and others I am unable to acknowledge here but are dear to my heart, I say Thank You".

My heartfelt thanks also go to staff of Ecological lab, University of Ghana, Legon especially Prince for their support and help during the laboratory phase of this thesis especially.

Finally, I wish to thank all workers of Pro-link Ghana, especially my man Dzidzorm Adiku (Dziblack) for their patience and support. I salute the Deputy Director Mrs. Gertrude Nunoo, the Executive Director, Mrs. Heloo, Mr. Thomas Quanoo, Mr. Assisi Edem for proof reading the final corrections and all ADRA peer educators at Pro-link. I am so grateful to you all. God richly bless you

ABSTRACT

The use of inorganic fertilizers in crop production in Sub Saharan Africa is very low due to exorbitant cost. Coincidentally nitrogen which is a limiting nutrient in sub Saharan African soils is locked up in organic waste with the waste breeding flies and having become an environmental nuisance in most towns in the sub region. Composting these organic wastes to be used as organic amendment has been proposed as one of the ways of improving on the low fertility status in soils and ridding the towns of filth in sub Saharan Africa. Ecological fertilizer is an organic N fertilizer formulated by the Department of Soil Science, University of Ghana from agricultural waste for Eco Products Limited. Though the nutrient composition of the fertilizer is known, its efficacy in relation to crop production is yet to be investigated to ascertain its effectiveness and competitiveness with the traditional inorganic N fertilizer sources. A greenhouse study was, therefore, conducted to test the efficacy of Eco-fertilizer on the growth of maize on Akuse Series, Vertisol and Toje Series, an Acrisol. Exactly 8.0 and 9.7 kg respective weights of fine earth fraction of the Vertisol and the Acrisol were weighed into plastic buckets with perforated bottoms to a predetermined height of 6.2m to attain the field bulk density of the two soils. The packed soils were left undisturbed for three weeks prior to the application of treatments to allow for stabilization of microbial activity. Each soil was kept at two moisture contents of field capacity (FC) and 75% field capacity. Maize of variety Obatampa was sown at three seeds per pot and one week after sowing, two N fertilizers; one organic (Eco-fertilizer) and an inorganic fertilizer , $(NH_4)_2SO_4$ were surface applied at three rates of 0, 20 and 40 kg/ha. Each treatment was replicated three times and the pots were arranged in a randomized complete block design pattern, giving a 2×2×2×1×3x3 factorial experiment. Sampling of soils was done at 28 and 65 days after sowing, after which the soils were tested for NH_4^+ and NO_3^-. Agronomic parameters such as chlorophyll content, leaf area index, plant height at 28 and 65 days after sowing at the two moisture levels were also measured. Net assimilation rate was estimated and dry matter yield measured after 65 days of sowing. Results of the study showed that leaf area index, dry matter yield, total nitrogen content of the maize plant, net assimilation rate, plant height and chlorophyll content increased with fertilization of the two soils for both fertilizers. When the two soils were amended with the fertilizers, LAI at 28 days after sowing (LAI-1) was higher in the Akuse series than the Toje series at the two moisture contents due to the superior inherent fertility of the former soil. The higher LAI-1 in the Akuse soils is also supported by the higher available N in the soil at 28 days after sowing which also tied in very well with higher chlorophyll content at 28 days after sowing. At 20 kg/ha for the Akuse series, the nitrogen content in the plant was higher in the inorganic amended soil than that of the organic amended one. However at 40 kg/ha the nitrogen contents of the plants were statistically the same. In the Toje series, the nitrogen content of the plants at the two rates of application, irrespective of fertilizer type were similar just as dry matter yield (DMY).Similar growth parameters such as LAI, height and DMY at both 28 days and 65 days of sowing in the organically and inorganically amended Toje soil and the fact that there was generally no difference in DMY in the two soils at the two application rates indicated that the organic fertilizer competes favourably with the inorganic one in maize growth. There was generally no difference in moisture content at FC and 75% FC on N accumulation and hence DMY of maize plants after 65 days of sowing. At 28 days after sowing which is the vegetative stage of the maize plant, the NH_4^+ contents in the soils was higher at 75%FC than at FC suggestive of the fact that more NH_4^+ had been absorbed at FC due to the prevailing optimum condition for N absorption

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 Background

In order to meet the demands of food grain production for an ever increasing population, improving and maintaining soil fertility have become important in developing countries. Good soil fertility management ensures adequate nutrient availability to crops and increased yields (Mandal et al., 2007). However it is impossible to guarantee sustainable crop yields without the application of fertilizers (Grudzeva et al., 2007). Fertilizers do not only control crop productivity but also soil biota which in turn controls the dynamics of the nutrients added to the soil.

From long-term experiments, it has been concluded that N is the most limiting nutrient for the production of crops in Sub Saharan Africa (Henao and Banaante, 1996). This essential plant nutrient stimulates crop development as well as uptake of other nutrients. In most ecosystems, nitrogen moves from the soil to the plant and from the plant residue back to the soil through microbial biomass. It undergoes many transformations, which are all included in the ‘nitrogen cycle’. In natural ecosystems, this cycle is more or less closed, in that, nitrogen inputs are in equilibrium with nitrogen losses. In agricultural ecosystems however, this cycle is disturbed by the export of substantial amounts of nitrogen with harvested products. External N inputs are, therefore, required to restore the N equilibrium. As a consequence, the use of inorganic nitrogen fertilizers has been an essential factor in keeping or increasing soil productivity. Inorganic fertilizers are easier to handle and produce quicker results than their organic counterpart in the restoration of fertility to exhausted soils.

Many Sub-Saharan African (SSA) farmers and for that matter Ghanaian farmers, are aware of the potential contribution of inorganic fertilizers to crop production. However, the use of inorganic fertilizers in sub-Sahara Africa is very low compared to the world average (Woomer and Munchena, 1993). On the average, less than 5 kg ha^{-1} of mineral fertilizer materials are applied to food crops in sub-Sahara Africa (Tisdale et al., 2002). The low adoption of fertilizer has been attributed to high costs coupled with low producer price of most food crops (IFDC., 1999). Due to the bad road network infrastructure and poor fertilizer storage conditions, mineral fertilizers are frequently unavailable in amounts and quality required. The few farmers who use inorganic fertilizers cannot afford to apply the recommended rates. Consequently the N nutrition of crops is largely based on the supply from the native soil N pool and to a lesser extent on animal manure or other organic resources. The constraints to inorganic fertilizer in sub Saharan Africa calls for investigation into the possibility of reducing the fertilizer N rates by substituting and or complementing with alternate means to meet the N requirements of crops without any significant decrease in yield.

There is an increasing advocacy by governments and non-governmental organizations on the need to intensify inorganic fertilizer use in farming systems of SSA. There is also the need to use fertilizers without compromising the integrity of the environment. Maintaining this balance is always difficult. Alternate sources of nutrients which are cheaper but can sustain and increase current crop production levels and in the future with minimal environmental degradation are, therefore, needed. Organic fertilizers have been proposed as the panacea to this problem. However, organic fertilizers are beset with problems. The nutrients in the fertilizer material are not in the readily available form and may not be in the right proportion. Release of nutrients from the material is more often than not, gradual and may not meet crop demand. Application of organic fertilizers and hence nutrient release will, therefore, have to be synchronized with crop uptake (Darko, 2007).

1.2 Justification

Ironically, a lot of nitrogen which is limiting in SSA and particularly in Ghanaian soils is locked up in agricultural waste. More often than not, these wastes become environmental nuisance breeding flies. They are, therefore, either burnt or discarded as garbage. Composting these agricultural wastes could rid most communities of filth with its attendant flies. More importantly, composting the waste will provide a very cheap source of N which when applied as organic amendment will improve the physical properties of soils.

Ecological fertilizer is an organic N fertilizer formulated by the Department of Soil Science, University of Ghana from agricultural waste for Eco Products Limited. It has 3% N concentration and other nutrients like Mg and P. Though the nutrient composition of the fertilizer is known, its efficacy in relation to crop production is yet to be investigated to ascertain its effectiveness and competitiveness with the traditional inorganic N fertilizer sources. It is also imperative to gain an insight into the management of the product in relation to moisture status of the soil. These will provide the basis for efficient and judicious use of the product to achieve optimum yield at least cost. To be able to transfer the results to other agricultural soils of the country, it is also important for an agronomic trial to be carried out on both light and heavy textured soils.

1.3 Objectives

The objectives of this research are, therefore, to:

i. evaluate the effect of the organic nitrogen fertilizer, viz eco-fertilizer on maize growth in a Vertisol (Akuse series) and an Acrisol (Toje series);

ii. determine the competitiveness of the fertilizer in terms of application rate with the established ammonium sulphate fertilizer on maize growth;

iii. determine the effect of moisture at field capacity (FC) and 75% FC on N release in maize growth.

CHAPTER TWO

LITERATURE REVIEW

2.1 Nitrogen in agricultural soils

Nitrogen occurs in the soil in several forms and inter-conversion among these forms is the net result of a large number of dynamic processes, many of which are mediated by microorganisms (Prakasa-Rao and Puttanna, 2000). Most of soil nitrogen occurs as part of organic molecules and are associated with 2:1 silicate clays (e.g. smectite, vermiculite, illite) or with resistant humic acids. The amount of nitrogen in soils is closely related to the amount of organic matter (Rowell,1994). It is thought that about 90% of the N in the surface layer of soils occurs in organic forms, including, ammonia –N, amino acid-N and amino sugar-N, with most of the remainder being present as clay-fixed ammonium (NH_4^+) (Stevenson, 1994). This association helps shield organic compounds from rapid microbial breakdown.

2.2 Nitrogen mineralization in agricultural soils

Incorporation of ammonium into organic compounds by microbial assimilation is known as immobilization, while the reverse process where micro-organisms oxidize organic matter to produce energy and convert organic nitrogen into inorganic forms is known as mineralization. These two processes occur simultaneously (Prakasa-Rao and Puttanna, 2000). Nitrogen mineralization is defined as the process by which soil organic nitrogen is transformed into the inorganic forms NH_3, $NH_4^+$and NO_3^- by microorganisms. Nitrite is also produced but this rarely accumulates in soils or quickly oxidized to NO_3^-.

Mineralization increases with a rise in temperature and is enhanced by adequate, although not excessive, soil moisture and a good supply of oxygen. In most soils, ammonium is rapidly converted to nitrate via nitrite by a process called nitrification, where ammonium is oxidized to nitrite and then to nitrate by the action of the aerobic bacteria such as

Nitrosomonas, and *Nitrobacter*, respectively (Prakasa-Rao and Puttanna, 2000). Plants take up nitrogen in mineral form (ammonium or nitrate). If environmental conditions are not limiting, the NH_4^+ is oxidized to NO_3^- almost as rapidly as it is formed (Schmidt, 1982). Thus, NO_3^- -N is usually the dominant form of plant-available N in most arid and semi-arid regions (Kaboneka et al., 1997).

The average N concentration in natural organics is typically between 1and 13% (Tisdale et al., 2002) although some sources like chicken excreta could contain more. Organic fertilizer quality is very much dependent on the source from which it is made from and its method of composting or manufacture. If it is made from crop residues or plant parts, the soils on which they are applied are very important, because it can lead to N deficiency in low fertility soils

Organic fertilizers or organic sources of N at one time were thought to release their N slowly, thereby supplying the crop with N while avoiding excessive uptake and reducing potential losses by leaching and denitrification. This has been shown by several instances not to always be the case as sometimes most of the N is made available within the first 2 to 4 weeks after application (Tisdale et al; 2002).

2.3 Factors influencing N-equivalence of organic fertilizers

The state of organic manure and its C:N ratio are the major properties that affect N yield. Composting stabilizes organic fertilizer (manure) with the product releasing N slowly over time. Farm yard manure is a typical example (Katyal, 1980a) of a slow releasing N source. Tanaka (1977) showed that the recovery of N from composted manure by rice was only 6.6%. Green manure is usually added without composting. Following its addition there is deluge in microbial metabolism. For that reason a green manure tends to liberate more of its N in soluble form. At least half of the N contained in it can be recovered by the beneficiary crop (Tanaka 1977).

Carbon to nitrogen ratio (C:N ratio) is another major characteristic of an organic fertilizer/manures that decides the rate of N-release. Temperature and moisture regulate the rate of organic manure decomposition (Sims 1986). In sandy soils, the decomposition is faster than in clayey soils.

2.4 Benefits of organic fertilizers other than N

Organic fertilizers contain several nutrient elements other than N. Although the amounts are highly inconsistent and low, regular treatment with organic fertilizers on long term basis can avert occurrence of several nutrient deficiencies. For instance regular application of FYM over 10 year period led to build up of plant available-Zn (Katyal and Randhawa 1983)

Organic manures enhance nutrient availability through complexation or by promoting transformations that favor nutrient mobilization. Green manuring reduces pH (Katyal, 1977) and suppresses ammonia volatilization (De Datta, 1990).

Finally organic manure decomposition produces organic compounds and promotes mycorrhizal associations which improve soil structure and minimize soil erosion. Long term manure application produces more water stable aggregates, reduces bulk density, increased carbon content and leads to associated improvement in water holding capacity (Nambiar and Gosh, 1984).A general improvement in soil microfloral population is an important outcome of organic manure use (Gaur et al; 1984).

2.5 Rate-limiting steps in turnover of N in Eco-systems and actual use

Soil is the focal point of N cycle processes. A host of chemical and biochemical processes are involved in the turnover of N in the soil. In the internal N cycle operating in the soil, immobilization and mineralization are continuously changing the mineral N reserves of the soil. In the external cycle operating between the soil and the atmosphere, gains in soil N occur through biological N_2 fixation, nitrogen deposition or N fertilization, while loss of N is via ammonia volatilization from soil or flood water and denitrification. Mineral N in the soil is of course, also removed by crop plants. Through non-harvested crop residues and organic manures, a part of the plant N is returned to the organic pool of the soil. Finally mineral N may leach down beyond the reach of crop roots if excessive water percolation occurs.

In any given ecosystem, some N forms are readily transformed and flow rapidly through time and space whereas other forms may remain inactive over a long period having little short term impact on the system. Some processes involve different amounts of various forms of N to form products that become substrates for other N transformations. Different N transformation processes are subject to constraints related to physical and biological environment actual pathways followed and their rate-limiting steps vary with geographical location and season. Factors controlling rate-limiting steps in different processes can therefore be environmental conditions inhibition of lack of substrate or lack of essential co-factors (Singh and Singh, 1993).

2.6 Mineralization-Immobilization Turnover (MIT) in Soils

The transformation that N undergoes between entering and leaving the soil system can be adequately described through two individual processes i.e. mineralization and immobilization. Mineralization-immobilization turnover occur simultaneously in soil and the amount of mineral N found at any time represents the difference in the magnitude of the two opposing processes (Singh and Singh 1993).

Mineralisation and immobilization turnover is the result of complex interactions between microbial populations and activities. It is affected by many factors including composition of soil organic matter, environmental factors particularly moisture and temperature and soil factors. Variations in environmental parameters such as drying and rewetting (Argawal et al., 1971), freezing and thawing (Campbell et al, 1971) or fluctuating temperatures appear to be particularly important. These phenomena often cause a flush in microbial activity and N mineralization. Fluctuations in environmental conditions can cause death of a significant proportion of the biomass and the dead biomass is readily mineralized by the surviving microflora.

2.6.1 Effect of Substrate Quality on MIT

Regulation of the extent of the two opposing processes in MIT and the resulting net effect usually depends on the ratio between the carbonaceous material (energy source) and the N in the organic matter. Well balanced nutritional conditions of the soil biomass in a normal arable soil are represented by a C/N ratio of 25 when immobilization and mineralization are about in equilibrium (Vlek and Craswell, 1981). Therefore, organic materials having C/N ratio greater than 30 result in net immobilization by microorganisms. On the other hand, organic materials with C/N ratios below 20 lead to increased mineral N levels through mineralization.

When rapid decomposition occurs under conditions favorable for microbial activity, mineral-N is consumed by microorganisms resulting in net immobilization of N. However, when the C/N ratio of the decomposing material gets lowered to about 20, there occurs a net mineralization. Apart from N content, other important indices of substrate quality include concentration of polyphenols and particularly, lignin.

2.7 Nitrification

Ammonium N mineralized from, organic matter and other organic products or gained by soil through N_2 fixation and additions of fertilizers and manures, is either assimilated by microorganisms or plants or oxidized to NO_3^- by processes called nitrification. In the context of MIT, it is interesting to note that although heterotrophic microorganisms prefer NH_4^+ over NO_3^- during immobilization, yet NO_3^- is utilized when $NH_4^+$is lacking (Tisdale et al., 2002).

The rate-limiting step of N mineralization at pH 7 is the conversion of organic N to NH_4^+. The two subsequent step conversion of NH_4^+ to NO_2^- by *Nitrosomonas* and NO_2^- to NO_3^- by *Nitrobacter* comprising the process of nitrification are faster and rarely limit the rate of production (Smith, 1982). There is considerable evidence that a limiting supply of NH_4^+ regulates nitrification in many ecosystems (Singh and Singh, 1993). Under submerged soil conditions, limited nitrification takes place.

2.8 Ammonia Volatilization

Rapid changes in NH_4^+ level can be observed due to chemical volatilization of NH_3. Overall rate of ammonia volatilization can be controlled by any one step in the chain represented by:

$$NH_4^+ \rightarrow NH_{3(aq)} \rightarrow NH_{3(g)} \rightarrow NH_{3(atm)}$$

Conversion of NH_4^+ in soil solution to $NH_{3(aq)}$ is an extremely rapid first order process (rate constant 24.6/sec) (Emerson et al., 1960) and is, therefore, rarely a rate limiting step in the overall process. $NH_{3(aq)}$ changes linearly with temperature and increases about 10-fold with every unit increase in pH up to pH 9 (Vlek and Stumpe, 1978). Ammonium ions interact with soil cation exchange complex or may get fixed in clay lattice and also enter into equilibrium reactions with $NH_{3(aq)}$. According to Hayens and Sherlock (1986), it is the conversion of

NH_4^+ to $NH_{3(aq)}$ that normally regulates potential loss of NH_3 through volatilization when N in the form of urea is applied to the soil.

2.9 Denitrification

Nitrate-N is lost rapidly from the soil via denitrification when (i) bacteria possessing the metabolic capability for denitrification are present, (ii) suitable electron donors such as organic C compounds, reduced S compounds or molecular hydrogen are available, (iii) conditions are anaerobic or O_2 availability is restricted, and (iv) there is a supply of NO_3^- to serve as terminal electron acceptor. The occurrence of denitrification in various environments depends on the interaction of many limiting factors. As a result, high rates of denitrification from soil are frequently observed as ‘short pulses’ which occur when soil conditions become congenial (Aulakh et al., 1992).

Several studies have reported that increases in C content of the system increases the denitrification potential of the soil provided other factors are favorable. Significant correlations have been observed between denitrification and the content of available C in the soil, water soluble C, mineralizable C assessed under anaerobic conditions, and total C (Singh and Singh 1993). In the rhizosphere, denitrification may be related to plant photosynthesis. The effect of moisture on denitrification is largely due to its effect on aeration but as temperature decreases, the minimum soil water content for denitrification to occur is increased (Singh et al; 1988).

2.10 Factors affecting Nitrification/Denitrification in soils

The rapidity and the extent of nitrification and denitrification is greatly influenced by soil environmental conditions because of the involvement of microbial activity. Generally, the environmental factors favoring the growth of most upland agricultural plants are those that also favor the activities of nitrifying or denitrifying bacteria. Factors affecting nitrification in soils are mainly (1) supply of both NH_4^+ and/or NO_3^-, (2) population of microorganisms, (3) soil pH, (4) soil aeration, (5) soil moisture and (6) Temperature (Tisdale et al., 2002).

2.10.1 Supply of NH_4^+/NO_3^-

The supply of NH_4^+ is the first requirement for nitrification. If conditions do not favor mineralization of NH_4^+ from organic matter or if NH_4^+ containing/or forming fertilizers are not added into the soil, nitrification does not occur. Temperature and moisture levels that enhance nitrification are also favorable to ammonification. In the same way, a good supply of NO_3^- and/ NO_2^- in soil is a prerequisite for denitrification and exert a strong influence on the ratio N_2O to N_2 in the gases released from the soil by denitrification (Tisdale et al., 2002)

2.10.2 Population of microorganisms

Soils differ in their ability to nitrify NH_4^+ even under similar conditions of temperature, moisture and the level of added NH_4^+. One factor that may be responsible is the variation in the numbers of nitrifying organisms present in different soils. The presence of different sized populations of nitrifiers results in differences in the lag time between the addition of the NH_4^+ and the buildup of NO_3^- in the soil. Because of the tendency of microbial populations to multiply rapidly in the presence of an adequate supply of C, the total amount of nitrification is not affected by the number of organisms initially present in the soil provided that temperature and moisture conditions are favorable for sustained nitrification (Tisdale et al., 2002).

2.10.3 Soil pH

Nitrification/denitrification takes place over a wide range in pH (4.5-10). However, for nitrification, the optimum pH is 8.5. The nitrifying bacteria need an adequate supply of Ca^{2+} and $H_2PO_4^-$ and a proper balance of micronutrients. Denitrification is markedly influenced by soil acidity because many of the bacteria responsible for it are sensitive to pH especially low pH values. As a result many acid soils contain small populations of denitrifiers. Denitrification is very negligible in soils of low pH (below pH 5.0), but very rapid in high-pH soils (Tisdale et al., 2002; Singh and Singh., 1993).

2.10.4 Temperature

Denitrification is very sensitive to soil temperature, and its rate increases rapidly in the 2^oC to 25^oC temperature range. Denitrification will proceed at slightly higher rates when the temperature is increased in the range of 25^oC to 60^oC. It is inhibited by temperatures above 60^oC. The rapid increase in denitrification at elevated soil temperatures suggests that thermophilic microorganisms play a major role in denitrification.

The temperature coefficient, Q_{10}, of N mineralization is 2 over the range 5^oC to 35^oC. Thus a two-fold change in the mineralization rate is associated with a shift of 10^oC within this temperature range. Below 5^oC and above 40^oC, the rate of N mineralization declines, with the optimum commonly lying between 30^oC and 35^oC. Significant amounts of NO_3^-however, form in just months when the temperature ranges between $0^o$and 2^oC. Optimum temperature for nitrification of NH_4^+ to NO_3^- is between 25^oC and 35^oC, although nitrification can occur over a wide temperature range.

2.10.5 Effects of soil aeration on Nitrification and Denitrification

The aerobic nitrobacteria will not produce NO_3^- in the absence of O_2. Soils that are coarse textured or possess good structure facilitate rapid exchange of gases and ensure adequate supply of O_2 for nitrobacteria (Tisdale et al., 2002; Singh and Singh, 1993).

Aeration or O_2 availability affects denitrification in two apparently contrasting ways. Formation of NO_3^- and NO_2^- is dependent on an ample supply of O_2. Their denitrification, however, proceeds only when the O_2 supply is too low to meet microbiological requirements (Tisdale et al., 2002).

2.10.6 Effects of soil moisture on the Nitrification/Denitrification

Nitrobacterial activity is sensitive to soil moisture. The rates of nitrification are generally highest at soil water contents equal to 1/3 bar matric suction. Water occupies about 80 to 90% of the total pore space at this matric suction (Tisdale et al., 2002).

Of the various environmental conditions, soil water content is one of the most important denitrfication losses. Waterlogging of soil results in rapid denitrification by impeding the diffusion of O_2 to sites of microbiological activity (Tisdale et al., 2002).

2.11 Influence of nitrogen on plant development

Nitrogen is an integral component of many compounds, including chlorophyll and enzymes, essential for plant growth processes. It is an essential component of amino acids and related proteins, which are critical not only as building blocks for plant tissue but also in the cell nuclei and protoplasm in which hereditary control is vested. Nitrogen is essential for carbohydrate use within plants and stimulates root growth and development as well as the uptake of other nutrients (Brady and Weil, 2001).

Plants respond quickly to applications of nitrogen. This element encourages aboveground vegetative growth and gives a deep green color to the leaves. It increases the plumpness of cereal grains and tends to produce succulence, a quality particularly desirable in crops such as lettuce and radishes. Nitrogen deficiency is evident when the older leaves of plants turn yellow or yellowish green and tend to drop off (Brady and Weil, 2001).

When too much nitrogen is applied, excess vegetative growth occurs, and the plants lodge (fall over) with the slightest wind. Crop maturity is delayed, and the plants are more susceptible to diseases and insect pests (Brady and Weil, 2001). However, not all plants are harmed by large amounts of nitrogen. Many crops such as the cereals (e.g. maize) and vegetables need nitrogen in large quantity for optimum development. Detrimental effects to vegetable crops and grasses should not result unless excessive quantities of nitrogen are applied or nitrate levels in the foliage become toxic to humans or other animals.

2.12 Forms of N absorbed by plants

Plants absorb both NH_4^+ and NO_3^-. Nitrates generally occur in higher concentrations than NH_4^+, and it is free to move to the roots by mass flow and diffusion. Some NH_4^+ is always present and will influence plant growth and metabolism in ways that are not completely understood (Tisdale et al., 2002). Preference of plants for either NH_4^+ or NO_3^- is determined by the age and type of plant, the environment, and other factors. Cereals, sugar and some other crops use either forms of N, while others like kale prefer NO_3^- (Tisdale et al, 2002). The rate of NO_3^- uptake is usually high and is favored by low-pH conditions. When plants absorb high levels of NO_3^-, there is an increase in organic anion synthesis within the plant coupled with a corresponding increase in the accumulation of inorganic cations (Ca^{2+}, Mg^{2+} and K^+). The growth medium will become alkaline, and some HCO_3^- can be released from the roots to maintain electro neutrality in the plant and in the soil solution (Tisdale et al., 2002).

There are many reports of net alkalization of growth medium associated with nitrate uptake suggesting an involvement of antiport system of $OH^-_{(o)}/NO_3^-{}_{3(i)}$. There is likelihood, however, of alkalization being more related to OH^- efflux with nitrate reduction rather than a direct mechanistic relationship with nitrate uptake (Nair et al., 1993).

Ideally, NH_4^+ is the preferred N source since energy will be saved, when it is used instead of NO_3^- for the synthesis of protein. Nitrate reduction is an energy-requiring process that uses two NADH molecules for each NO_3^- ion reduced in protein synthesis. Also NH_4^+ is less subject to losses from the soil by leaching and denitrification (Tisdale et al., 2002).

Plant growth is often improved when the plants are nourished with both NO_3^- and NH_4^+ compared to either NO_3^- or NH_4^+ alone. There is increasing evidence that mixtures of these forms are beneficial at certain growth stages for some genotypes of corn, sorghum, soybeans, wheat and barley (Tisdale et al., 2002).

Nitrogen in soils occurs as inorganic or organic N, with 95% or more of total N in surface soils present as organic N (Tisdale et al., 2002). However, plants roots absorb nitrogen from the soil solution in the inorganic form, principally as both NH_4^+ and NO_3^- (Brady and Weil, 2001). In most soils, NH_4^+ released during soil organic matter decomposition and not immediately absorbed by plant roots or reused by microbial organisms, is rapidly transformed to NO_3^- (Paul and Clark, 1989). In this regard, nitrate abounds in most agricultural soils and as such is taken up in large quantities by plant roots compared to ammonium.

2.13 Effect of moisture on ammonium and nitrate availability to crops

Plant roots take both NH_4^+ and NO_3^- in soil solution. Generally, mineralization reactions producing NH_4^+ are less sensitive to moisture stress (Paul and Clark, 1989) and therefore accumulate in water-stressed conditions (Nye and Tinkler, 1977). In soils, concentrations of NH_4^+ are usually so low that relatively little movement occurs with flow of water (Kamprath, 2000). Quantities of NH_4^+-N can exceed those of NO_3^-- N in anaerobic soils or in soils recently treated with NH_4^+-containing or -producing fertilizers (Kamprath, 2000). This can also occur immediately after precipitation has leached out ambient NO_3^- or when nitrification has had insufficient time to convert NH_4^+ to NO_3^-.

Because moisture affects the aeration regime of the soil, the moisture status of the soil has an influence on NO_3^- production in soils (Paul and Clark, 1989). Waterlogging or moisture saturation limits diffusion of oxygen and therefore suppresses nitrification. Thus, nitrate is often the most abundant form of nitrogen that can be taken by plants in well-aerated soils (Barber., 1984). On the other extreme, nitrification is often retarded by insufficient soil moisture. Nitrate is subject to removal off site by both wind and water (Paul and Clark, 1989). Because of its ready solubility, NO_3^- more easily enters into surface runoff in addition to being leached from the root zone of most soils.

2.14 Growth stages of maize plant

Nature greatly influences maize growth and yield. However, the maize plant producer can manipulate the environment with managerial operations including hybrid selection, soil tillage, crop rotation, soil fertilization, irrigation, and pest control. A producer who understands growth and development of maize will understand the importance of timelines when using production practices for higher yields and profit (Heather and Joe, 2011).

A typical maize plant develops 20-21 total leaves, silks about 65 days after emergence and matures around 120 days after emergence. The specific time interval, however, can vary among hybrids, environments, planting date, and location. The length of time between each growth stage, therefore, is dependent upon these factors. For example, an early maturing hybrid may produce fewer leaves or progress through the different growth stages at a faster rate. In contrast, a late-maturity hybrid may develop more leaves and progress through each growth stage at a slower pace (Heather and Joe,, 2011).

The development of a maize plant is divided into two major phases: (a) the vegetative stage and (b) the reproductive stage. The vegetative stage starts from the seedling emergence up to tasseling. The reproductive stage commences at silking and pollination, up to grain-filling and maturity. Agronomists have further divided the vegetative stage by using the number of matured leaves (with expanded leaf collar) present on the maize plant. The reproductive stage starts with the fertilization of kernels and ends with grain maturity.

Fertilizer application, usually done in two batches, must be completed within the first month to aid the crop's physiological progress. By the time the plant reaches the fifth leaf stage or fourteenth after emergence, all leaves, ear, shoots and the tassel are already formed in miniature. Although the plant may be only 20 cm in height, the numbers of kernel rows on the ear have already been determined. At this time, the growing point is still at or below the soil surface protecting the young plant from yield reductions due to outside stresses ((Dynagro Seed., 2005)

The final vegetative stage is full emergence of the tassel. At this point, the maize plant has nearly attained its full height. The 14-day period before and after silking is crucial to final yield. Growing conditions that place the plant under stress will reduce yield, since final plant elongation, and ear development will be affected. When the maize plant reaches silking, with good fertility, good water reserves and no physical damage, growers will be well on their way to an excellent crop (Dynagro Seed, 2005).

2.15 Growth analysis in maize

The primary measurements that must be made to enable an analysis of growth include leaf area, total dry weights, and often, the dry weights of the leaves, stems, and roots. These values are usually measured at intervals of one, two or three weeks, throughout the growth period of the crop (Blake et al, 1967).The response of maize to applied nitrogen levels has been found to be governed by the moisture stored in the soil (Quaye, 1999). Power (1990) also noted that available soil water has a dominating effect on the utilization of soil nitrogen by plants.

Quaye (1999) observed a strong interaction between nitrogen and water content on the dry matter yield (Leaf, stem and root) production in maize. Total dry matter yield increased significantly with increasing rate of nitrogen application and soil moisture availability. ArunKumar et al. (2007) observed that increases in maize yield are usually closely related to the amount of nitrogen applied to the crop. Das Gupta and Sen (1969) also observed that there is an optimum water and nitrogen combination for best crop yield in maize.

2.15.1 Net assimilation rate in maize

The most usual measure of average photosynthetic capacity is the net assimilation rate which is defined as the actual gain in dry matter per unit leaf area per unit time.It is apparent that the net assimilation rate is an average value for all leaves of the plant and thus overestimates the efficiency of some leaves and underestimates the efficiency of others. Although not strictly correct in many situations, the arithmetic mean of the leaf areas at the start and end of the period is a common approximation (Blake et al., 1967).

2.15.2 Leaf area index

Development of adequate leaf area index is essential for a crop canopy with respect to light interception and utilization, CO_2 fixation and dry matter production. At early stages of crop growth, rapid leaf area development not only covers the ground to enhance light interception but also checks soil water loss through evaporation and weed growth (Sivasanakar et al., 1993). In maize, Meeker et al. (1974) found that there is little N accumulation in leaf after it had reached its full expansion stage.

If the leaves were all horizontal and arranged so that no two leaves overlapped, then a leaf area index of 1 or 100 percent would give complete ground cover. The leaf area index is basically a measure of leafiness and is defined as the area of leaf surface per unit area of ground surface (Blake et al., 1967).In practice, the leaf angle, leaf spacing and the habit of the plant are all complicating factors, but even so, for a given crop, the leaf area index is a useful guide to the amount of leaf surface exposed to sunlight and in which photosynthesis can occur (Blake et al., 1967).

2.16. Relationship between crop growth indicators, age and the environment

Net assimilation rate is a measure of dry matter gain per unit leaf area per week or day, and the mean leaf area index is a measure of leaf area per unit ground surface. It, therefore, follows that the crop growth rate is directly proportional to the net assimilation rate and the leaf area index. Any increase in yield can thus be analyzed in terms of net assimilation rate or leaf area index (Sivasanakar et al. 1993).The net assimilation rate for a whole plant declines at the plant ages. Even for individual leaves, the value of the net assimilation rate falls regularly and rapidly (Chatterjee et al., 1981).

The proportion of heterotrophic tissues such as roots, woody stems, and the storage tissues increases as a plant ages and this leads to increased losses through respiration, and so to a reduced net assimilation rate of gain in dry matter. The capacity of leaves for photosynthesis declines as the plant ages and the combined effect of these two factors is a rapid decrease in the rate of net assimilation of the plant as a whole (Field and Mooney., 1986).

Net assimilation rate is also influenced by the environment. Because the net assimilation rate is a measure of the surplus of photosynthesis over daily respiration, factors that affect the rate of photosynthesis and rate of respiration also affect the net assimilation rate. Without exception, light intensities below the saturation value for a given species produce a lower net assimilation value (Blake et al., 1967).

Leaf area index has an apparent inverse relationship with the net assimilation rate. This is partly a result of increased self-shading, and partly because leaf area index and average leaf age both increase with time. High temperatures during the day and low temperatures at night give maximum net assimilation rates. Provided mineral deficiencies are not limiting, increasing the mineral nutrient status, even though it may dramatically increase the leaf area, has only a slight effect on the net assimilation rate (Blake et al., 1967).

Leaves developed under low light conditions tend to be larger, within limits; but the increase in area is rarely sufficient to offset the decline in long term net assimilation rate caused by this reduced light intensity.

2.16.1 Relationship between chlorophyll content and maize yield

Since the early 1960s, scientists have looked for natural short-cuts to estimating productivity based on the biophysical characteristics of vegetation related to photosynthesis. Among them was the total chlorophyll content per unit area (Whittaker and Marks, 1975). It has been shown that canopy chlorophyll is a very direct expression of the photosynthetic apparatus of a plant community, and that for a given species or type of community, chlorophyll content may be strongly related to productivity. Medina and Liet (1964).Osborne and Raven (1986) found a very close linear relationship between chlorophyll content and productivity in maize.

Changes in canopy chlorophyll content are related to both crop phenology and photosynthetic capacity, and may also be affected by water and thermal stresses (Ustin et al., 1998; Zarco-Tejada et al., 2002).

At the leaf level, numerous studies have demonstrated a strong link between nitrogen content and photosynthesis (Field and Mooney, 1986; Wullschleger, 1993). Baret et al.

(2007) found that canopy chlorophyll content is well suited for quantifying canopy level nitrogen content. They concluded that canopy chlorophyll content is a physically sound quantity since it represents the optical path in the canopy where absorption by chlorophyll dominates the radiometric signal.

Thus, absorption by chlorophyll provides the necessary link between remote sensing observations and canopy state variables that are used as indicators of nitrogen status. A close relationship between contents of nitrogen and chlorophyll at canopy level rather than at leaf level was also clearly demonstrated in an experiment conducted over wheat crops subjected to a range of nitrogen stresses (Houle`s et al., 2006). Total chlorophyll content was defined as the product of leaf chlorophyll content and total leaf area index (Gitelson et al., 2005; Ciganda et al., 2009).

2.17. Effects of fertilizer management and application methods on maize yield

Application of full amounts of N fertilizer prior to sowing may result in better economic returns than carrying out split N applications (Bruns and Abbas, 2005). They concluded that the economic loss due to decreased grain yield may be insignificant when compared to additional production costs associated with split fertilization, such as several trips to the field.

The most efficient time for N application is at the growth stage of 28 days after sowing when maize plants are actively developing and therefore have significant increases in N plant needs (Wells and Blitzer, 1984; Wells et al. (1992). Nitrogen uptake rate is known to be affected by many factors such as weather, planting date, and time of fertilizer application but is usually highest between 28 days and 42 days after sowing (Russelle et al., 1981). Fast development of corn plants during middle vegetative stage (after 14 days) results in maximum N uptake, meaning that even N-deficient maize should be able to respond to delayed N application (Binder et al., 2000)

Many researchers agree that the best practice in managing maize is the application of N fertilizer at the time (or near the time) when both the need for N and N uptake are maximum for maize plants (Welch et al., 1971; Stanley and Rhoads, 1977; Russelle et al., 1981; Olson and Kurtz, 1982; Aldrich, 1984). This is because it promotes higher nitrogen use efficiency by reducing denitrification, N immobilization and leaching processes.

2.18. Eco-fertilizer

Eco-fertilizer is an organic N fertilizer formulated by the Department of Soil Science, University of Ghana from agricultural waste for Eco Products Limited, Accra, Ghana. The waste materials used for the preparation of the fertilizer are *Chromolaena odorata*, Cocoa shells, Cocoa powder waste, Coconut husks and shells and pineapple peels. The materials were chopped into small pieces to aid degradation and packed into barrels and were composted anaerobically amidst intermittent turning to give the Eco-fertilizer.The fertilizer has 3%N, 3.3%P_2O_5, 4.5%K_2O, 1.0%Mg, 1.42%Fe, 0.25%Cu, an electrical conductivity (EC) of 1.2mS/cm, a pH of 7.1 and a moisture content of 7.1%. The fertilizer is powdery, light in weight and light brown in colour.

2.19 Summary of literature review

Nitrogen is perhaps the most important nutrient needed for successful agricultural production. It is added into the soil via atmospheric fixation, rainfall, lightening etc, and through application of N-based fertilizers (both organic and inorganic). Even though this very essential element is very important to farming, many farmers are unable to afford it due to economic, logistical/infrastructural constraints and above all lack of knowledge about its effective management. Fertilizer usage in the sub-region averages about 10kgN/ha, which is among the lowest in the world. The main reason for its low patronage is the cost of N-fertilizers in the market.

Alternative sources of N which are cheap, easily manageable, and environmentally friendly will go a long way to improve agricultural production. However, there seems to be inadequate knowledge about the management of organic fertilizers in Ghana. Nitrogen coming from organic sources also undergoes the same reactions as inorganic sources of N, such as mineralization, nitrification, immobilization, and volatilization. These processes are affected by environmental factors such as soil reaction, soil moisture status, temperature and mediated microorganisms. Nitrogen is usually lost through denitrification, ammonia volatilization, fixation into soil cavities gaseous losses and leaching into the subsoil.

Maize is a very important staple in the Ghanaian cuisine. It is a heavy feeder of N and therefore, continuous cropping of soils with maize (especially leads to high N exports from the soil which are not easily replaced from external sources by farmers tropical in Africa. The main indices measured to determine the N-status of plants include leaf area index, net assimilation rate, dry matter yield, chlorophyll content, height, total nitrogen content and grain yield. Most crops take N in the form of NH_4^+ and NO_3^-, and depending on energy dynamics and environmental conditions, NH_4^+-N or NO_3^- -N will dominate.

Eco-fertilizer is an organic fertilizer composted anaerobically from organic waste products to form an organic fertilizer. This fertilizer has a potential of increasing corn yields in our agricultural systems. Therefore, researching into its use in our farming systems is very crucial for agricultural production.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Soils, sampling and soil preparation

The soils used for the study were Toje series and Akuse series. The Toje series has been classified as a Ferric Acrisol(Dowuona et al., 2011) with the Akuse series as a TypicCalciustert (Eze, 2008) and neutral to alkaline. The Toje series soil is kaolinitic and acidic whereas the Akuse series is smectitic alkaline to neutral in soil reaction. The plough layer (0-20cm) of Toje series was sampled from the University of Ghana Farms, Legon. Samples from the Akuse series were collected from the University of Ghana Research Centre at Kpong. Undisturbed clod samples were collected for bulk density analysis.

All foreign materials were removed from the soils (e.g. dry leaves, roots and twigs) and the soils air dried. The two soils were then passed through a 2 mm sieve to obtain the fine earth fraction. After sample preparation, the soils were sent to the laboratory for routine physical and chemical analyses.

3.2. Physical analyses

3.2.1 Bulk density

Bulk density was determined by the clod method. Clods from the soil samples were selected and oven-dried overnight at 105 ^{o}C and upon removal, cooled in a dessicator and the oven dried weight determined on a weighing balance. A 100 mL measuring cylinder was filled with very fine river sand to the 30 mL mark amidst gentle tapping and shaking. A clod whose bulk density was to be determined was carefully placed on the river sand in the measuring cylinder. A known volume (b mL) of the river sand in a second measuring cylinder was carefully poured onto the clod in the first cylinder amidst gentle tapping and shaking until the clod was completely covered with the river sand. The final volume i.e. 30

mL + b mL + volume of clod was noted. The 30 mL + b mL volume was subtracted from the final volume to give the volume of the clod. The bulk density was then determined using the equation below:

$$BD = (\text{oven dry mass of clod}) / (\text{volume of clod}) \qquad (3.1)$$

Where, BD is the bulk density

3.2.2 Particle size distribution

Forty grams of the fine earth fraction of the soil was weighed into a plastic bottle and 100 mL of 5% calgon (sodium hexametaphosphate) solution was added. The content of the bottle was then shaken on a mechanical shaker for 2 hours after which it was transferred into a 1.0 litre measuring cylinder and topped up to the mark with distilled water. The suspension was then agitated with a plunger and five minutes thereafter, the density of the suspension (silt and clay) was taken using a hydrometer. The hydrometer reading of the suspension was taken again after eight hours (clay). The temperatures of the suspensions, T_1 and T_2 were respectively recorded during the 5 minute and 8 hour hydrometer readings. The contents of the cylinder after the eight hour reading were emptied onto a 47-µm sieve. The sand retained on the sieve was then washed off into a moisture can and dried at 105 ^{o}C for 24 hours, after which the dry weight of the sand was recorded. Blank sample hydrometer readings at five minutes and eight hours respectively were also taken for the 5% calgon topped up to 1.0 L. The particle size distribution was then determined using the formulae below.

Temperature of the suspensions at T_1 and T_2 = 28°C

$$\% \text{ Clay and Silt} = \frac{(\text{5 minute reading} - \text{correction for temperature})}{\text{oven dry mass of sample}} \text{ X } 100 \qquad (3.2)$$

$$\% \text{ Clay} = \frac{(\text{8 hour reading} - \text{correction for temperature})}{\text{oven dry mass of sample}} \text{ X } 100 \qquad (3.3)$$

$$\% \text{ Silt} = \% \text{ (Clay and Silt)} - \% \text{ Clay} \qquad (3.4)$$

$$\% \text{ Sand} = \frac{(\text{oven dry weight of particles retained on the 47 µm sieve})}{\text{oven dry mass of sample}} \text{ X } 100 \qquad (3.5)$$

Temperature effects on density of the soil particles was accounted for using the relation provided by Day (1965). For every 1°C increase in temperature, above 19.5 °C, there is an increase of 0.3 in the density of the particles in suspension.

Correction for temperature = blank hydrometer reading – increase in weight of particles

3.2.3 Soil moisture at field capacity and 75% field capacity

A 500 g soil sample was saturated with water and placed in a filter paper-lined-perforated plastic container of 15 cm diameter and 20 cm height. The top was covered with a plastic and allowed to drain for 3 days. Sub samples were then taken and oven dried at 105 ^{o}C for 24 hours. The gravimetric water content was determined as the difference in mass between moist soil and oven-dried soil per oven-dried soil. This was considered to be the moisture content of the soil at field capacity. The soil moisture content at 75% field capacity was then estimated as three-quarters of the moisture content at field capacity.

3.3. Chemical analyses

3.3.1. Soil pH

The pH of the fine earth of the two soils was determined in a 1:1 soil to distilled water ratio. A 10 g soil was weighed and 10 mL of distilled water added, stirred vigorously and allowed to stand for 30 minutes. A microprocessor pH 213 meter was calibrated, and then inserted in to the supernatant of the soil solution and the pH read. The pH in 0.01 M $CaCl_2$ solution of the soil samples was similarly determined using a 1:2 soil to solution ratio.

3.3.2. Soil organic carbon

The organic carbon content of the soil was determined using the wet combustion method of Walkley and Black (1934). Ten millilitres of 0.167 M potassium dichromate ($K_2Cr_2O_7$) solution and 20 mls of concentrated sulphuric acid (H_2SO_4) were added to a 0.5 g soil which had been passed through a 0.5 mm sieve in an Erlenmeyer flask. The flask was then swirled to ensure full contact of the soil with the solution after which the mixture was allowed to stand for 30 minutes. The unreduced $K_2Cr_2O_7$ remaining in solution after the oxidation of the oxidizable organic material in the soil sample was titrated with 0.2 M ferrous ammonium sulphate solution after adding 10 mL of orthophosphoric acid and 2 mL of barium diphenylamine sulphonate indicator from a dirty brown colour to a bright green end point. A standardization titration of the $K_2Cr_2O_7$ with the ferrous ammonium sulphate was done and the amount of organic carbon calculated by subtracting the number of moles of unreduced $K_2Cr_2O_7$ from the number of moles of $K_2Cr_2O_7$ present in the standardized titration.

3.3.3 Total nitrogen

Total N of the fine earth was determined by using the Kjeldahl digestion procedure as outlined by Anderson and Ingram (1993).A 1.00 g of 0.5 mm-sieved fine earth was weighed into a digestion tube, followed by addition of 5 mL concentrated H_2SO_4. The mixture was heated at low heat on a digestion block for 30 minutes, and then 2 mL of hydrogen peroxide was added. The heating temperature was then increased to 360 ^{o}C and maintained till the mixture changed to a permanent colourless solution. The digest was cooled, transferred and made up to volume with the aid of distilled water in a 100 mL volumetric flask

A 20 mL aliquot was transferred into a tecator distillation flask, 10 mL of 40% NaOH solution added and distilled. The ammonia liberated was condensed and collected in a 10 mL boric acid to which bromocresol green and methyl red solution indicator had been added. The distillate was then back titrated with 0.01 M HCl solution. Similar procedure was adopted for a blank which had no soil sample to account for traces of N if any, in the reagents and water used. The concentration of N in the soil was estimated from the number of moles of HCl consumed in the reaction with ammonium borate formed when the ammonia was trapped in boric acid.

3.3.4 Available nitrogen

Five grams of the soil sample was weighed into a 100-mL centrifuge bottle and 50 mLof 2 M KCl solution added. The contents were shaken for 30 minutes on a mechanical shaker after which the sample was filtered through a Whatman No. 42 paper. Five millilitres of the filtrate was pipetted into a 100 mL micro Kjeldahl flask and 0.2 g of MgO was added. The flask was connected to a distillation apparatus and about 30 mL of the distillate was collected in 5 mL of 2% boric acid to which three drops of methyl red – methylene blue indicator mixture had been added. The distillate was then back titrated against 0.01 M HCl to a purplish end point for ammonium-N determination.

One millilitre of sulphamic acid and 0.2 g Devarda's alloy were then added to the contents of the flask and the distillate collected in a new conical flask containing 5 mL of 2 % boric acid and three drops of the mixed methyl red and methylene blue indicator. The distillate was then back titrated against 0.01 M HCl from a green to a purplish end point to account for the level of nitrate in the soil. The respective concentrations of NH_4^+ and NO_3^- in the soil were then determined from the number of moles of HCl consumed in the two back titration reaction.

3.3.5 Available phosphorus

Available phosphorus was determined by the method of Bray1 (Bray and Kurtz, 1945) for the Acrisol and the Olsen et al. (1954) method for the Vertisol. In the Bray 1 method for available P determination of the Acrisol, a 5g soil sample (fine earth fraction) was taken and 50 mL of Bray's extractant (0.03M NH_4F and 0.025M HCl) added. The mixture was shaken for 5 mins and allowed to stand for 5 mins for the soil particles to settle. The supernatant was then passed through a Whatman No. 42 filter paper to get a clear solution.

The method of Murphy and Riley (1962) was then used for colour development. An aliquot of 1mL of the sample solution was pipetted into a 50 mL volumetric flask and a drop each of P-nitrophenol and ammonium hydroxide were added. Then, 8 mL of a solution containing concentrated sulphuric acid, ammonium molybdate, potassium antimony tartrate, and ascorbic acid were added. The content was topped up to the 50 mL mark with distilled water. The concentration of phosphorus was then determined on a Philips' UV spectrophotometer at a wavelength of 712 nm.

In the Olsen et al. (1954) method for the P concentration in the Vertisol, two and a half grammes of each sample was weighed into 250 mL conical flask. Fifty millilitres of 0.5 M $NaHCO_3$ (pH 8.5) was added and the suspension shaken on a reciprocating shaker for 30 minutes. The suspension was then filtered into vials through a Whatman No. 42 filter paper. The extract was then analysed for available P using the Murphy and Riley method (1962) as described above.

3.3.6 Cation Exchange Capacity

Five grams of the fine earth fraction of the soil was weighed into an extraction bottle and 50 mL of 1.0 M ammonium acetate at pH 7.0 added. The contents were then shaken for 30 minutes and filtered through a Number 42 Whatman filter paper. The non-adsorbed NH_4^+ was then washed off with methanol and the NH_4^+ saturated soil leached four times with acidified 1.0 M KCl. A 10 mL aliquot was transferred into a tecator distillation flask and distilled to liberate NH_3 into 2% boric acid as described in Section 3.3.3 for total nitrogen determination. The ammonium ion concentration (mol / L) in the KCl filtrate was determined and the CEC of the soil in $cmol_{(c)}$ / kg estimated.

3.4. Greenhouse experiment

The greenhouse used for the study is located at the Department of Crop Science, College of Agriculture and Consumer Sciences, University of Ghana, Legon. Daytime temperatures in the greenhouse ranged from 32 to 35°C.The relative humidity of the greenhouse was between 63and 84%. Exactly 8.0 kg of the Vertisol and 9.7 kg of the Acrisol were weighed into plastic buckets with perforated bottoms to a predetermined height to attain the field bulk density of the two soils. The packed soils were left undisturbed for three weeks prior to the application of treatments to allow for stabilization of microbial activity.

Each soil was kept at two moisture contents of field capacity (FC) and 75% field capacity. Maize of variety Obatampa was sown at three seeds per pot and one week after sowing, two N fertilizers; one organic (Ecological fertilizer), having 3%N and an inorganic fertilizer , $(NH_4)_2SO_4$ were surface applied at three rates of 0, 20 and 40 kg/ha. Each treatment was replicated three times and the pots were arranged in a randomized complete block design pattern, giving a 2×2×2×1×3x3 factorial experiment. There were thus a total of 72 pots. The whole experiment lasted for 10 weeks. The equivalent amounts of the fertilizers in grammes applied to the soils are given in Table 1.

Table1. Fertilizer application rates and equivalent amounts (g) applied per pot.

	--------Organic Fertilizer----------			-----------Inorganic Fertilizer-------		
	--------------------------------Application rate (kg/ha) -------------------------------					
Soil	0	20	40	0	20	40
Akuse	0	1.9	3.8	0	0.27	0.54
Toje	0	2.7	5.4	0	0.39	0.78

3.5. Soil and plant sampling

Soils were sampled from the various pots twice during the growing season for available N determination. The first sampling was done 28 days after sowing (DAS) and the second sampling 65 days after sowing (DAS). Three replicate samples were taken from the upper 7 cm of each soil in the pot. On the first soil sampling day, plant height, chlorophyll content of the leaves and the leaf area were also taken. The heights of the plants were measured with a metre rule whilst the chlorophyll content was measured with a chlorophyll meter. On the second soil sampling day the aforementioned plant parameters were again taken after which the maize plants in the various pots were carefully removed ensuring as much as possible that the plants with the roots were intact. All extraneous materials, especially the soil around the roots, were washed off. The plants were put in paper envelopes and dried in the oven at 65 °C until a constant weight was attained (i.e. 48 hours). The dry matter yield was then estimated from the oven dried weight. The oven dried maize plants were milled and then analyzed for their total nitrogen contents.

3.6 Organic fertilizer analysis for nitrogen

A 0.05 g sample of the organic fertilizer was weighed into a conical flask and 10 mL of concentrated H_2SO_4 added. The mixture was then heated slowly and drops of H_2O_2 added until the mixture became colourless. The digest was allowed to cool and a small volume of distilled water added. The digest was then decanted into a 50 mL volumetric flask and topped to the mark with distilled water. A 20 mL aliquot was transferred into a tecator distillation flask and the procedure outlined in section 3.3.3 for N distillation and estimation employed.

3.7 Maize plant parameters

3.7.1 Total nitrogen

An amount of 0.1 g of each of the substrates was weighed into separate conical flasks and 10 mL of concentrated H_2SO_4 added. Each mixture was then heated slowly and drops of H_2O_2 added until the mixture became colourless. The digest was allowed to cool and a small volume of distilled water added. The digest was then decanted into a 50 mL volumetric flask and topped to the mark with distilled water. The N content was then determined as outlined in section 3.3.3.

3.7.2 Leaf area index (LAI)

The leaf area of the maize plant per unit area was measured using a leaf area meter and the leaf area index estimated using the formula below:

$$\text{LAI} = \frac{Leaf\ area\ (m^2)}{Land\ area\ (m^2)} \times 100 \qquad (3.8)$$

3.7.3. Measurement of plant height and Dry Matter Yield

Plant height was measured at 28 and 65 days after sowing using a meter rule. The maize plant was uprooted after 65 days of sowing and shoot cut off from the root system. . Thereafter the shoot was chopped into smaller pieces to facilitate drying ,packed into quarto-sized envelops and dried in an oven at 65°C for 72 hours. The oven-dried shoots were allowed to cool in a desiccator, and the weights determined on a weighing scale.

3.7.4. Net assimilation rate

The net assimilation rate was determined by the formula given by Blake (1967)

$$NAR = \frac{TDM}{LAD} \qquad (3.6)$$

Where TDM is total dry matter yield and LAD is leaf area duration.

Leaf Area Duration (LAD) was calculated by the formula of Blake (1967) thus,

$$\text{LAD} = (\text{LAI}_1 + \text{LAI}_2) \times (\text{T}_1 - \text{T}_2) / 2 \qquad (3.7)$$

Where $\text{LAI}_1$is leaf area index at T_1,

$\text{LAI}_2$is leaf area index at T_2,

T_1 is the time of first observation (28 days after sowing) and

T_2 is the time of second observation (65 days after sowing.

3.8 Data analyses

The concentrations of soil and plant parameters analyzed and determined were subjected to analysis of variance (ANOVA) using Genstat 9 to establish treatment effects.

CHAPTER FOUR

RESULTS

4.1 Characterization of soil

The physical properties of the Toje and Akuse series used for the fertilizer trial are presented in Table 2. The Toje soil has a higher sand content (51%) than the Akuse series (33%). The silt contents of the two soils were similar with values of 16.8% and 12% respectively for Toje series and Akuse series, respectively. The clay content was, however, 22.5% higher in the Akuse series (55%) than the Toje series (32.5%). The two soils also have medium dry bulk density of 1.2 and 1.4 Mg/m^3 respectively, for Toje series and Akuse series.

Table 3 shows some chemical properties of the two soils used for the study. The Toje soil is slightly acidic with the pH in H_2O value of 5.8 similar to that recorded by Danso (2010). The Akuse soils had a neutral pH value of 7.5 in water. The Toje soil has a low organic carbon content of 7.6 g/kg typical of Ghanaian savannah soils. Total nitrogen content of the soil was consequently low (0.5 g/kg) and similar to the 0.6 g/kg reported by Danso (2010) for Toje series. The Toje soil has a low available P content of 6.0 mg/kg which is consistent with values obtained for similar soils in the landscape (Darko, 2007). The Akuse soil has a higher organic carbon content of 9.5 g/kg with corresponding higher total nitrogen and available nitrogen contents of 0.91 g/kg and 1.3 mg/kg, respectively. The CEC of the Akuse soil is very high (33.32 cmol$_{(c)}$/kg) and about six times higher than the Toje soil (7.6 cmol$_{(c)}$/kg)

4.3 Effect of Management on Maize Growth Parameters

The organic and inorganic fertilizers were surface applied at rates of 20 kg/ha and 40 kg/ha and at field capacity and 75% FC. This section seeks to look at the effect of these

Table 2. Some physical properties of the two soils

Soils	Bulk Density	Sand	Silt	Clay	Textural Class
	Mg/m^3	--------%-------------			
Toje	1.2	50.7	16.8	32.5	Sandy clay loam
Akuse	1.4	33.0	12.0	55.0	Loamy Clay

Table 3 Some Chemical properties of the two soils

Soils	pH		Avail.P	Total N	NH_4-N	NO_3-N	Organic C	C/N ratio	CEC
	H_2O(1:1)	$CaCl_2$ (1:2)	(mg/kg)	(g/kg)	--------mg/kg-------		(g/kg)		(cmol$_c$/kg)
Toje	5.8	4.9	6.0	0.5	0.96	0.23	7.6	15.2	5.72
Akuse	7.5	6.8	8.95	0.91	0.78	0.52	9.5	10.5	33.3

*CEC = cation exchange capacity

Management practices on agronomic parameters like leaf area index, chlorophyll content, height, net assimilation rate total nitrogen in the plant and dry matter yield. The critical stages of N availability in the soils for maize growth are at 28 and 65 days after sowing (Wells and Blitzer, 1984; Wells et al., 1992) and therefore, the aforementioned parameters were measured on these two days after sowing. The effect of moisture content of soil (FC and 75% FC on surface application of fertilizer on the aforementioned agronomic parameters of maize are presented in Tables 3 and 4.

4.3.1 Effect of moisture content at FC on Leaf Area index (LAI)

The leaf area indices after 28 days of sowing (LAI-1) in the non-amended soils was on the average 12.8 and 1.96 respectively, for the Akuse series and Toje series (Table 4). From Table 4, it is also seen, that LAI-1 of the maize plants generally increased with increasing application rate in the two soils for the two fertilizers. The LAI at 28 days after sowing (LAI-1) was also higher in the Akuse series (Vertisol) than the Toje series (Acrisol). When the organic amendment was surface applied at FC in the Akuse series, the LAI-1 was 17.5 and 18.5 respectively at 20 kg/ha and 40 kg/ha as compared to 2.45 and 12.53 for the same rates in the Toje series. It is worthy to note that when the two fertilizers were surface applied at 20 kg/ha to Akuse series, the LAI-1 was significantly higher ($p< 0.05$) in the organic fertilizer than its inorganic counterpart while, there was no significant difference in LAI-1 of the two fertilizers at 40 kg/ha. In the Toje series, however, LAI-1 was similar at 20 kg/ha for the two fertilizers but was higher in the organic fertilizer than the inorganic one at 40 kg/ha.

There were general significant increases with increasing organic fertilizer application rate in LAI at 65 days after sowing (LAI-2), in the Akuse series. These increases were approximately twice those recorded at 28 days after sowing (LAI-1). In the Toje series, LAI-

Table 4 Agronomic parameters of maize grown in the two soils when fertilizers were surface applied at field capacity.

Soil		LAI-1	LAI-2	CH-1 (SPAD)	CH-2 (SPAD)	TN (g/kg)	NAR (g m^{-2} day^{-1})	H-1 (cm)	H-2 (cm)	DMY (g)
	Eco-fertilizer									
Akuse	0kgN/ha	13.30	12.63	101.3	131.7	9.60	0.0183	10.50	81.0	15.04
	20kgN/ha	17.50	34.13	218.3	139.7	16.20	0.0367	10.83	99.33	30.87
	40kgN/ha	18.50	41.81	251.0	174.3	32.37	0.0505	15.20	101.0	48.74
	Ammonium Sulfate									
	0kgN/ha	12.30	12.17	113.0	131.2	10.67	0.0478	11.00	79.2	14.38
	20kgN/ha	14.17	27.21	197.5	141.4	27.40	0.0680	13.77	146.33	28.31
	40kgN/ha	16.23	37.37	229.7	181.8	31.97	0.2803	20.87	160.33	41.25
	Eco-fertilizer									
Toje	0kgN/ha	1.95	10.70	67.4	55.70	7.07	0.0643	8.04	45.00	11.46
	20kgN/ha	2.45	17.81	123.7	72.70	14.23	0.0549	10.47	55.67	15.75
	40kgN/ha	12.53	19.21	132.1	115.0	18.97	0.1837	11.78	62.67	25.58
	Ammonium Sulfate									
	0kgN/ha	1.97	10.48	69.3	67.0	7.23	0.0338	9.00	44.00	10.48
	20kgN/ha	2.73	16.77	179.4	91.6	14.79	0.0549	9.88	59.67	16.22
	40kgN/ha	9.73	11.32	196.2	109.2	19.21	0.1717	10.47	62.67	24.40
L.s.d (0.05) =		1.985	9.719	7.35	11.43	5.269	0.0118	3.834	18.75	11.436

*LAI-1 = Leaf area index at 28 days after sowing, LAI-2=Leaf area index at 65 days after sowing, CH-1=Chlorophyll content at 28 days after sowing, CH-2 = Chlorophyll content at 65 days after sowing, TN= Total Nitrogen, NAR = Net Assimilation Rate, H-1= Height at 28 days after sowing, H-2 = Height at 65 days after sowing, DMY= Dry matter yield.

2 in the two amended soils were statistically the same as fertilizer rate increased and did not also differ significantly from values recorded for the control. The LAI-2 values for the Toje series were, however, generally higher than LAI-1.

4.3.2 Effect of moisture content at field capacity on chlorophyll content

There were general increases in the chlorophyll content at 28 days after sowing (CH-1) in the two soils with increasing rate of fertilizer application (Table 3). The CH-1 of plants in the non amended soil was higher in the Akuse series than the Toje series. It was between 101.3 and 113 in the Akuse series compared with between 67.4 and 69.3 SPAD for the Toje series. The CH-1 was also higher in plants grown on the Akuse series at all the application rates for the organic fertilizer than the inorganic one. On the contrary, CH-1 was higher in inorganic fertilizer than the organic one for the Toje series.

At 65 days after sowing, the chlorophyll content (CH-2) was higher by 30.4 SPAD than CH-1 for the non amended Akuse soil. The CH-2 increased with increasing application rate of the two fertilizers in the two soils. Unlike at 28 days where the chlorophyll content was higher in the organic fertilizer treatments than the inorganic counterpart, at 65 days the chlorophyll contents in the maize plants for the two fertilizers were the same. However, the CH-2 values were lower than the CH-1 values for the Akuse series.

In the Toje series, the CH-2 was also lower than values recorded for CH-1. It was only at 20 kgN/ha that the inorganic fertilizer recorded higher chlorophyll contents than the organic one, otherwise the CH-2 level were statistically the same.

4.3.3 Effect of moisture content at field capacity on plant height

The height of the maize plant in the non-amended soils 28 days after sowing (H-1) were statistically the same and ranged between 8.04 and 11.00 cm (Table 3). When the soils were amended with the two fertilizers at 20 kg/ha, there were still no significant changes in height as the heights ranged between 9.88 cm and 13.77 cm. At 40 kg/ha in the Akuse series, there were significant increases in plant height of the maize plants for both fertilizers. These increases were higher in the inorganic fertilizer amended soil than its organic amended counterpart. However, in the Toje series, there were still no changes in plant height from that of the non-amended soil.

Plant height at 65 days after sowing (H-2) was between 79.2 and 81 cm for the non-amended Akuse soil and these were significantly higher than those of plants in the Toje soil (44 cm – 45 cm). In the organically amended soils, the plant height did not change significantly from that of the non-amended soil when the fertilizer was applied at 20 kg/ha. However, at 40 kg/ha application rate of the amendment, there was significant increase in height from 81 cm to 101 cm. When the Akuse series was amended with the inorganic $(NH_4)_2SO_4$ fertilizer, there were significant increases in height from that of the non-amended soil at the two application rates. This increase in height was, however, not significant between the two rates of fertilizer application. The H-2 in the Toje series did not change from that of the non-amended soil even with increasing application rates of the two fertilizers.

4.3.4 Effect of moisture content at field capacity on Net Assimilation rate and Dry matter Yield

The net assimilation rate which is the rate of plant biomass increment per unit leaf area (Blake et al., 1967) was taken at 65 days after sowing and just like the LAI-2 and CH-2, it increased with increasing application rate for the two amendments in the two soils. In the Akuse series, the NAR were significantly higher in the inorganic fertilizer than in the organic fertilizer as the plant fertilized with the inorganic fertilizer recorded values of 0.068 and 0.28, respectively, at 20 kg/ha and 40 kg/ha compared to the 0.0367 and 0.0505 for the organic fertilizer at the same rates. However, these higher increases in NAR in the inorganic fertilizer treated soil over the organic fertilizer treated soil in Akuse did not reflect in dry matter yield (DMY) as DMY at any rate of fertilizer application was statistically the same. The plants under the two fertilizers in the Akuse series did not record any statistical differences in dry matter yield (DMY). At 20 kg/ha and 40 kg/ ha for the Eco fertilizer, the DMY was, respectively, 30.87 and 48.74 which were not significantly different from the 28.3 g and 41.25 g DMY at the same rates for the inorganic fertilizer

In the Toje series, the NAR values were statistically the same for both fertilizers at each of the two application rates and this reflected in statistically similar DMY of between 15.75 g and 16.22 g at 20 kg/ha and 24.4 g and 25.58 g at 40 kg/ha. The NAR values at each application rate for the organic amendment were higher in the Toje series than the Akuse series. However, DMY was higher in the Akuse series than the Toje series. In the inorganic fertilizer treated soils, the NAR was higher in the Akuse series than the Toje series and this reflected in higher DMY values in the Akuse soil over the Toje soil.

4.3.5 Effect of moisture content at field capacity on N contents in Maize plants

The nitrogen content of the maize plant on the two non-amended soils 65 days after sowing were statistically the same and ranged between 7.07 g/kg and 10.67 g/kg. When the Akuse soil was amended with the two fertilizers at the two rates, there were corresponding increases in the N contents of the plant. At 20 kg/ha for the Akuse series, the nitrogen content in the plant was higher in the inorganic amended soil than that of the organic amended one. However at 40 kg/ha the nitrogen contents of the plants were statistically the same.. In the Toje series, the TN of the plants at the two rates of application, irrespective of fertilizer type, was similar and followed the trend of DMY.

4.3.6 Effect of moisture content at 75%field capacity on Leaf Area index (LAI)

When the moisture content was kept at 75% FC, the leaf area index (LAI-1) of the maize plant at 28 days after sowing in the two non-amended soils was statistically higher in the Akuse soil than the Toje counterpart (Table 5). When the soils were amended with the two fertilizers at the two rates, the LAI-1 increased significantly from that of the non-amended soils. The increases in LAI-1 in the Akuse series were significantly higher at the two rates than in the Toje series. At any given rate of organic fertilizer application in Akuse series, LAI-I was higher at FC than at 75% FC. In the Toje series, LAI-1 at 75% FC and FC were statistically the same when the two fertilizers were surface applied at 20 kg/ha. At 40 kg/ha application rate, however, LAI-1 was higher at FC than at 75% FC.

At 65 days after sowing, LAI-2 generally increased with increasing fertilizer rate for the two amendments in the Akuse series whilst it was the same in the Toje series. The LAI-2 was in all cases significantly higher in the Akuse series than the Toje series at 75% FC. Apart from the organically amended Akuse soil which showed higher LAI-2 values at FC than at 75% FC, all the other treatments showed statistically similar LAI values.

Table 5 Agronomic parameters of maize grown in the two soils when fertilizers were surface applied at 75%field capacity.

Soil		LAI-1	LAI-2	CH-1 (SPAD)	CH-2 (SPAD)	TN (g/kg)	NAR (g $m^{-2}day^{-1}$)	H-1 (cm)	H-2 (cm)	DMY (g)
	Eco-fertilizer									
Akuse	0kgN/ha	5.87	10.70	121.1	134.4	12.03	0.0270	10.00	102.67	13.75
	20kgN/ha	19.27	23.95	159.8	154.4	19.90	0.0430	12.17	118.00	23.95
	40kgN/ha	21.97	31.53	211.1	194.4	28.93	0.0640	13.93	120.00	31.53
	Ammonium Sulfate									
	0kgN/ha	5.07	10.0	125.9	131.3	13.33	0.0207	10.33	103.69	14.98
	20kgN/ha	18.43	22.70	181.1	164.3	18.99	0.0519	15.33	119.23	24.27
	40kgN/ha	21.53	43.67	197.2	171.2	24.33	0.0789	17.80	121.20	39.47
	Eco-fertilizer									
Toje	0kgN/ha	2.97	9.92	87.33	81.0	9.95	0.0149	9.00	38.67	12.46
	20kgN/ha	3.97	11.23	122.2	99.3	16.66	0.0530	12.00	69.00	14.56
	40kgN/ha	4.98	12.56	188.6	100.2	19.34	0.1460	15.34	71.23	22.83
	Ammonium Sulfate									
	0kgN/ha	2.07	9.99	86.89	89.01	10.01	0.0753	8.50	35.67	11.56
	20kgN/ha	3.79	11.52	136.7	123.5	15.23	0.1517	13.00	66.70	19.32
	40kgN/ha	5.10	13.10	173.7	143.3	18.34	0.2193	19.33	73.00	21.56
L.s.d (0.05) =		1.985	9.719	7.35	11.43	5.269	0.0118	3.834	18.75	11.436

*LAI-1 = Leaf area index at 28 days after sowing, LAI-2=Leaf area index at 65 days after sowing, CH-1=Chlorophyll content at 28 days after sowing, CH-2 = Chlorophyll content at 65 days after sowing, TN= Total Nitrogen, NAR = Net Assimilation Rate, H-1= Height at 28 days after sowing, H-2 = Height at 65 days after sowing, DMY= Dry matter yield.

4.3.7 Effect of moisture content at 75% field capacity on chlorophyll content

There were general increases in the chlorophyll content at 28 days after sowing (CH-1) in the two soils with increasing application rate of fertilizer. The CH-1 of the maize plants in the non-amended soils was higher in the Akuse series than the Toje series. It was between 121.1 and 125.9 in the Akuse series compared with between 86.9 and 87.3 SPAD in the Toje series. It is worthy to note that these CH-I values of the two non-amended at 75% FC were significantly higher than the values at FC. At 75% FC of the Akuse soil at 20 kg/ha application rate, CH-1 was higher when the two soils were inorganically amended than when they were organically amended. At 40 kg/ha, however, CH-1 was higher in the two organically amended soils than their inorganically amended counterparts.

The chlorophyll content at 65 days after sowing increased with increasing application rate in the two soils. The CH-2 was higher in the Akuse series especially when it was amended with the organic fertilizer at 40 kg/ha than when it was with the inorganic one. In the Toje series, CH-2 was generally higher when the soil was amended with ammonium sulphate.

The CH-2 in the organically amended Akuse soil was significantly higher at 75% FC than at FC. When the same soil was inorganically amended at 20 kg/ha, the CH-2 at 75% was higher than at FC. The CH-2 at 75% FC was generally significantly higher than that at FC in the Toje series.

4.3.8 Effect of surface application of fertilizer at 75% field capacity on plant height

The height of the maize plant in the non-amended two soils 28 days after sowing (H-1) were statistically the same and ranged between 8.5 cm and 10.33 cm. When the soils were amended with the two fertilizers at 20 kg/ha, there were significant changes in height from that of the non-amended only in the $(NH_4)_2SO_4$ amended soil. At 40 kg/ha, though the heights did not significantly change from that at 20 kg/ha, they had increased significantly from those of plants grown on the non-amended soils. At the two application rates, H-1 was generally the same in the two soils at the two moisture contents except in the inorganically amended Toje series where at 75% FC, H-1 was higher than at FC.

Plant height at 65 days after sowing (H-2) was between 102.67 cm and 103.69 cm for the non-amended Akuse soil and these were significantly higher than heights of plant in the Toje soil (35.67 cm – 38.67 cm). In the amended Akuse soil, the plant height did not change significantly from that of the non-amended soil when the fertilizer was applied at the two rates. There were, however, increases in plant height with increasing application rate of fertilizer in the Toje soil. The H-2 in Akuse series were higher at 75% FC than at FC when organically amended but higher at FC than 75% FC when inorganically amended. However the H-2 was statistically the same at both moisture contents in the Toje series.

4.3.9 Effect of moisture content at 75% field capacity on NAR and DMY

In the Akuse series, the NAR were significantly higher in the inorganic fertilizer than in the organic fertilizer as the plant fertilized with the inorganic fertilizer recorded NAR values of 0.0519 and 0..0789 respectively at 20 kg/ha and 40 kg/ha compared to the 0.0430 and 0.0640 for the organic fertilizer at the same rates. However, these higher increases in NAR in the inorganic fertilizer treated soil over the organic fertilizer treated soil did not reflect in dry matter yield (DMY) just as was observed at FC. At 20 kg/ha and 40 kg/ ha, the DMY was respectively, 24.27 g and 39.47 g for the inorganic fertilizer treatment which were not significantly different from the 23.95 g and 31.53 g DMY at the same rates for the organic fertilizer. These DMY values were also not significantly different from those at FC for the same soil except at 40 kg/ha where it was higher in the organically amended Akuse soil at FC.

In the Toje series, the NAR values were higher in the inorganic amended soil than the organic amended one. However DMY in the soil at the two application rates were statistically the same. There were no changes in DMY for Toje at the two application rates at the two moisture levels.

4.3.10 Effect of moisture content at 75% field capacity on N contents in maize plants

The nitrogen content of the maize plant on the two non-amended soils 65 days after sowing were statistically the same and ranged between 9.95 g/kg and 13.33 g/kg. When the two soils were amended with the two fertilizers at the two rates, there were corresponding increases in the N contents of the plants. Nitrogen content of the maize plant was statistically the same at FC and 75% FC when the Akuse soil was organically amended. When the same soil was inorganically amended N content was higher at FC than at 75% FC. In the Toje series, the TN of the plants at the two rates of application, irrespective of fertilizer type was statistically the same at the two moisture levels and followed the trend of DMY.

4.4 Available nitrogen in soils at 28 days and 65 days after sowing at FC

The available N in the two soils after 28 days and 65 days after sowing at FC and 75 % FC are presented in Tables 6 and 7. From the tables, it is seen that under all conditions, ammonium, the precursor of nitrate, was higher than nitrate. In both the organically and inorganically fertilized soil series, the ammonium and nitrate contents significantly increased with increasing application rate.

At FC, the available nitrogen in the non-amended Akuse soil was between 1.14 mg/kg and 1.19 mg/kg and between 0.78 mg/kg and 0.87 mg/kg in the Toje series 28 days after sowing. When the Akuse soil was amended with the organic fertilizer, the ammonium

Table 6 Source derived soil mineral N at 28 and 65 days after sowing for surface application of fertilizers at field capacity.

Soils	NH_4^+	NO_3^-	Av.N	NH_4^+	NO_3^-	Av.N
			mg/kg			
	Eco-Fertilizer			Ammonium Sulfate		
			28 Days after Sowing			
Akuse						
0kg/ha	0.73	0.41	1.14	0.72	0.47	1.19
20kg/ha	1.13	0.72	1.85	1.23	0.88	2.11
40kg/ha	1.40	0.94	2.35	1.26	0.99	2.25
Toje						
0kg/ha	0.62	0.24	0.87	0.53	0.24	0.78
20kg/ha	0.76	0.38	1.14	1.24	0.72	1.96
40kg/ha	1.33	0.78	2.12	1.30	0.84	2.14
Lsd(0.05)	0.1098	0.03584		0.1098	0.03584	
			65days after Sowing			
Akuse						
0kg/ha	0.46	0.21	0.67	0.52	0.26	0.78
20kg/ha	0.96	0.26	1.22	0.98	0.30	1.28
40kg/ha	1.29	0.27	1.56	1.29	0.55	1.85
Toje						
0kg/ha	0.57	0.12	0.69	0.56	0.10	0.66
20kg/ha	0.65	0.26	0.92	0.92	0.58	1.51
40kg/ha	0.77	0.34	1.11	1.10	0.72	1.82
Lsd (0.05)	0.06572	0.02701		0.06572	0.02701	

Table 7 Source derived soil mineral N 28 and 65 days after sowing for surface application of fertilizers at 75%field capacity.

Soils	NH_4^+	NO_3^-	Av.N	NH_4^+	NO_3^-	Av.N
	mg/kg					
	Eco-Fertilizer			Ammonium Sulfate		
	28 Days after Sowing					
Akuse						
0kg/ha	0.55	0.24	0.79	0.57	0.23	0.81
20kg/ha	1.26	0.72	1.99	1.34	0.57	1.91
40kg/ha	1.96	0.84	2.81	1.96	0.84	2.81
Toje						
0kg/ha	0.46	0.13	0.60	0.44	0.13	0.57
20kg/ha	0.97	0.38	1.35	0.96	0.56	1.52
40kg/ha	1.24	0.67	1.92	0.94	0.84	1.79
Lsd(0.05)	0.1098	0.03584		0.1098	0.03584	
	65days after Sowing					
Akuse						
0kg/ha	0.46	0.28	0.74	0.42	0.26	0.68
20kg/ha	0.88	0.27	1.15	0.47	0.29	0.77
40kg/ha	1.23	0.26	1.49	0.95	0.45	1.50
Toje						
0kg/ha	0.41	0.17	0.59	0.44	0.16	0.60
20kg/ha	0.75	0.26	1.01	0.91	0.27	1.18
40kg/ha	0.96	0.34	1.31	0.94	0.34	1.28
Lsd (0.05)	0.06572	0.02701		0.06572	0.02701	

content increased from 0.73 mg/kg to 1.13 and 1.4 at 20 kg/ha and 40 kg/ha, respectively.. The nitrate contents at the same rates were respectively, 0.72 and 0.95 giving corresponding available N values of 1.85 and 2.35. The ammonium contents in the inorganically amended soil was 1.23 and 1.26 mg/kg with the nitrate being 0.88 and 0.99 respectively at 20 kg/ha and 40 kg/ha. These gave similar available N values of between 2.11 and 2.25 mg/kg.

In the Toje series at FC, available N was slightly lower especially when the Eco fertilizer was applied at 20 kg/ha. This was as a result of the slightly lower ammonium content of 0.76 mg/kg which gave rise to a low nitrate content of 0.38 mg/kg and thus a low available N content of 1.14 mg/kg. This value was 0.82 less than the available N recorded when the same soil was amended with ammonium sulphate. At 40 kg/ha, the Eco fertilizer recorded 2.12 mg /kg of available N similar to that recorded after 28 days when the same soil was amended with ammonium sulphate.

Sixty five days after sowing, the available N in the soils organically amended reduced to 1.22 mg/kg and 1.56 mg/kg, respectively at 20 kg/ha and 40 kg/ha from the values at 28 days in the Akuse series. The inorganically amended Akuse soil also decreases in its available N recording values of 1.25 and 1.85, respectively at 20 kg/ha and 40 kg/ha. The Toje soil also recorded decrease in available N. These were 0.92 mg/kg and 1.11 mg/kg at 20 kg/ha and 40 kg/ha respectively for the organic fertilizer and 1.51 and 1.83 at the same rates for inorganic fertilizer.

4.4.1 Available nitrogen in soils at 28 days and 65 days after sowing at 75%FC

At 75%FC, the available nitrogen in the non-amended Akuse soil was between 0.79 mg/kg and 0.81mg/kg and between 0.57 mg/kg and 0.6 mg/kg in the Toje series 28 days after sowing (Table 6). When the Akuse soil was amended with the organic fertilizer, the ammonium content increased from 0.55 mg/kg to 1.26mg/kg and 1.97mg/kg at 20 kg/ha and 40 kg/ha, respectively. The nitrate contents at the same rates were respectively 0.72 and 0.84 giving corresponding available N values of 1.98 and 2.8. The ammonium contents in the inorganically amended soil was 1.34 and 1.96 mg/kg with the nitrate being 0.57 and 0.85 respectively, at 20 kg/ha and 40 kg/ha. These gave similar available N values of between 1.91 and 2.81 mg/kg.

In the Toje series at 75%FC, available N was slightly lower especially when the Eco fertilizer was applied at 20 kg/ha. This was as a result of the slightly lower ammonium content of 0.97 mg/kg which gave rise to a low nitrate content of 0.38mg/kg and thus a low available N content of 1.35 mg/kg. This value was 0.17 mg/kg less than the available N recorded when the same soil was amended with ammonium sulphate. At 40 kg/ha, the Eco fertilizer recorded 1.92 mg /kg of available N which was 0.13 higher than the available N recorded for the ammonium sulfate.

Sixty five days after sowing, the available N in the soils organically amended soil reduced to 1.15 mg/kg and 1.49mg/kg respectively at 20 kg/ha and 40 kg/ha from the values at 28 days in the Akuse series. The inorganically amended Akuse soil also decreased in its available N recording values of 0.77 mg/kg and 1.50 mg/kg, respectively at 20 kg/ha and 40 kg/ha. The Toje soil also recorded decrease in available N. These were 1.01 mg/kg and 1.31 mg/kg at 20 kg/ha and 40 kg/ha respectively for the organic fertilizer and 1.18 and 1.28 at the same rates for inorganic fertilizer.

CHAPTER FIVE

DISCUSSION

5.1 Soil Characterization

The 50.7% sand content, 16.8% silt and 32.5% clay make the Toje soil sandy clay loam in texture is with the particle size distribution of 33% sand, 12% silt and 55% clay. The Akuse soil is loamy clay in texture according to the USDA system of classification (Soil Survey Staff, 2003). The higher sand content of 50.7% in the Toje soil than the Akuse (33%) soil is due to the fact that the former has been formed from tertiary sand with the latter from garnetic ferrous hornblende gneiss (Brammer, 1962). The medium bulk density of 1.2 $Mg/m^3$of the Toje series reflects the sandy clay loam characteristic of soils in the landscape. The higher bulk density of the Akuse series than the Toje series could be due to the presence of high activity clays like montmorillonite in the soil. The presence of this mineral will make the soil harden on drying to increase the bulk density. The higher bulk density of the Akuse series could also be due to its higher Ca contents (Dowuona, 1985) which would promote aggregation. The lower bulk density in the Toje series will make root penetration easier especially in the dry season than in the Akuse series

The Akuse soil has a higher pH than the Toje series probably because of the presence of $CaCO_3$ nodules found in the soil (Ahenkora, 1997). The high sand content and low clay content coupled with the average daily temperature of 28^oC prevailing in the Toje environment would promote fast decomposition and low retention of added organic matter. Consequently organic matter and therefore organic carbon contents of the soil are low with a concomitant low total nitrogen content of approximately 0.63 g/kg and available P of 6.0 mg/kg. Clay has been found to accommodate more organic carbon, total N and P contents than silt and sand (Jones et al., 2006). It is, therefore, not surprising that with its higher clay content, the Akuse series has comparatively higher organic carbon and available P contents. The higher available P content in the Akuse series than the Toje series is also attributed to the 7.5 pH (H_2O) value of the former as opposed to the 5.8 of the latter. This 7.5 value is closer to the second pK value of orthophosphoric acid (7.15) (Evangelou, 1998) than 5.8. Thus, more of the orthophosphate anion HPO_4^{2-} will be in soil solution.

The Toje soil with a lower clay content of 32.5% is dominated by low activity clays mainly kaolinite (Eze, 2008). Additionally, its organic carbon content is very low and these in part, may explain the soil's very low CEC value of 5.7 $cmol_{(c)}$/kg. The fact that the Akuse series is 22.5% higher in clay content coupled with its higher organic carbon contents in part, account for its higher CEC. The six times higher CEC in the Akuse series than the Toje series is also attributed to the presence in large quantities of high activity clays, particularly montmorillonite (Dowuona, 1985)

5.2 Effect of soil type on crop growth parameters

The leaf area index (LAI-1) after 28 days of sowing was higher in the non-amended Akuse soil than the non-amended Toje soil mainly because of the higher fertility status of the Akuse series. The Akuse series was higher in organic carbon content by 1.9 g/kg than the Toje series. This higher organic carbon reflected in a corresponding higher total and available N and coupled with its neutral pH of 7.5 in water, P availability was higher. Furthermore the fact that the Akuse soil is six times higher in CEC than the Toje series will imply that exchangeable bases will be more available. It is therefore, not surprising that LAI-1 in the non-amended soils were higher in the Akuse series than the Toje series at the two moisture levels. This higher LAI-1 in the non-amended Akuse series is corroborated by higher available N in the soil, and higher CH-1. Nitrogen is one of the major components of chlorophyll (Tisdale et al., 2002) and therefore, with higher available N in the Akuse soil, it is expected that chlorophyll content will be higher with a concomitant higher leaf expansion and hence a higher leaf area index.

When the two soils were amended with the fertilizers, LAI-1 was higher in the Akuse series than the Toje series at the two moisture contents due to the superior inherent fertility of the former soil. The higher LAI-1 in the Akuse soils is also supported by the higher available N in the soil at 28 days after sowing which also tied in very well with higher CH-1. Crops grown on the Akuse series recorded higher LAI-1 and LAI-2 than the crops grown on the Toje series soil because the former has been found to support growth better than Acrisols. The fact that plant height on the Toje series was not increasing significantly at 65 days after sowing is a reflection of the poor quality of this soil.

Though NAR was significantly higher in the inorganically amended Akuse soil than its organically amended counterpart, it did not reflect in DMY and this shows that the soil did not discriminate in terms of fertilizer N type with respect to dry matter production at the vegetative stage. Perhaps, differences will emerge at the reproductive stage. In the Toje series, the two fertilizers recorded the same NAR values at the two application rates showing that the application rate did not have any significant impact on N assimilation of the crop and this reflected in a statistically similar dry matter yield. The higher dry matter yield recorded for the crops on the Akuse series reflects the higher nutrient status of the soil and its ability to support crop production, irrespective of the water content of the soil.

5.3 Effect of fertilizer type and application rate on crop growth parameters

The fact that at 20 kg N/ha, the maize grown on the organic fertilizer had higher leaf area indices at both 28 days and 65 days after sowing than the crop grown on the inorganic fertilizer could be attributed to the fact that the organic fertilizers contain humic substances which increase nutrient uptake, (Vaughan and Ord, 1985), and modify mechanisms involved in plant growth stimulation (Lee and Bartlett., 1976). These added advantages have not been observed in inorganic fertilizers. The fact that there were no significant differences in the LAI-1 of the two fertilizers at the 40kg/ha in the Akuse series and the similar DMY at both rates of the two fertilizers on Akuse series show that the organic fertilizer was competing favourably well with the inorganic fertilizer and can be relied upon to supply adequate N in maize production on the Akuse soil. Similar maize growth parameters such as LAI-1 and LAI-2, H-1, H-2 nitrogen contents of plants and DMY recorded in the organically and inorganically amended Toje soil and the fact that there was generally no difference in DMY in the two soils at the two application rates also indicate that the organic fertilizer competes favourably with the inorganic one.

Availability of N in the soils increased with increasing application rates and this reflected in leaf area of the maize plants in both soils increasing with increasing application rate of the two fertilizers. Large supply of nitrogen enhances apical branching (Purseglov., 1972), implying that more leaves would be formed per plant over a period of time. The tables of available nitrogen in the two soils showed that there were higher amounts of available nitrogen in the amended soils than the non-amended ones, and this reflected in higher leaf area indices in these soils. The general increases in the leaf area index at 65 days of the crops can be explained by the fact that as crops grow, their number of leaves increase to intercept more sunlight and CO_2 to enhance photosynthetic abilities

The decreasing chlorophyll content of the crops in the two soils and the two fertilizers at 65 days after sowing is due the remobilization of the N in the leaves to tasseling and cob or grain production which was visible in all the crops at this stage. Veronica et al. (2008) observed that total chlorophyll content increased during vegetative growth (28 days after sowing) period, reaching a maximum close to tasseling and then decreased during the reproductive and senescence periods. The similar availability of N in both Eco Fertilizer and ammonium sulphate amended Akuse soil further corroborates the assertion that the organic fertilizer competes favourably with the inorganic one in the supply of N.

There is a direct relationship between the net assimilation rate and the dry matter yield of a crop; as the net assimilation rate increases, the dry matter production increases (Marschner, 1995). Dry matter production is also related to leaf area index, a higher leaf area index reflects in higher dry matter yield. Leaf area index increased with increasing fertilization and this is reflected in the increased dry matter production in the two soils with increasing fertilization. The fact that there were no significant differences in the dry matter yield of the crop under the two fertilizations even though there were differences in NAR could be a reflection of the statistically similar leaf area indices.

5.4 Effect of moisture content on crop growth parameters

Leaf area index of maize plants at 28 days after sowing in the organically amended Akuse series was higher at FC than at 75% FC due to the higher level of moisture content at FC. The Eco fertilizer though composted is not 100% mineralized like in the mineral ammonium sulphate fertilizer. An increase in moisture content will increase the microbial diversity and population. These will invariably increase mineralization to increase available N as corroborated by higher available N in the organically fertilized Akuse series with a concomitant higher CH-1. These ultimately led to a higher LAI-1 at FC in the organically amended Akuse series. In the Toje series, moisture content at 20kg/ha led to no significant differences between the LAI-1 of the crops at 75%FC and FC, but at 40kg/ha the LAI-1 was higher showing that before water can have a significant impact on agronomic yield there must be high levels of nutrient in the soil. The N contents in the maize plants after 65 days were generally the same accounting for the similar LAI-2 in the maize plant grown in the two soils at both FC and 75% FC these similar N contents could in part, explain the similar DMY.

5.6 Effects of soil type on NH_4^+ and NO_3^- availability

Soil organic matter decomposition and N mineralization show complex interactions with microbial biomass, environmental factors, particularly soil moisture and temperature and soil mineralogy. In terms of the two soils, NH_4^+ was the dominant ion in the two soils at 75%FC and FC. This was no coincidence since several factors including soil organic carbon content, pH and clay content has an influence on the N form dominant in a soil system. Soil clay and organic matter content have a predominantly negative charge and are able to attract and hold positively charged cations such as NH_4^+ by the process of cation exchange, chelation, and complexation (Cameron and Haynes, 1986). However, the amount of NH_4^+ retained on the Vertisol (Akuse series) was higher for the two fertilizers than the Acrisol (Toje series). Several factors could account for this especially pH. Under acidic conditions in soils, the positively charged sites on 1:1 clays and sesquioxides including iron and aluminum oxides and hydroxides increase, hence restricting NH_4^+ ion entry to the soil surface (Kinjo et al, 1971). The Toje series has kaolinite as the dominant clay mineral while the Akuse is dominated by montmorillonite with permanent negative charges (Dowuona, 1985). Consequently more NH_4^+ will be retained by the vertisol. The higher CEC of the vertisol coupled with its interlayer space about the size of the ammonium ion and larger surface area present greater opportunities for NH_4^+retentionthan in the acrisol.

The presence of organic matter influences the retention of NH_4^+. This is because the presence of carboxyl (COOH) and phenolic OH groups in organic matter increase the number of negative charges in soils and lead to retention of NH_4^+ more than NO_3^-. The Akuse series had higher organic carbon content than the Toje series; hence the former is likely to hold more NH_4^+ than the latter.

At 65 days after sowing, the available N content decreased in both soils. For the two fertilizers, the amounts of NH_4^+ and NO_3^- decreased significantly in both soils for the amended and non-amended soils. The highest moisture content of the two soils was at FC. The soils were, therefore not saturated with water and therefore losses as a result of denitrfication and leaching would be negligible. The decreases in soil N content 65 days after sowing could therefore be attributed mainly to plant uptake

5.7 Effect of moisture content on NH_4^+ and NO_3^- availability in the two soils

The moisture status of a soil not only determines the availability of water for crop uptake but also the aeration status of the soil. In the case of nitrogen, the aeration or saturation status of the soil not only determines the N retained but also the pathways by which it is lost as well (Keshab, 2005). Twenty-eight days after sowing, the maize plants were growing very fast and would need a lot of leaf expansion to intercept a lot of sunlight for photosynthesis (Purgselove, 1972). This would require a lot of chlorophyll formation and hence N absorption. Since energy involved in absorption of NH_4^+ by plants is less than that required for NO_3^- (Tisdale et al., 2002), it is not surprising that NH_4^+ concentration at 75% FC is significantly higher than that at FC. This is because optimum conditions for absorption would prevail at FC. With a higher preference for $NH_4^+$for chlorophyll formation, a lot more of the nutrient would be absorbed with a concomitant decrease in solution concentration. This is reflected in the higher levels of CH-1 of the maize plants at FC. The higher preference of NH_4^+which is a precursor for NO_3^- could, in part, explain the low concentration of the anion in the soil.

CHAPTER SIX

6.1CONCLUSIONS

The study has shown that the Akuse soil has higher organic carbon contents with concomitant higher nitrogen content and a higher CEC which is six times more than the Toje series. The neutral pH of the Akuse series as opposed to the slightly acidic pH of the Toje series makes P more available in the former. Consequently, the Akuse series which is a Vertisol has a higher inherent capacity in terms of fertility to support maize growth than the Toje series, the Acrisol.

When the two soils were amended with the fertilizers, LAI at 28 days after sowing (LAI-1) was higher in the Akuse series than the Toje series at the two moisture contents due to the superior inherent fertility of the former soil. The higher LAI-1 in the Akuse soils is also supported by the higher available N in the soil at 28 days after sowing which also tied in very well with higher chlorophyll content at 28 days after sowing.

At 20 kg/ha for the Akuse series, the nitrogen content in the plant was higher in the inorganic amended soil than that of the organic amended one. However at 40 kg/ha the nitrogen contents of the plants were statistically the same. In the Toje series, the nitrogen content of the plants at the two rates of application, irrespective of fertilizer type were similar and followed the trend of DMY.

Similar growth parameters such as LAI-1 and LAI-2, H-1, H-2 nitrogen contents of plants and DMY in the organically and inorganically amended Toje soil and the fact that there was generally no difference in DMY in the two soils at the two application rates also indicate that the organic fertilizer competes favourably with the inorganic one in maize growth. There was generally no difference in moisture content at FC and 75% FC on N accumulation and hence DMY of maize plants after 65 days. In both soils, NH_4^+ was more abundant than NO_3^-. At 28 days after sowing which is the vegetative stage of the maize plant, the NH_4^+ content in the soils was higher at 75%FC than at FC suggestive of the fact that more NH_4^+ had been absorbed at FC due to the prevailing optimum condition for N absorption

6.2 Recommendation

To fully ascertain the full effect of Eco fertilizer on maize cultivation, it is recommended that the fertilizer be tried on maize under field conditions up to physiological maturity of the crop. It is also recommended that the product is incorporated to see how it will fare with the surface applied ammonium sulphate.

The fertilizer Eco fertilizer is organic with a high C content and could therefore emit methane gas when applied under anaerobic conditions such as in rice or sugar cane cultivation. Further studies will, therefore, have to be carried out to quantify the amount of methane that could be released and also the method of application that could reduce the methane gas production

Finally this fertilizer is a very light material and could easily be blown away under windy conditions. It is most advisable to incorporate the fertilizer into the soil just before the commencement of the rainy season to minimize losses. Research could also be carried out into pelleting the fertilizer to enhance its efficacy and minimize losses through winds

REFERENCES

Ahenkora, E.K., Dreschel, Y., and Oteng J.W. 2001.Improving the productivity of Vertisols for small holders on the Accra plains of Ghana. Proceedings of the International Board for Soil Research and Management(IBSRAM) 20, 155-171.

Ahenkora, Y. 1997. Effective Utilization of the Vertic Soils of the Accra-Plains.Prospects, constraints and the way forward. Inaugural Lecture, Ghana Academy of Arts and Sciences. 26pp.

Aldrich S. 1984. Nitrogen management to minimize adverse effects on the Environment. In: Hauck R.D (Ed), Nitrogen in crop production. Soil Science Society of America, Madison Publishers. pp 663-673.

Anderson, J.M and J.S.I Ingram. 1993. Tropical soil biology and fertility. A handbook of methods. 2nd Ed. 221pp.

Argawal A.S, Smith B.R and Kaneiro Y. 1971. Soil nitrogen and carbon mineralization as affected by drying-rewetting cycles. Soil Science Society of America. 35, 96-100.

Arun-Kumar, M.A., Gali S.K., and Hebsur N.S. 2007. Effect of different levels of NPK on growth and yield parameters of sweet corn. Karnataka Journal of Agric. Science 20, 41-43.

Aulakh M.S., Doran J.W., and Mosier A.R. 1992. Soil denitrification-significance-measurement, and effects of management. Advances in Soil Science. 18, 1-57.

Barber, S.A. 1984. Soil nutrient bioavailability. A mechanistic approach. John Wiley and Sons, New York, NY.

Baret, F., Houles,V., Guerif M. 2007. Quantification of plant stress using remote sensing observations and crop models: the case of nitrogen management. Journal of Experimental Botany 58, 869-880.

Binder, D.L., Sander, D.H., and Walters, D.T. 2000. Maize response to time of nitrogen application as affected by level of nitrogen deficiency.Journal of agronomy 92, 1228-1236.

Blake C.D., Campbell, K.O., Collins-George, K.O., Collins-George, Graham P.H., Jackson, D.L., and Robinson. 1967. Fundamentals of modern agriculture 1st ed. Sydney University Press 81pp.

Brady, N.C and Weil R.R. 2001. The nature and properties of soils 11th ed. Prentice-Hall, New Jersey. pp 22-56.

Brammer, H. 1962. Soils.Agriculture and land-use in Ghana.Oxford university press, London, pp 88-126.

Bray, R.H., and Kurtz L.T. 1945. Determination of total and organic and available forms of phosphorus in soils. Journal of Soil Science 59, 39-45.

Bruns, R.H., and Abbas, H.K. 2005.Ultra-high plant populations and nitrogen fertility effects on corn in the Mississippi valley. Journal of Agronomy 97, 1136-1140.

Cameron, K.C., and Haynes, R.J. 1986. Retention and movement of nitrogen in soils. Mineral-nitrogen in the plant-soil system. Academic Press Inc. New York pp 167-241.

Campbell C.A., Bierderbeck V.O., and Warder F.G. 1971. Influence of simulated rainfall and spring conditions on the soil system, Effects on soil nitrogen. Proceedings of the Soil Science Society of America 35, 480-483.

Charttajee, S.R., Pokhriyal, T.C., and Abrol, Y.P. 1981a. Nitrogen economy of main shoot of field grown barley (*Hordeumvulgare* L). Dry weight duration and nitrogen content in different organs. Journal of Experimental Bot. Oxford 32, 689-699.

Ciganda, V., Gitelson, A.A., and Scheppers, J. 2009.Non-destructive determination of maize leaf and canopy chlorophyll content. Journal of plant Physio. 166, 157-167.

Danso, F. 2010. Removal of nitrate and phosphate from domestic wastewater using sorbents under constructed wetland. MPhil Thesis. University of Ghana Legon Accra, 24pp.

Darko, D.A. 2007. Synchronizing nitrogen release from plant residues and maize uptake; the effect of residue type, application method and soil moisture. MPhil Thesis, Department of Soil Science, University of Ghana Legon, 93pp.

Das Gupta, D.K and P.K. Sen. 1969.Water relation of rice. Proceedings of Agric. Society of India.September 1958, Delhi.145-156.

Day, P.R. 1965. Particle fractionation and particle-size analysis. pp.545-567. In: Black, C.A.(Ed), Methods of soil analysis. Agronomy No. 9, Part 1, Am. Soc.Of Agron. Madison, Wisconsin.

De Datta, S.K. 1990. New frontiers in rice agronomic research for changing needs. Abstracts from the proceedings of international symposium on rice research new frontiers. Indian council of agricultural research held at Hyderabad November 14-18th, 1990.

Dowuona, G.N.N. 1985. Correlation of Ghanaian system of soil classification with other international systems. Msc.Thesis. Dept. of Soil Science, University of Ghana, Legon, Accra 220pp.

Dowuona, G.N.N., Adjetey, E.T., Nartey, E.T.,Adjadeh, T.A., and Heck, R. 2011. Carbon accumulation and aggregate stability in an acrisol under different fallow management in Ghana. Journal of Soil Science and Environmental Management 2(12), 393-403.

Dynagro S.. 2005. Growth stages in maize.www.google.com.

Emerson M.T., Grunwald, F and Kromhout, R.A. 1960. Diffusion control in the reaction of ammonium ion in aqueous acid. Journal of Chemistry 33, 547-555.

Evangelou, V.P. 1998. Environmental Soil and Water Chemistry: Principles and Applications. Willey and Sons Inc.New York, 564pp.

Eze, P.N. 2008. Characterization, classification and Pedogenesis of soils on a legon catena in the Accra plains, Ghana. MPhil Thesis. University of Ghana, Legon, Accra. 126pp.

Field C.B. and Mooney H.A. 1986. The photosynthesis-nitrogen relationship in wildplants. In: Givnish T.J (Ed.), The economy of plant form and function. Cambridge University Press. New York. 25-55.

Gaur, A.C., Neelankantan, S. and Dargan K.S. 1984. Organic manures. Indian council of Agric. Research, 159 pp.

Gitelson A.A., Vina, A. Masek, J.G., Verna S.B and Suyker A.E. 2005.Synoptic monitoring of gross primary productivity of maize using the landsat data.Geoscience and Remote sensing letters 5, 2-10.

Grudzeva, LI., Matveeva E.M., Kovalenko T.E. 2007. Changes in soil nematode communities under the impact of fertilizers. Journal of Eurasian Soil Science 40, 681-693.

Hayens, R.J. and Sherlock, R.R. 1986. Gaseous losses of nitrogen. In: Hayens, R.J. (Ed.), Mineral nitrogen in the plan-soil system. Academic Press, New York, 242-302.

Heather, D. and Joe, L. 2011. Critical stages in plant physiology. Journal of Plant Physio.pp 17-20.

Henao, J., Baanante C.A. 1996. Estimating rates of nutrient depletion inn soils of agricultural lands of Africa. International Fertilizer Development Centre, Muscle shoals, Alabama, USA.

Houle's, V., Guerif M., Mary, B., Gate P., Machet, J.M and Moulin S. 2006. Elaboration d'un indicator de nutrition azote e du ble base sur l'indice follaire et la teneur en chlorophylle pour la pre conisation de doses da'azote. In: Gue Ref M. and King D. (Eds), He te roge neite parcelled et gestion des cultures. Vers une Agriculture de precision, pp 179-198.

IFDC, 1999. A strategic Framework for African Agricultural Input Supply System Development. IFDC T-63.

Jones, J.W., Koo, J., Naab, J.B., Bostick, W.M., Traore, S., and Graham, T. 2006.Integrating stochastic models and in situ sampling for monitoring soil carbon sequestration. Agric. Systems 94, 52-62.

Kaboneka, S., Sabbe., W.E., and Mauromoustakos A. 1997. Carbon decomposition kinetics and nitrogen mineralization from corn, soybean, and wheat. Communications in Soil Science and Plant analysis 28, 1359-1373.

Kamprath, E.J. 2000.Soil fertility and plant nutrition. In: Sumner, M.E. (Ed.) Handbook of Soil Science. CRC press. Washington D.C. pp 3-15.

Katyal, J.C and Randhawa, N.S. 1983. Micronutrients; FAO Fertilizer and Plant Nutrient Bull. 7. FAO, Rome pp.82.

Katyal, J.C. 1977. Influence of organic matter on the chemical and electrochemical properties of some flooded soils. Soil Biol. Biochem, 9: 259:266.

Katyal, J.C. 1980a. Influence of Farm Yard Manure on the chemical kinetics and growth of rice in a submerged Vertisols. Field Crops Res. 3, 137-145.

Keshab, R.J. 2005. Managing seasonal soil N-dynamics in rice-wheat rotation systems of Nepal, University of Bonn 39pp.

Kinjo, T., Pratt P.F., and Page A.L. 1971. Nitrate adsorption 3: Desorption movement and distribution in Andepts. Journal of Soil Science Society of America 40, 876-879.

Lee Y.S., and Bartlett R.J. 1976. Simulation of Plant growth by Humic substances. Journal of American Society of Soil Science 40, 876-879.

Mandal, A., Patra, A.K., Singh D., Swarup, A., and Masto, R.E. 2007.Effect of long-term application of manure and fertilizer on biological and biochemical activities in soil during crop development stages.Bio resource Technology 98, 3585-3592.

Marschner, H. 1995. Mineral nutrition oh higher plants.2nd Edition. Harcourt Brace and Company. New York. 889pp.

Medina, E., Lieth H. 1964. Die Bezienhungenzwischen chlorophyll ge halt, Assimilieren der Flaech und Trocken subsatanz production in einigen Pflanzengemeinschaften.

Meeker G., Purvis A.C., Neyra, C.A., and Hangeman, R.H. 1974.Uptake and accumulation of nitrate reductase activity in corn leaves. Journal of Indian National Science Academy 3, 39-47.

Murphy, J. and Riley J.P. 1962. A modified single solution method for the determination of phosphate in natural water. Acta Journal of Analytical Chemistry 27, 31-36.

Nair T.V.R., Chatterjee S.R and Abrol Y.P. 1983. Nitrate reductase induction potential in the seedling of cereals- the likely limiting factor in applied N utilization. Journal of Plant Physiol. Biochem. 10, 176-184.

Nambiar K.K.M and Gosh A.B. 1984. Highlights of Research of a Long term Fertilizer Experiment in India. LTFE Res. Bull, 1, 97.

Nye, P.H. and Tinkler P.B. 1977.Solute movement in the soil-root system.Indian National Academy of Science, Journal of nitrogen 3, 161-169.

Olsen S.R., Cole, C.V., Watanabe F.S., and Dean L.A. 1954. Estimation of available bicarbonate phosphorus. USDA Circ.939, Washington D.C.

Olson R.A. and Kurtz L.T. 1982. Crop nitrogen requirement, utilization, and fertilization. Journal of Agronomy. 22, 567-599.

Osborne, B.A and Raven, J.A. 1986. Light absorption by plants and its implications for photosynthesis. Biological reviews 61, 1-60.

Paul, E.A and Clark F.E. 1989.Soil microbiology and Biochemistry. Academic Press Inc. San Diego, CA pp 115-162.

Power J.F. 1990. Fertility management and nutrient cycling. In: Singh , R.P., Parr, J.F and Stewart B.A (Eds.), Dry land Agriculture, strategies for sustainability. Advances in soil science, Springer 13, 15-25, Verlag, New York.

Prakasa-Rao, E.V.S.and Puttanna, K. 2000. Nitrates, Agriculture and Environment.Current trends in science, 79, 9-10.

Purseglov, J.W. 1972. Tropical Crops.Monocots. Longman Scientific and Technical. London. 607pp.

Quaye, A.K. 1999. Soil water and nitrogen interaction on maize grown on a vertisol. Bsc. Dissertation, Soil Science Department, University of Ghana Legon.

Rowell, D.L. 1994. Soil Science: Methods and Applications. Longman Group UK Ltd, pp 219-243.

Ruselle M.P., Deibert, E.J., Hauck, R.D., Stavanovic, M. and Olson R.A. 1981. Effects of water and nitrogen management on yield and ^{15}N-depleted fertilizer use efficiency of irrigated corn. Journal of Soil Science Society of America, 45, 553-558.

Schmidt E.L. 1982. Nitrification in soil. In: Stevenson F.J (Ed.) Nitrogen in agricultural soils. 22, 253-288.

Sims J.T. 1986. Nitrogen transformations in a poultry manure amended soil: Temperature and moisture effects. Journal of environmental quality 14, 59-63.

Singh B and Singh Y. 1993. Rate-limiting steps in nitrogen Turn-over. Ecosystem-based Nitrogen needs and actual use. Journal of the Indian National Science Academy, 3, 16-18.

Singh B., Ryden J.C., and Whitehead D.C. 1988.Denitrification potential and actual rates of denitrification in soils under long-term grassland and arable cropping. Journal of Soil Biology and Biochmeistry, 21, 897-901.

Sivasanaka, A. 1993. Leaf growth and photosynthesis in relation to nitrogen supply in wheat (*Triticumaestivum* L.). PhD, Thesis submitted to the Indian Agricultural Research institute, New Delhi.

Smith, O.L. 1982. Soil microbiology: A model of decomposition and nutrient cycling. Boca Raton, CRC Press Inc. 22pp.

Soil Survey Staff, 2003.Keys to soil Taxonomy.9th Edition.United states Department of agriculture.National Resource Conservation Service. Washington D.C.

Stanley, R.L.J., and Rhoads F.M. 1977. Effect of time, rate and increment of applied fertilizer on nutrient plant uptake and yield of corn (*zea mays* L).Proceedings of Soil Science society of Florida, 36, 181-184.

Stevenson, F.J. 1994. Humus Chemistry Genesis, Composition and Reactions 2nd ed. John Willey and Sons, Inc. pp 1-23.

Tanaka, A. 1977. Role of organic matter. International Rice Research Symposium on soils and Rice pp 605-620.

Tisdale, S.L., Nelson W.L., Beaton, J.D and Havlin J.L. 2002. Soil Fertility and Fertilizers, 5th ed. Prentice Hall, New Delhi India, pp 109-172.

Ustin, S.L., Smith, M.O, Jacquemond, S, Verstrate M.M and Govarts Y. 1998. Rencz A.N (ed) Journal of GeoBotany, Vegetation mapping for earth sciences 3rd ed. Manual of Remote Sensing for the Earth sciences, 3, 189-248.

Vaughan, D., and Ord, B.G. 1985. Soil Organic Matter; a perspective on its nature, extraction, turnover and role in soil fertility. In: Vaughan D., and Malcolm R.E (Eds), Soil organic Matter and Biological Activity. Dordrecht, Boston, pp 1-36.

Veronica, C., Anatoly, G., and James S. 2008. Non-destructive determination of maize leaf and canopy chlorophyll content. Journal of Plant Physiology, 25, 1-23.

Vlek, P.L.G., and Crasswell E.T. 1979. Effect of Nitrogen Source and management on ammonia volatilization losses from flooded rice-soil systems. Soil Science Society of America Journal of soil Science. 43, 352-358.

Vlek, P.L.G., and Stumpe, J.M. 1978. Effect of solution chemistry and environmental conditions on the ammonia volatilization losses from aqueous systems. Journal of Soil Science Society of America, 42, 416-421.

Walkley, A. and Black I.A. 1934. An examination of the Degtjaref method for determining soil organic matter, and a proposed modification of the chronic acid titration method. Journal of Soil Science, 37, 29-38.

Welch, L.F., Mulvaney, D.L., Oldham M.G, Boone, L.V and Pendleton, J.W. 1971. Corn yields with fall, spring and side dress nitrogen. Journal of agronomy, 63, 119-123.

Wells, K.L, Thom, W.O and Rice, H.B. 1992. Response of no-till corn to nitrogen source, rate, and time of application. Journal of Agric. Production, 5, 607-610.

Wells, K.L. and Blitzer, M.J. 1984. Nitrogen management in no-till system. In: Hauck R.D (Ed.), Nitrogen in crop production, Madison Publishers ASA, CSSA and SSSA, 535-549.

Whittaker, R.H. and Marks P.L. 1975. Methods of assessing terrestrial productivity. In: Lieth,R, and Whittaker, R.H. (Eds), Primary productivity of the biosphere. Journal of Ecological Studies, 14, 55-118.

Woomer, P.L and Muchena, F.N. 1993. Overcoming soil constraints in crop production in tropical Africa. In: Ahenkora, E., Owusu-Bennoah, E., Dowuona, G.N.N (Eds.), Sustaining soil productivity in intensive Africa agriculture. Technical Centre for agricultural and rural co-operation, CABI publishing, Oxford, pp 155-171.

Wullscheleger, S.D. 1993. Biochemical limitations to carbon assimilation in C3 plants-A retrospective analysis of the A/Ci curves from 109 species. Journal of Experimental Botany. 44, 907-920.

Zarco-Tejada, P.J., Miller J.R., Mohammed, G.H, Noland T.L and Sampson, P.H. 2002. Vegetation stress detection through chlorophyll a+b estimation and fluorescence effects on hyper spectral imagery. Journal of Environmental Quality, 31, 1433-1441.