EFFECTS OF NITROGEN AND MICRONUTRIENTS ON YIELD AND PROTEIN QUALITY OF MAIZE IN A NORTHERN GUINEA SAVANNA ALFISOL OF NIGERIA

BY

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DECLARATION

I declare that the work in this Dissertation entitled "Effects of Nitrogen and Micronutrients on yield and Protein Quality of Maize in a northern Guinea savanna Alfisol of Nigeria" is a record of my own research work and it is written by me under the supervision of Professor E.O. Uyovbisere and Doctor W.B. Malgwi.

The information derived from literature has been duly acknowledged in references and citations. The subject matter therein has not been presented in any previous application for a higher degree at Ahmadu Bello University or any tertiary Institution in Nigeria and elsewhere.

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CERTIFICATION

This Dissertation titled: EFFECTS OF NITROGEN AND MICRONUTRIENTS ON THE YIELD AND PROTEIN QUALITY OF MAIZE IN A NORTHERN GUINEA SAVANNA ALFISOL OF NIGERIA BY BOLANLE TITILAYO OLOWOOKERE meets the regulations governing the award of the degree of Doctor of Philosophy, Ph.D in Soil Science (Soil fertility and Plant nutrition) of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to God Almighty, the great and awesome God who gave me the strength, showed me His mercies and grace throughout the course of this study.

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ABSTRACT

The experiment consisted of a greenhouse and field experiments. The field experiments were conducted during the rainy seasons of 2008 and 2009 at the Institute for Agricultural Research farm in Samaru (11^0 11' N, 7^0 38' E) within the northern Guinea savanna ecological zone of Nigeria to study the effects of nitrogen and micronutrients on yield and protein quality of maize. The study was therefore conducted with the following objectives; to determine the suitable levels of nitrogen and micronutrients on the yield of quality protein maize and normal maize varieties in the northern Guinea savanna, to establish the effects of nitrogen and micronutrients on the lysine and tryptophan contents of maize as well as to determine the soil nutrient factors influencing the nutritional quality of QPM varieties introduced to the northern Guinea savanna in comparison with normal maize. The greenhouse and field treatments consisted of four rates of nitrogen fertilizer (0, 50, 100 and 150kgNha^{-1}), two rates of micronutrients (0, cocktail mixtures) Cu, Fe, Zn, B and Mo and four maize varieties SAMMAZ 14 and SUSUMA (QPM) and SAMMAZ 11 and SAMMAZ 12 (normal maize) which gave a total of thirty-two (32) treatments with basal application of 60kgha^{-1}P as P_2O_5 and 60kgha^{-1}K as K_2O. These were tested in a completely randomized design in the greenhouse and randomized complete block design on the field with three replications with a total of 96pots/plots respectively. The fertilizer treatments were factorially combined. The results from the study revealed that in the greenhouse micronutrients application enhanced the performance of the QPM than the normal maize. SUSUMA variety (QPM) was superior in performance than SAMMAZ 14 (QPM) in that it produced taller plants (65.50cm), more number of leaves (12.75) and higher dry matter yield of 6.67g/pot at low application of nitrogen (50kgNha^{-1}). The results from the field showed that all the maize varieties responded well to the nitrogen applied and that the QPM (SAMMAZ 14 and SUSUMA) varieties were superior in their response to nitrogen in that they responded significantly to nitrogen rate of 100kgNha^{-1} while the normal maize (SAMMAZ 11 and SAMMAZ 12) responded to nitrogen at the highest rate applied (150kgha^{-1}) in this order of response SUSUMA> SAMMAZ 14 > SAMMAZ 11 > SAMMAZ 12.The Stover yield, plant height, 1000-grain weight, cob length and cob diameter were increased as nitrogen fertilizer increased from 0- 150kgNha^{-1}. The interaction between nitrogen fertilizer and micronutrients gave a crude protein content of 9.1%, lysine content of 14.3% and tryptophan content of 16.7% by the QPM varieties over the normal maize varieties. SUSUMA the most superior variety gave lysine and tryptophan contents of 3.19% and 5.08% higher than SAMMAZ 11(NORMAL MAIZE). The correlation analysis showed that all the agronomic parameters, total nitrogen, calcium, zinc, copper, boron and soil pH influenced and increased the grain yield positively. The principal component and correlation coefficient analysis revealed that as grain yield increased the nitrogen and protein contents of the maize decreased. The factors most responsible for enhanced grain quality in the QPM varieties from the correlation analysis and PCA were nitrogen, potassium, calcium and zinc contents of the soil. Gross margin analysis showed that SUSUMA (QPM) variety was more profitable than SAMMAZ 14, SAMMAZ 12 and SAMMAZ 11. It produced higher grain yield at 50kg N/ha and with the application of micronutrients. Farmers can therefore adopt the QPM varieties (SUSUMA and SAMMAZ 14) since it is easy to cultivate like the normal maize in the same environment and climatic conditions with higher yield and of more quality than the normal maize.

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CHAPTER ONE

1.0 INTRODUCTION

Improving nutritional quality of agricultural crops is a noble goal, which is particularly important in cereal crops where meeting protein nutrition needs is one of the greatest challenges because plants tend to be low in protein and this protein has poor nutritional quality (Vassal, 2006). The nutritional well being and health of all people are known to be vital prerequisites for the development of societies (Prasanna *et al.,* 2001). The nutritional quality of maize is determined by the amino acid make up of its protein. Proteins are linear polymers built of monomer units called amino acids, this contain a wide range of functional groups which include alcohols, carboxamides, carboxylic acid, thioethers and a variety of basic groups (Berg *et a.l,* 2001). Protein is essential in human's diet as a source of amino acids that cannot be synthesized from simple sources of nitrogen and energy for growth, reproduction and maintenance (Okai, *et al.*,2005, Vassal, 2006). It constitutes important sources of carbohydrate, vitamins B, minerals, 15% of all food crop protein and other nutrients such as micronutrients.

Maize seed contains three groups of proteins: The storage proteins (made up of amino acid reserved deposited early in seed development), the enzyme proteins (involved in plant metabolism) and the structural protein (Essen and Stetler, 1987). The predominant protein in maize is the alcohol soluble prolamins protein called zein. Zein stores N, C, S and other nutrients which it supplies to germinating seedlings and is characterized by low levels of lysine and tryptophan (Biston *et al.,*1996). These deficiencies lead to poor utilization of plant protein in diets so improving the balance of amino acids is an important grain quality objective. The effects of the relative concentrations of the different free amino acids and of the proteins could be a decisive factor in determining the nutritional quality of maize,

especially in lysine and tryptophan which have been found to be low in normal maize (Berg *et al.,* 2001).

Maize is gaining popularity in the northern Guinea savanna zone of Nigeria. In fact, it is replacing the traditional cereals, millet and sorghum (Onwueme and Sinha, 1991). Whatever the type of maize, they all require heavy fertilizer application for optimum yield (Singh, 1987; Awotundun, 2005). For mineral fertilizer, a rate of 100-150 kg N, 40-50 P_2O_5 and 80-100 kg K_2O ha^{-1}has been recommended for maize in the savanna zone (Onyinbe *et al.*, 2006). While, FPDD (2002) recommended 120 kg N, 60 kg P_2O_5, and 60 kg K_2O ha^{-1} of mineral fertilizer for optimum yield of maize in the savanna zone.

Despite the widespread use across the country, maize consumed in Nigeria is mainly dent maize which has a nutritional constraint as human food needs, because even though it has about 7-13% protein content (Moro *et al.*, 1996), it is deficient in two essential amino acids, lysine and tryptophan needed to produce quality proteins and is regarded therefore as being of poor quality (Obi, 1982; Okai *et al.*,2005; Vassal, 2006). Thus, conventional maize is a poor-quality food staple; unless consumed as part of a varied diet which is beyond the means of most people in the developing world. Nevertheless, identification of Opaque-2 mutant gene by Bjarmason and Vassal (1992) as the most amenable genotype for use in breeding programmes for quality protein maize (QPM) has changed the opinion of people about nutritive quality of maize and it is known to yield 10% more grain than the normal varieties of maize (Babu, 2005; Showemimo *et al.*, 2005) and the resulting maize is therefore known as quality protein maize (QPM). Quality protein maize in comparison with conventional maize has higher quality because it contains higher amount of lysine and tryptophan than normal maize.

1.1 Statement of the Problem

Maize is progressively assuming the position as the major crop of the sub-humid and semi- arid savanna with respect to economic prospects for the farmers. It is a staple food crop in the ecological zone. However, it is devoid of some major amino acids, such as lysine and tryptophan (Obi, 1982; Okai *et al.*, 2005; Vassal, 2006) though high in others such as glutamine, leucine and prolamin. The development of QPM varieties improved the nutritional properties of maize and has given hope to many as a source of affordable protein for good health. The QPM varieties introduced to the Nigerian savanna ecologies still have problems of adaptation when the levels of amino acid content that characterize the varieties are considered. Though breeders may have developed genetically stable materials, environmental factors seem to have great influence on the protein content of the crop, since environmental and management factors interact greatly in ensuring the stability of the chemical composition of the grains. A study was carried out to assess the effects of nitrogen fertilizer and some micronutrient mixtures (copper, iron, zinc, boron and molybdenum) on the protein quality of four varieties of maize; two quality protein maize and two conventional maize varieties in a northern Guinea savanna Alfisol of Nigeria.

1.2 The Objectives of the Study are:

i. To determine the suitable levels of nitrogen andmicronutrientsontheyield of quality protein maize and normal maize in the northern Guinea savanna.

ii. To establish the effect of nitrogen and micronutrient levels on the lysine and tryptophan content of maize.

iii. To determine the soil nutrient factors influencing the nutritional quality of QPM varieties introduced to the northern Guinea savanna in comparisonwith normal maize.

1.3 Scope of the Study

The study was conducted at the Institute for Agricultural Teaching and Research farms in Samaru, Zaria during the 2008 and 2009 cropping seasons. Four levels of nitrogen fertilizer (0, 50, 100, 150kgha^{-1} N) were used in combinations with two levels of micronutrients mixtures on four maize varieties; two QPM varieties (SAMMAZ 14 and SUSUMA) and two conventional maize varieties (SAMMAZ 12 and SAMMAZ 11).

1.4 Significance of the Study

Application of nitrogen fertilizer to enhance protein synthesis in cereal grains and therefore enhance quality is of paramount importance in maize production in the area of study. The study will therefore provide useful information to farmers, researchers and policy makers with better understanding of the optimum rates of nitrogen fertilizer and the essentiality of micronutrients in the maintenance of the protein quality of the maize crop and to establish the effect of nitrogen and micronutrient levels on the lysine and tryptophan content of maize.

CHAPTER TWO

2.0 REVIEW OF LITERATURE

2.1 Soils of the Savanna

The soil of the northern Guinea savanna which stretches from latitude 7^{o} – 12^{o}N is characterized by the sub-humid climate covering well over 50% of the land area. The savanna soils are highly weathered, coarse textured, low in organic matter content (2.0-10.0gkg^{-1}) and cation exchange capacity (6.0-10.0$cmolkg^{-1}$). They are generally acidic and poorly buffered with respect to most nutrients (Jones and Wild, 1975; Balasubramanian and Nnadi;1980, Kang and Wilson,1987). The annual rainfall ranges from 800mm-1900mm (Uyovbisere and Lombin, 1991). They are generally low in total nitrogen (N), values range from 0.08 to 0.29 percent, with a mean of 0.05 percent (Jones and Wild, 1975). This low value is closely linked with low organic matter content of the soils. Total phosphorus (P) is also generally low too with values ranging from 13 to 630ppm, but a range of about 100 to 400ppm have been reported in the savannah soils (Mokwunye,1974).

Potassium content varies widely according to parent materials but compared with other nutrients, amounts are often high (0.2- 0.3$cmolkg^{-1}$).Calcium and magnesium are the dominant exchangeable cations in virtually all savannah soils and few deficiencies have been reported. The soils are acidic to neutral in reaction (pH 5.0 – 7.0) and low in clay content with kaolinite as the dominant clay mineral (Udo, 1985). The effective cation exchange capacity (ECEC) of many savanna soils are low, often 4$cmol(+)kg^{-1}$ and is closely related to the organic matter and clay contents of the soils, most of which has variable charge (Sanchez,1976). The soils are predominantly Alfisols with associated well drained Ultisols and Oxisols (Esu, 1989; Ogunwole *et al.*, 2001). These soils mostly degrade quickly because of the rapid rate of organic matter decomposition, intensive leaching of nutrient and soil erosion on cleared lands. The soils are well-drained and shallow, loamy sand to sandy loam

in texture in the topsoil while the argillic sub-soils are sandy loam to sandy clay loam (Moberg and Esu, 1989).The soil texture, low organic matter content and CEC values of these soils make them to be of poor buffering capacity (Udo, 1985). The agricultural value of these soils is usually rated poor to average in terms of nutrient levels and soil moisture deficiency is one of the primary limiting factors to crop growth in soils of these areas. Even in the more humid areas, the seasonal distribution of rainfall described earlier is an important determining factor for crop growth, depending on the moisture-storage capacity within the rooting depth of a particular soil. Most of the soils of the savanna are under continuous cultivation. The soils are poorly managed with the use of heavy implements which increase soil compaction and erosion that leads to rapid decline in organic matter, leaching of basic cations and high rates of acidification (Jones and Wild, 1975; Vanlauwe and Saginga,2004; Ogunwole, 2008). Therefore, there is the need for the use of mineral fertilizers on such soil to produce crop and maintain the soil fertility. Gromove *et al.* (1994) reported that the efficiency of utilization of nutrients from fertilizers applied to soils depends on weather condition, biological characteristics of the crops and fertilizer rates.

2.1.1 Organic matter status of northern guinea savanna soils

Organic matter is of crucial importance in the savanna soil. Once the vegetation is cleared and the soil is cultivated, soil organic matter breaks down rapidly depending on the moisture content. Soil organic matter consists of relatively unstable humus and organic materials that are subject to fairly rapid decomposition (Brady and Weil, 2004). Oguntoyinbo *et al.* (2005) reported that the soils of the tropics are known to have low organic matter content which influence many properties of the soils, and thus low nutrient supply for crop needs. Olaitan and Lombin (1988), recognized different materials that made up organic matter in the soil as carbohydrates (starch, sugar and cellulose), lignin, protein, minerals, fats

(oils and waxes), resins, tannins and some pigments of which lignin and protein make up the greatest portion.

2.1.2 Nitrogen status of northern guinea savanna soils

Nitrogen (N) is an important plant nutrient and is the most frequently deficient of all nutrients in tropical soil systems. This is because of the relatively large amount required by plants and its high mobility in the soil. Nitrogen is of particular interest because it is usually the most limiting nutrient for crop production while fertilizer N represents a major variable input cost (Gil and Fick, 2001). Soil N has a variety of pathways for input and outflow and these can have important negative environmental impacts when lost from the production system. Understanding the behaviour of nitrogen in the soil is essential for maximizing agricultural productivity and profitability while reducing the impacts of nitrogen fertilization on the environment (Tisdale *et al.*, 2003). Soil degrades seriously when mineral fertilizers are used to produce crop. The degradation includes the progressive loss of organic matter, soil acidification, decline in CEC, buffering capacity and fertility status; particularly K reserves (Graham *et al.,* 2002). Rayar (2000) stated that intensive use of chemical fertilizers, though have found to increase crop yield, can still result in deterioration of food quality, destruction of natural soil chemical and biological properties by upsetting natural nitrogen cycle.

Sources of nitrogen may be through application of inorganic fertilizer containing nitrogen, organic nitrogen and from nitrogen fixation by leguminous crops, which can supply sufficient nitrogen for optimum crop production. A major source of the nitrogen used by plants is nitrogen gas (N_2) but higher plants cannot metabolize nitrogen (N_2) directly into protein. Nitrogen gas must be converted to a form available to plant by one of the following methods:

- Fixation by microorganisms that live symbiotically on the roots of legumes and certain non-leguminous plants (Tisdale *et al*., 2003).

- Fixation by free-living or non-symbiotic soil microorganisms.
- Fixation as oxides of nitrogen by atmospheric electrical discharges.
- Fixation as NH_3, NO_3^-, CN_2^{2-} by the manufacture of synthetic nitrogen fertilizers (Tisdale *et al.,* 2003).

Soil N availability is determined by its mineralization, microbial conversion of organic N to ammonium (NH_4^+) with further oxidation to nitrate (NO_3^-) and is a key stage in the nitrogen cycle (Tisdale 2003). Soil organic matter contains about 5% N and during a single growing season, 1 to 4% organic is mineralized to inorganic nitrogen which is adsorbed by plants as (NO_3^-) and ammonium ion (NH_4^+) ions and as urea. The total nitrogen content of soils range from less than 0.02% in subsoils to more than 2.5% in peats (Tisdale *et al.,* 2003). Nitrogen in soils occurs as inorganic or organic nitrogen with 95% or more of total nitrogen in surface soils present as organic nitrogen (Tisdale *et al.,* 2003)

In warm, moist well aerated soils, the NO_3^- form is dominant (Tisdale *et al.,* 2003). Ammonium (NH_4^+) being readily adsorbed, is not easily leached, but under most normal conditions, its rapid condition conversion to NO_3^- or inorganic forms ensures that the amounts present are generally small. Steele and Vallis (1988) in their own work submitted that under certain conditions, soil microflora can compete with plants for NH_4^+ and convert it into microbial proteins, thus immobilizing the N into an organic, temporarily unavailable form. However, plants uptake of NH_4^+ proceeds best at neutral pH values and is depressed by increasing acidity. Absorption of NH_4^+ by roots reduces Ca^{2+}, Mg^{2+}, and K^+ uptake while increasing absorption of phosphoric ion (H_2PO_4), sulphate ion (SO_4^{2-}) and chloride (Cl^{-1}) (Tisdale *et al.,* 2003).

The rate of NO_3^- uptake is usually high and is favoured 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:

calcium (Ca), magnesium (Mg), and potassium (K). The growth medium will become alkaline, and some carbonic ion (HCO_3^-) can be released from the roots to maintain electro-neutrality in the plant and in the soil solution (Tisdale *et al.*, 2003). Seasonal patterns of soil inorganic N has been reported by Tunner (1997) for natural grasslands. The low soil inorganic N early in the season was attributed to high rates of plant N uptake at that time and to the low rates of soil N mineralization. Therefore, Sanginga *et al*. (2001) suggested that N supplied from the breakdown of organic matter must be supplemented with N from other sources. Adequate soil moisture and temperature in the late season together with slow growth rate and, consequently, low soil N uptake by the plants, may have been the main reasons for the observed increase in soil inorganic N at that time.

The quantities of nitrogen available in forms of NH_4^+, NO_3^- depend largely on the amount applied as nitrogen fertilizers and mineralized from organic soil nitrogen. The amounts released from organic nitrogen and to some extent those existing in the soil after the addition of NH_4^+ or NO_3^- depend on many factors affecting nitrogen mineralization, immobilization and loss from the soil.

Organic soil nitrogen occurs as proteins, amino acids, amino sugars and other complex nitrogen compounds. The proportion of total soil nitrogen in these various fractions is as follows: bound amino acids; 20 to 40%; amino sugars such as the hexosamines, 5 to 10%; and purine and pyrimidine derivatives, 1% or less. Very little is known about the chemical nature of the 50% or so of the organic nitrogen not found in these fractions (Tisdale *et al*., 2003). Proteins are commonly found in combination with clays, lignin and other materials resistant to decomposition. Analytical techniques are now available to isolate free amino acids from soils that are not in peptide linkages or in combination with high molecular weight polymers, clays or lignin (Tisdale *et al.*, 2003). Plant absorbs nitrogen as both NH_4^+ and NO_3^-, while NO_3^- occurs generally in higher concentrations than NH_4^+ and is free to

move to the roots by mass flow and diffusion. The 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 use either forms of nitrogen but 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, Mg, K) (Tisdale *et al.,* 2003). The relative proportions of N taken up by the maize plants in form of NH_4-N and NO_3-N depend on the age of the plant. Young maize plants absorb NH_4-N more rapidly than NO_3-N while older plants absorb for up to 90% of total nitrogen as NO_3-N.Nitrogen has essential role as a constituent of proteins, nucleic acids, chlorophyll and growth hormones. It is also essential for seed formation and maturity. Nitrogen deficiencies are widespread in the savannah farming systems, and are often limiting factors to crop growth. Nitrogen is the most frequently deficient nutrient in crop production; therefore, most non-legume cropping systems require nitrogen inputs.

2.1.3 Phosphorus status of northern guinea savanna soils

Phosphorus (P) does not occur as abundantly in soils as N and K (Tisdale *et al.*,2003) and is a critical element in natural andagricultural ecosystems throughout the world where seasonality strongly affects nutrition processes. Total concentration in surface soils varies between 0.02 and 0.10%. Unfortunately, the quantity of total phosphorus in soils has little or no relationship to the availability of P to plants. The underlying geology and soil forming processes cause the low phosphate (PO_4^{3-}) contents of the northern Guinea savanna soils (Jones and Wild, 1975; Esu, 1989). Moreover, increasing intensification of cultivation with disregard to good soil and organic matter management is another reason for the poor phosphorus status of the soils. The Guinea savanna zone is dominated by sandy soil thus it has low phosphorus fixing capacity and the phosphorus deficiency has greatly reduced the soil productivity. In the northern Guinea savanna (NGS) region, the soil is expected to supply

30kg P ha^{-1} in plant available forms for 1 ton of grain produced (Weber, 1996). Phosphorus availability in soils is controlled by both the sizes of pools and the transformation rates among these pools (Zou *et al.*, 1992). P availability is affected by pH, at low pH, insoluble phosphate of Al-P, Fe-P is formed. At higher pH, P is adsorbed as insoluble Ca-P while optimum availability is at pH 6.5. P adsorption by soil and soil components is at maximum at the pH range of 2-4. Jones and Wild (1975) and Uyovbisere (1979) also submitted that the availability of P status in savanna soils is a function of P content of the parent material which is low for most savanna soils of Nigeria. P is generally low with values from 80-150ppm, which is low compared with temperate soils that have average contents of about 1500-3000ppm. Of these amounts, less than 10% is said to be in active/labile and Ca-P forms (Uyovbisere, 1979). It is generally recognized also that organic P becomes available to plants only after it has been mineralized and it will be of considerable importance in plant nutrition. High phosphorus level inhibits the uptake of iron due to the formation of insoluble iron phosphate and zinc in soils (Kanwal *et al*., 2010).

Most phosphorus present in the topsoil is in organic combination as organic compound to which inorganic phosphorus is linked and source of phosphorus for plants is from the organic form (Mokwunye and Chien, 1980). Olaitan and Lombin (1984) pointed out that the organic phosphorus in savannah soils range between 200 – 300gkg^{-1}, other values of organic phosphorus reported in the savannah soils were 170 – 250gkg^{-1} (Bache and Rogers, 1970). While Udo (1985) gave a higher value of 400gkg^{-1} in Amapu (1999).These differences will not be unconnected with differences in clay and organic matter contents and the prevalent soil management practices of the sites where the studies were conducted.

Soil phosphorus is solely derived from apatite, a major mineral. As weathering proceeds with the resultant decrease in soil pH, the mineral phosphorus gets dissolved but eventually gets re-fixed in sesquioxide complexes. The phosphorus compounds are largely

unavailable to plants (Uyovbisere, 1994; Agbede, 2009). P is absorbed by plants largely as orthophosphate ions ($H_2PO_4^-$and HPO_4^{2-}) which are present in soil solution. The amount of each form depends on soil pH. Phosphorus absorption entails the transfer of phosphate ions from the soil to the roots and into plants, a characteristic feature of phosphate absorption from soil is the ability of the plant to accumulate and maintain a high concentration of inorganic phosphate within its tissue despite the low concentration of this ion in the soil solution (Adams and Odom, 1985; Whalen and Chong, 2001).

Rainfall distribution during the growing season affects the ratio of soil fertilizer phosphorus taken up by crop. In the wet season, the crop will take up nearly all its phosphate from the surface soil. While in the dry season, this phosphate becomes unavailable when the surface soil becomes dry (Amapu and Babalola, 2006) because the phosphorus is not in solution hence cannot be taken up by plants.

2.1.4 Phosphorus and plant growth

Phosphorus is often considered the next most limiting nutrient to nitrogen for plant productivity in soils (Brady and Weil, 2004; Agbede, 2009). Phosphorus is a key component of cellular compounds and is vital to both plants and animal life. Although the phosphorus requirement is only one tenth of the nitrogen and one fifth of the potassium, adequate supply of easily available P is essential particularly during early stages of growth when the limited root system is not yet capable of drawing sufficiently on the phosphorus reserves in the soil. Phosphorus is taken up by maize continuously from the seedlings stage to maturity.The concentration in the plants should be much higher during the seedling stage but the capacity of the roots to obtain phosphorus is then low and any deficiency of phosphorus is usually seen before the crop is 60-75cm tall in maize. Phosphorus uptake is maximum during the third and sixth week of growth.It is slightly ahead of dry matter accumulation early in the

season and is then generally parallel to dry matter accumulation until the early dent stage after which phosphorus uptake practically ceases.

Phosphorus plays many roles in plant growth. It is a constituent of the cell nucleus and essential for cell division, it is involved in enzymic reactions which depend on phosporylation. Phosphorus is associated with root development in seedlings and adequate supplies of phosphorus in the seedbed are essential for most crops. It is involved in the development of meristem tissue and is particularly required in the early rapid phase of growth. It is used for the synthesis of proteins, carbohydrates and lipids and also affects the quality of cereals and fruits, feeds and forages (Brady and Weil, 2004)

Organic phosphate include adenosine di and tri phosphate (ADP and ATP), and sugar phosphate which play an essential role in metabolic process. (Brady and Weil 2004: Agbede, 2009).

2.1.5 Phosphorus deficiencies

Phosphorus deficiencies are widespread in the savannah soils and many authorities consider lack of phosphorous to be the primary nutrient limiting crop production in this region (Kowal and Kassim, 1978).Phosphorus deficiency is not easily recognised in plants however deficiencies in cereals are exhibited by stunting and retardation of the development process. The deficiency of phosphorus shows as dark green coloration of the foliage, leaves are small in size, stems are fragile and shoot and root growth reduced and it shows as purple coloration in the veins of the leaves of maize (Tisdale *et al.*, 2003).

2.2 Potassium

Potassium is essential in the synthesis of amino acids and proteins from ammonium ions. Adequate supplies of potassium are also essential for efficient photosynthesis. It is also involved in the transport mechanism of other nutrients across cell membranes. In many situations, potassium supplies in the soil are adequate for crop growth, but where high

nitrogen and phosphorus fertilizer levels are used, potassium may become a limiting factor to growth. K fixation can occur as a result of K becoming trapped within clay sheets as they dry and collapse. Soils with high exchangeable K or recent K fertilizer applications are dried while higher rates of K allowed for the efficient use of more N which resulted in better early vegetative growth and higher grain and straw yield as K and N rates increased. In the field, better N uptake and utilization with adequate K mean improved N use and higher yields. Crops respond to higher K levels when N is sufficient and greater yield response to fertilizer occurs when K is sufficient.K also interacts with P and that together they may interact with other nutrients. A good example is the observed reduction of P- induced Zn deficiency of corn when available K levels are increased. Good S levels along with adequate K improve Zn uptake. Interactions with some micronutrients B, Fe and Mo have resulted in decreased uptake when K was added while the use of K has increased micronutrient utilization of Cu, Mn and Zn. Potassium does not affect the root/shoot ratio while nitrogen supply greatly influences this ratio, which increases when nitrogen supply is reduced (Rejado, 1979). Nitrogen has the largest effect on leaf area; both phosphorus and potassium have positive effects at the higher levels of nitrogen. It has been demonstrated that potassium increases weight per grain (1000 grain weight). Potassium also increases apparent grain density by about 10%. Also potassium increases grain protein content of wheat thus improving quality while it increases the oil content of maize grain, (Rejado, 1979).

It has also been observed that potassium fertilizer increases the harvest index grain: straw ratio and grain: cob ratio in maize. It increases the carbon assimilation index during grain filling thereby increasing the carbohydrate contents of ears and root.

Maize uptake of K from the soil is mainly through diffusion process and is rapid in the early stages of growth. During the time of peak uptake, potassium is taken up at the rate of 3.1 – 6.0kgha^{-1}day. A sub-deficient level of potassium availability over this period can be

decisive for final yield.Potassium uptake follows a much different pattern from that of dry matter accumulation. Prior to silking, potassium uptake is faster than dry matter accumulation and by silking almost 90% of the potassium has accumulated. Maximum potassium uptake is reached sometime before maximum dry matter production and the potassium content decreases as the grain matures, though there are varietals and seasonal variation.

Maize takes up 75 – 90% of its potassium requirement before flowering, stage with 60% by the time the 9^{th} leaf emerges. Most of the potassium taken up by maize in the period of maximum absorption accumulates in leaves, where potassium deficiency first becomes apparent. Potassium is translocated to the grain from all part of plant except the stem and at harvest, 40% of potassium is found in the stem, 20% in leaves, 15% in sap and 20-25% in grain. The straws of maize contain twicepotassium as much as in the grain alone (Rejado, 1979). Varieties and species differ considerably in the ability to take up nutrients. The newer hybrids are more potassium demanding than the other varieties. Singh and Singh (2003) identified that continuous application of mineral fertilizers induces K deficiency.

2.3 Sulphur

Sulphur is an essential nutrient for the production of amino acids: cysteine and methionine, which are important for protein synthesis. Soil and plant analyses are commonly used to compile fertilizer programmes for nutrients such as phosphorus, potassium and nitrogen but not for sulphur. This is probably due to the fact that sulphur is dynamic and mobile in soil (Grobler *et al.*, 1999). The sulphur requirements of crops are very similar to their phosphorus requirements namely between 10-30kgha^{-1} of each. On the whole, grains and cereals tend to take up less sulphur than phosphorus, namely about 10kg/ha while legumes have about 25 to 30kg ha^{-1}. Sulphur deficiency is most widely found on both leguminous crops and grain legumes such as clovers. Sulphur occurs as sulphate in many igneous rocks particularly basic rocks, and as the rock weathers it is released as sulphate.

Sulphur deficiency in crops is normally found in regions well away from industrial areas or the sea where the rainfall returns less than about 5kgha^{-1}, sulphur deficiency is only found in arid areas. The ratio of protein nitrogen to organic sulphur in the leaves of a variety of crops is about 15, so if a crop is growing on a low sulphate soil, the amount of leaf protein the crop can synthesize is strictly limited. In general, plants need about 0.2% total sulphur in the dry matter of their leaves if growth is not to be limited by its lack (Sachdev and Deb, 1990).

2.4 Effects of Nutrients on Maize Yield

2.4.1 Response of maize to nitrogen fertilizer

Low soil nitrogen is one of the most important abiotic factors limiting maize yields in thetropics (Ighalo *et al*., 2008). Farmers initially relied on shifting cultivation or bush fallow for soil fertility maintenance but it has become increasingly difficult to sustain these systems because of increasing population pressure. As a result,organic matter in the soil is depleted with a corresponding decrease in yield. Hu *et al.* (2010) reported that six consecutive years of nitrogen addition to soil significantly decreased soil pH and total P but had little effect on soil total organic and total nitrogen concentrations. Long time application of 60, 90 and 120kgNha^{-1} showed significant increases in nitrogen, humus and soil CEC while the sum of bases and base saturation decreased (Dragan *et al.*,2010).

2.4.1.1 Effects of nitrogen on plant nutrient concentration and uptake

Positive response of maize to nitrogen fertilizer has been reported by Atlakpui *et al.*, (1997). Hussaini *et al.* (2008) stated that chemical analysis is used to estimate the fertilizer needs of plants and give some relationships between nutrient supply and the chemical composition of the plant. In an experiment at Samaru, increased application of nitrogen fertilizer tended to increase the Stover and ear leaf concentration of N, K, Ca and Mg in maize (Tanimu *et al.*, 2007). Daudu (2004) reported in his work that nitrogen uptake was observed to increase with increasing levels of inorganic fertilizer level (120kgNha^{-1}).

2.4.1.2 Effects of nitrogen on growth and yield of maize

Crop nitrogen requirement is a physiological component which is directly related to the genetic potential of a crop and its plant growth condition (Zotarelli *et al.*, 2009). Ayub *et al*. (2002) observed that growth parameters like plant height, number of leaves per plant,stem diameter; leaf area/plant green fodder yield, dry matter yield and dry matter percentage were influenced by the application of nitrogen. Many investigators found that there was an increase in the protein content of forage maize by increasing nitrogen levels (Cox *et al*., 1993). Also, El-Gizawy (2009) reported that application of nitrogen fertilizer (60-120kgN/ha) significantly increased plant height, number of grain per ear and grain yield. However, he found that nitrogen fertilizer significantly decreased tasselling and silking date. Nitrogen had a significant effect on plant height, number of grains per cob, 1000grain weight and harvest index (Mahmood *et al.*, 2001). Wajid *et al.* (2007) evaluated the effect of three nitrogen levels and three maize cultivars, and observed that nitrogen rates significantly affected plant height, 1000grain weight, grain yield, harvest index, increase in total dry matter (TDM) and nitrogen accumulation.

Onasanya *et al.* (2009) in their findings reported that application of nitrogen enhanced vegetative growth of maize as expressed by the increase observed in number of leaves, plant height, leaf area index, total dry matter per plant and relative growth rate of maize. These increases in growth parameters confirmed the importance of nitrogen as a constituent of protein and also as an integral component of many other compounds essential for plant growth processes including chlorophyll and many enzymes. Mbagwu (1990) reported that nitrogen is known to be the most important constraint to maize production in the Guinea savannah of Nigeria and that nitrogen application increased the crude protein percentage of tropical grasses. In the maize crop, nitrogen is taken up at a slower rate during development but the rate of uptake picks up rapidly by tasselling stage when about 4kg of nitrogen is taken

up per hectare per day. The rate of uptake however decreases after grain formation and by the tasselling stage,maize plants have accumulated over 40% of their total requirement during the season. The percentage of nitrogen in the plant decreases with age of the crop and at harvest about two third of the total nitrogen should be in the grain. Deficiency of nitrogen even during early stages(up to 40 days from planting) may cause irrevocable reduction in the number of rows of grain in the maize ears.

Jaliya *et al.* (2008) observed that increase in fertilizer rate from 0:0:0 to 150:26:50kgNPKha^{-1} significantly increased the number of grains per cob and 100 grain weight of quality proteinmaize while further increase to 180:35:66kgNPKha^{-1} significantly reduced it in both years for number of grains per cob and 100 grain weight only in one year. Dry matter increases in response to nitrogen fertilizer (Ogunlela *et al.,* 1988) while some researchers have reported little or no response (Douglas *et al.,* 1972) when rates are greater than 700kgha^{-1}. It was observed that with increase in nitrogen application up to 100 or 150kgha^{-1}, there was increase in plant height and dry matter production (Ogunlela *et al.,* 1988).Nitrogen is known to affect the number of days to 50% tasselling and silking. Rathore *et al.* (1976) observed that nitrogen application increased the numbered of days to 50% tasselling while Ologunde (1974) observed a decrease in the number of days to 50% tasselling with increasing nitrogen rates. However, the variable responses in the number of days to 50% tasselling and silking to increment in nitrogen fertilization should be attributed to location effect, the variety and the prevailing climatic conditions. Nitrogen has been shown to significantly increase growth of maize; it plays a central role in plant biochemistry as an essential constituent of cell wall, cytoplasmic protein, nucleic acid, chlorophyll and vast array of cell components (Hay and Walker, 1989).

Balasubramanian *et al.*(1978) obtain yields of over 5 tons/ha with recommended optimum rate of between 100-120kgha^{-1} using improved production technology. The

response of maize to nitrogen fertilizer is known to be related to the level of soil organic matter, the total nitrogen content of the soil, the texture of the soil and the variety of the maize used (Singh and Singh, 1993).

2.4.1.3 The effect of variety on growth and yield components of maize

Modern agriculture is concerned with yield and nutritional quality of crops but environment plays its role on production of varieties (Derby *et al.,* 2004). It is a known fact that varieties differ in their yield potential, maturity period and canopy architecture (Dowsell *et al.*, 1996). In the study conducted in the Nigeria savanna by Hassan (1999), using two-maize varieties (GH110-28 and Obatanpa), it was revealed that GH110-28 produced significantly higher number of leaves/ plant, days to 50% tasselling and silking, grain yield, 100 seed-weight and cob weight than Obatampa. This was attributed to GH110-28 be more responsive to fertilizer and to its genetic make-up. However, Obatampa expressed its superiority over GH110-28 on plant height, leaf area index, dry matter per plant and lodging. It was asserted that these characters are genetically controlled and could also be influenced by environment to a certain extent.

2.4.2 Effect of phosphorus on maize yield

In a greenhouse experiment, maize was given 0.10 or 2.0mgPkg^{-1} soil, residual phosphorus increased dry matter yield in soils while direct application of phosphorus only increased dry matter production. Total phosphorus uptake by maize was increased by direct phosphorus application at all rates of residual phosphorus but soil phosphorus uptake was increased only with application of up to 10mgkg^{-1} soil. Percentage phosphorus utilization was 7.1-19.5% and it decreased with increase in residual and applied phosphorus (Saroa *et al.*, 1991). Williams and Hector (1995) observed maize grains yield increase of 0.38 and 0.7mgha^{-1} when 13 and 16 kgha^{-1} were applied respectively. Nguyen *et al.*(2001), reported that nine years of nitrogen application significantly reduced labile pools of soil inorganic P,

total soil P and soil extractable K and Mg while total soil N was only slightly increased in the 10- 30cm depth. Malhi *et al.* (1991) reported that there was a decline in extractable P in soils with nitrogen application up to 84kgNha^{-1} rate. It was reported that a further increase of applied nutrition resulted in a decline in extracted soil Ca, Mg and K. The results of different K and P levels depicted that higher rates of both fertilizers have significantly increased the number of grains ear, weight ear and 1000grain weight (Muhammed *et al*., 2002)

The rate of phosphorus to be applied to maize crops for optimum yields depends on the phosporus sorption capacity of the soil, as soil with higher sorption capacity required high level of phosphorus fertilizer when they are phosphorus deficient. Furthermore, under conditions of low phosphorus buffering capacity and low inherent phosphorus, it is beneficial to supply large initial dose of phosphorus to the soil to build up the phosphorus adequately to sustain good yield (Enwezor, 1997).

2.4.3 Effect of potassium on maize yield

A report by Brar and Singh (1995) revealed that when two rates of potassium (K), 0 or 90mgkg^{-1} soil were applied in a trial to study the response of maize to potassium fertilizer, the application of potassium increased plants height, leaves/plants, dry matter production and potassium concentration significantly. Dry matter production was found to be the best indicator for measuring crops response to potassium application, the response of potassium with respect to dry matter production was inversely related to soil potassium status, the lower the potassium status the higher the response to potassium application and vice versa (Brar and Singh, 1995). It was observed that potassium response to crops in the tropics and maize in particular depends on the soil parent rock, climate and cropping system adopted. Excessive rainfall can result in poor pollination and seed set and higher incidence of disease and pest. Maize plant generally responds appreciably to fertilizer nutrient application, the growth pattern and grain yield levels are enhanced when fertilizers are used, especially N.P.K.

Miklaszewski (1968) reported that the total carbon, nitrogen, free amino acids and C:N ratio determined at 10 days intervals in soil samples from bare and green fallow and intensely cultivated land under a 4-year rotation showed great variations during the growth season mainly due to weather conditions. Organic carbon, nitrogen and amino acids increased during dry and warm periods and decreased during raining and cold periods, probably due to variations during the growth period and the annual carbon and nitrogen status of the soil.

2.4.4 Sulphur in plants nutrition

The sulphur requirement of plants is largely dependent on the amount of sulphur found in protein and is therefore influenced by those factors which affect protein production. The incorporation of the sulphur, amino acids, cysteine and methionine into protein is under genetic control and as a result, the nitrogen to sulphur ratio of plant protein is relatively constant. The application of sulphur significantly increased the sulphur uptake by maize grain, which may be attributed to increase of S concentration in plant and dry matter yield. Increasing level of S progressively enhanced the averaged total N uptake by maize. This increase in N uptake may be attributed to increase in N content of plant and dry matter yields due to increasing S levels.

The wide variability in sulphur content of plant is not surprising when it is recognized that the requirement depends almost entirely on the amount of sulphur in protein. The protein content in turn varies widely with species, age, environment and nutrition. While nutritional and environmental factors may determine the amount and relative proportions of proteins formed, genetic factors control the amino acids composition of the specified proteins. The main function of S in plant is in the synthesis of protein, possibly via amino acids.

2.5 Micronutrients

Micronutrients are absolutely essential and play an active role in gene expression, biosynthesis of protein, nucleic acids, plant metabolism processes starting from cell wall

development to respiration, photosynthesis, chlorophyll formation, enzyme activity, nitrogen fixation and reduction (Bishnu et al., 2002). Micronutrients are becoming increasingly important to world agriculture as crop removal of these essential element increases (Adhikary et al., 2010). Investigation into the micronutrient status of soils of West African savannah had received little attention in the past due to rare incidences of their deficiencies (Yaro et al., 2002).In recent times,there is great demand on the land due to increase in population and the competing demand for land for non-agricultural uses which has resulted in intensive continuous cultivation in the savanna areas.With the increasing shift toward intensive continuous cultivation, the use of NPK fertilizers and improved varieties, micronutrient deficiencies are on the increase(Lombin,1983b; Kparmwang et al.,1995,1998). Increasing attention is being given to micronutrient deficiencies because increasing crop yield has led to increased uptake of micronutrients and most chemical fertilizers do not include the micronutrients. Evidence in literature has confirmed the deficiency of some of these micronutrients. Heathcote (1973b) confirmed molybdenum while Lombin (1983a and1983b) reported that copper, zinc and manganese do not appear to pose immediate treat to agriculture in the savannah but low levels of molybdenum and boron were bound to limit crop yields. Balasubranian and Nnadi (1980) found that groundnut and cotton responded to a mixture of trace elements(boron, copper, molybdenum and zinc) applied as foliar spray at Mokwa and attributed this to the boron components of the mixture. Joshy (1997) reported the critical limit of some micronutrients on maize. He mentioned the critical limit for sulphur was 14ppm, boron 95ppm and zinc 82ppm for maize crop. The trace elements which are bound up in crystal lattice of minerals are essentially unavailable to plants. The fraction which has been mobilized as a result of weathering may or may not be available to plants.

2.5.1 Soil factors that affect micronutrient availability

Physical and chemical characteristics of soil affect the availability and uptake of micronutrients:

- Soils low in organic matter (less than 2.0%) may have lower micronutrient availability.
- Soils with higher amounts of clay (fine texture) are less likely to be low in plant available micronutrients. Sandy soils (course texture) are more likely to be low in micronutrients.
- Soils that have very high levels of organic matter (greater than 30% organic matter to a depth of 30 cm) often have low micronutrient availability.
- Soil temperature and moisture are important factors. Cool, wet soils reduce the rate and amount of micronutrients that may be taken up by crops.
- As soil pH increases, the availability of micronutrients decreases, with the exception of molybdenum.

2.5.2 Zinc

The content of zinc in the soil ranges from 10-300ppm and averages approximately 50ppm.The concentration of zinc in the soil solution is 10^{-6} to 10^{-8} M of which between 30-70% was of inorganic ions (Olowookere, 1995). The active form of zinc in the soil is in the divalent cation Zn^{2+}.Plants vary in their Zn requirement as well as their abilities to extract Zn from the soil and crops which are sensitive to Zn deficiencies include maize, citrus, legumes and cotton. Zinc solubility is highly pH dependent. Plants available zinc is determined by pH, adsorption on clay surfaces, organic matter, carbonates, and oxide of minerals, complexation by organic matter, interactions with other nutrients and climate conditions and availability of zinc decreases with increase in soil pH. Studies on zinc availability using corn as an indicator plant showed that the availability may be influenced by soil temperature effects on microbial activity (Baeur and Lindsay, 1965).Application of nitrogen fertilizer can stimulate plant growth and increase zinc requirements as acid forming nitrogen fertilizers will increase the uptake of both native and supplemental zinc, uptake of Zn also decreases with increased soil pH and is adversely affected by high levels of available P and Fe in soils.

Zinc is also involved in multiple biochemical processes in plants. Of particular interest for corn, is zinc's role in photosynthesis where it is required for carbonic anhydrase function, nitrogen metabolism, starch formation, seed maturation and important for maize growth (Mengel and Kirkby, 2001). The enzyme carbonic anhydrase is part of the C4 photosynthetic pathway which gives plants such as corn higher photosynthetic rates than C3 plants such as soybeans (Shrotri et al., 1983). In addition, Zinc is important for protein synthesis related to pollen tube formation (Ender *et al*., 1983), responses of plants to stress, and carbohydrate dynamics (Shrotri *et al*., 1983).

It has been found to be a constituent of dehydrogenate, proteinase, peptidase and aldolase, adequate zinc is absolutely necessary for the synthesis of alanine, glycine, proline, threonine, serine, valine, etc and it has a specific role in the synthesis of tyrosine, tryptophan

and phenylalanine (Brady, 1984). It has been shown that zinc increases the fibre strength of cotton. High zinc uptake efficiency may depress root P uptake and may also involve in a high rate of zinc transport from roots to shoot via the Xylem and this may hinder P translocation from roots to shoot (Zhu *et al,* 2001). It also inhibited the reduction of Fe^{3+} to Fe^{2+}. Kanwal *et al.* (2010) found that zinc application to soil had a positive significant effect on grain yield and Rogo *et al.* (2001) reported an increase in grain yield of maize to zinc application. Orabi and Abdel-Aziz (1982) reported the application of zinc increased inorganic P, total carbohydrates, total protein, lysine and tryptophan in the leaves as well as in the grains. The effect of P application was similar to a great extent to that of Zn. This similarity is partly attributed to the positive relationship that was obtained between Zn- uptake and P-uptake by the plants.

Zinc deficiency is often associated with a low level of total zinc in the soil. Compacting a soil can also induce zinc deficiency. Zinc deficiency may also be induced by high phosphate manuring of calcareous soil low in available zinc. Shortage of zinc in a soil leads to a decrease in plant protein synthesis and a decrease in the uptake of phosphorus and nitrogen, whilemanganese uptake, on the other hand increases. Young male rats given a high zinc deficient diet displayed typical signs of zinc deficiency including anorexia and cyclic feeding within 3-4 days. Also zinc deficiency in tomatoes inhibits protein synthesis and free amino acids accumulation (Wallwork *et al.*,1981). Zinc deficiency can be cured by spraying with zinc sulphate at above $4kgha^{-1}$. Zinc deficiency impairs amino acid utilization metabolism(Wallwork *et al.*,1981).Zinc uptake was found to be insensitive to DNP, NO_3, CN^-, light (for leaf tissue) or temperature. In sharp contrast to the above results other evidence strongly suggests that zinc uptake is metabolically controlled.

2.5.3 Copper

This metal occurs in the divalent form in an active state in the soil, either as the simple divalent cation or possibly as the monovalent M(OH) ion. It can often be found in a form exchangeable with neutral ammonium. Organic matter in the soil also holds copper very strongly. Copper can also be held in a non-exchangeable form in neutral and sometimes in acid soils. Total Cu in soil falls in the range 2-100ppm while copper concentrations in the soil solution are usually between 10^{-6} and 10^{-7}M.Over 99% of the copper in the soil solution may be complexed with organic compounds. Copper availability is governed by the total amount in soil (Lucas and Knezek, 1972) and is influenced by soil pH although less than in other micronutrients. Availability decreases strongly with increasing pH.

Acetic acid or chelating agents such as EDTA will usually extract more and sometimes very considerably more than the neutral salt. If a small amount of this cation is added to a soil, little of the ion will exchange with a neutral salt such as sodium chloride, when the pH is over 6 though most will when the pH is below 4.5. On the other hand, most of the added cation is extractable with HCl or acetic acid or with a chelating agent such as EDTA (Brady and Weil, 2004).

Copper is involved in both photosynthesis and respiration, stimulates cell wall (Brady and Weil, 2004) and it is capable of acting as electron carriers in the enzymes systems that bring about oxidation-reduction reaction in plants. It plays an important primary role in plant and animal metabolism. Yates and Hallsworth (1963) investigated the role of copper in the metabolism of nodulated clover and found its effects to vary with the supply of combined nitrogen. Uptake by various tissue of the bean plant was shown to be typical of non-metabolic processes (Rathore *et al.,* 1976). Copper was reported to strongly inhibit the absorption of zinc by barley roots whereas manganese had essentially no effect. These results are similar to those of Bowen (1969) who reported that copper and zinc compete for the same absorption

site but that manganese was absorbed by another mechanism and thus had no effect on copper and zinc. Also it was observed that increasing calcium concentration was shown to reduce zinc absorption by isolated tobacco leaf cells but it is not certain that this represented an actual competition between these two cations. When copper were deficient, plants receiving nitrate-nitrogen accumulated amino acids showed a continuous increase in soluble amino acids correlated with the level of copper. Yates and Hallsworth (1963) obtained evidence suggesting that copper is directly concerned in the formation of y-amino-n-butyric acid in the plant nodules and as this acid is a particular constituent of nodule protein, the effect of copper appears to be a unique requirement.

Copper deficiency can be found in peat, low in clay and with a water table too deep to maintain a sufficiently moist surface soil during dry weather. High levels of Cu can induce deficiency symptoms of Fe and Zn, Conversely high levels of Fe and Zn have been found to induce Cu deficiency. Deficiency can be corrected either by adding a copper salt to the soil or spraying it on to the crop itself.

2.5.4 Iron

Iron is the fourth most abundant element in the earth's crust and soils rarely contain less than 1%. Plants may take up their iron in both the divalent form Fe^{2+}or the trivalent form Fe^{3+} (Russell, 1973). Iron acts as the component of enzyme nitrogenase which is essential for the processes of symbiotic and non-symbiotic nitrogen fixation. It is also important in chlorophyll formation and in the synthesis of proteins and nucleic acids.It is not known definitely in what form plant roots take up their iron, whether as the ferrous or the ferric ion. Plants differ in their ability to take up iron from soils particularly from calcareous soils.The characteristics of iron uptake are similar to those reported for other cations and uptake is inhibited by high phosphorus levels, due to the formation of insoluble iron phosphate. High Fe levels in the soil can interfere with the uptake of Zn, Cu or Mn. Mo has also been shown

to induce Fe formation of insoluble iron molybdate in plant roots. Iron deficiency is most observed on high-pH and calcareous soils in arid regions.

Heavy metal toxicities have been reported to cause iron deficiencies in a number of species. Lingle *et al.* (1963) reported that manganese, zinc, copper, calcium, magnesium and potassium reduced the iron in the stem exudates of decapitated soybean plants. Tiffin (1967) also reported that zinc reduced the iron accumulation in exudates of decapitated tomato plants. Zinc also inhibited the reduction of Fe^{3+} to Fe^{2+} while iron absorption is extremely sensitive to the influence of other cations, and this perhaps explains the wide variation encountered in iron deficiency of plants. Iron deficiencies can result from an accumulation of copper after extended periods of copper fertilization (Tisdale *et al.,* 2003).

2.5.5 Molybdenum

Micronutrient requirements differ among crops. Micronutrients that are of particular importance for corn include Molybdenum and Zinc. Molybdenum is essential for nitrogen metabolism in corn where it is needed for the function of nitrate reductase, which is necessary for the conversion of nitrate into nitrite and the eventual incorporation of nitrate-N into proteins. In addition, Molybdenum is involved in the synthesis of the phytohormones abscisic acid (implicated in plant responses to drought) and auxin (growth regulation such as lateral root formation, elongation, gravity sensing etc.). Among other things, Molybdenum deficiency in corn has been shown to shorten internodes, decrease leaf area, and reduce pollen grain development (Agarwala et al., 1978 and 1979). Molybdenum is needed for symbiotic nitrogen fixation, so legumes can only have active nodules in soils adequately supplied with this element. It is also required for the reduction of nutrients in plant tissues, but crops differ very considerably in their ability to take up sufficient to satisfy their requirements. It is taken up as either $HMoO_4^-$ orMoO_4^{2-}.

The molybdenum concentration in reasonably well supplied soils is of the order 0.1 to 40ppm, and the mass flow of soil solution to roots will bring more molybdate to the root

surface than in taken up (Jones, 1975).It is often cheaper to supply Mo in the form of sodium or ammonium molybdate to the crop either as a spicy or to the soil than to lime the soil to neutrality. Direct evidence to support or refute active transport of molybdenum in plants is lacking but uptake of molybdenum by tomato plants was severely depressed by increasing the soil pH. The enhanced molybdenum uptake was most pronounced in the tops, and the effect appeared to be specific for phosphate. Mo deficiency is found only on acid soils, the deficiency can often be cured by liming to pH 6.5 or 7 (Yermiyahu *et al.*, 1995). Among other things, Molybdenum deficiency in corn has been shown to shorten internodes, decrease leaf area, and reduce pollen grain development (Agarwala *et al*., 1978, 1979).

2.5.6 Boron

Boron is present in soil solution as boric acid $B(OH)_3$, it is adsorbed in acid conditions and liming increases its adsorption. The availability of B is related to the soil pH, this element being most available in acid soils. Boron is probably the trace element which most commonly limits yield and consequently is most widely used in agriculture, horticulture and even in forestry. Many root crops, leguminous crop and many fruit and forest trees have a relatively large boron demand while the cereals and legumes are more tolerant of a low boron supply in the soil. Boron requirement varies from crop to crop and between varieties of the same crop (Tisdale *et al.*,1985). Boron is an essential micronutrient that facilitates the translocation of sugars, ensures proper seed set, increases yield and modifies the nutritional quality of crops (Gupta,1993).

The total boron contents of soils in arid and semi aridclimates are in general, higher than in humid climatic zones. Soils in high rainfall areas are often deficient in boron.This is because of the non ionic nature of boron.Once it has been released from soil minerals it can be leached from the soil fairly rapidly.Lombin(1985)reported the levels of available boron in the savannah soils to be in the range of 0.14-0.25mgkg^{-1} which is sub-optimum for the

growth of boron sensitive crops. Daudu(1989) got a range of 37.9-44.5mgkg^{-1}B in some savannah soils developed from loess. Kparmwang (1993) obtained a range of 19-160mgkg^{-1}B in basaltic soils in Northern Guinea savannah soils of Nigeria. Oyinlola (1997)reported a range of 0.05-0.18mgkg^{-1} with a mean of 0.105mgkg^{-1} extractable boron. Boron deficiency is one of the most widespread micronutrient deficiencies in the Northern Nigeria savannah region. Boron is among those elements for which many plants have low range of tolerance and the amount of boron required for plants is so small that critical limits of boron toxicity and defiency are very narrow (Oyinlola and Chude,2004).

Boron deficiency is commonly found on acid light-textured soils low in organic matter and can often be induced in such soils by liming and particularly by over-liming. Boron demanding crops are likely to respond to boron fertilizer if the hot water soluble boron falls between 0.3 and 1.0ppm in the soil. The actual level depends on the crop and on the soil, for the level was lower for sands than for heavier soils and lower on acid than on neutral soils.

Some of the micronutrients tend to be held as complex combinations in organic (humus) colloids. For examplecopper is especially tightly held by organic matter that its availability can be very low in organic soils (Histosols). Correlations between soil organic matter and contents of copper, molybdenum and zinc had been noted (Brady and Weil, 2004). Although they are held in organic matter, when they are released through decomposition, they improved the fertility of the soil.

2.6 Botany and agronomy of quality protein maize

Maize (*Zea mays, L)* production in the Savannah ecological zones of Nigeria has increased tremendously in the last decade (Uyovbisere and Elemo, 2002). Estimates by the Ministry of Agriculture in 1989 indicate that 5.4 million tons of maize was produced from 3.5 million hectares, a situation that has improved by over 20% since then (World Bank Report,

1997). This improvement was partly made possible by the expansion of the maize production zone to the semi-arid savannah.

2.6.1 Production history

Maize (*Zea mays*) the American Indian word for 'corn' means literally "that which sustains life". Maize is one of the major cereal crops extensively cultivated in all the ecological zones of Nigeria (Enwezor *et al.,* 1989). It ranks third both in total production and utilization after sorghum and millet (Jaliya *et al.,* 2008). They constitute important sources of carbohydrates, vitamins B, minerals and about 15% of all food crops protein and other nutrients such as micronutrients. The grains are rich in vitamins A, C and E, carbohydrates, and essential minerals, and contain 9% protein. They are also rich in dietary fiber and calories which are a good source of energy. Therefore, maize serves as the primary staple food in most regions of the world (Maziya-Dixon, 2002; IITA, 1996; National Reseach Council,1988). Although cereal grains such as maize are inherently poor in iron (Fe) and zinc (Zn), they are excellent sources of (White and Broadley, 2005; Cakmak, 2008). According to FAO data, 589 million tons of maize was produced worldwide in the year 2000 on 138 million hectares of land. United States was the largest maize producer, producing about half the world's total (43%) followed by Asia (25%),Latin America and the Caribbean (13%).Africa produced 7% of the world's maize with Nigeria producing 7.68 million tons or 1.33% of the world's figures. The world's average yield in 2000 was 4255kg/ha, average yield in USA was 8600kg/ha while in sub-Saharan Africa it was 1316kgha^{-1} (Edache, 1996, FAO 1997). Some parts of Africa particularly South Africa, Malawi, Zimbabwe, Kenya, Tanzania, Ghana, Nigeria and Egypt are suitable for growing maize and it is fast replacing traditional staple food stuffs such as sorghum and millet.

The maize kernel is made up of the endosperm, the germ, the pericarp and the tip cap. The protein concentration is highest in the germ but the quality is better in the endosperm.

The germ contribute significantly to essential amino acids, so maize food product without the germ including QPM endosperm are lower in protein quality compared to the whole kernel. Of all cereals, maize has the highest average yield (Jennifer and Kling, 1991). Maize grows where a mean annual temperature exceeds 19^oC, a temperature range of $21^o - 27^oC$ is required for normal growth, while a minimum temperature of 10^oC is required for germination. Excessive temperature at pollination and fertilization reduce seed set. Optimum pH for maize production is 5.5-7.0 and a precipitation of 600-1200mm per annum is required for normal maize growth and yield (Onwueme and Sinha, 1991). Moisture deficit delays reproductive growth, particularly silking. Maize is a heavy feeder and requires nitrogen at 120-150kgha^{-1}, Phosphorous (P_2O_5) at 60kgha^{-1} and Potassium (K_2O) at 60kgha^{-1} (Onwueme and Sinha, 1991). In the savannah where the soils are gererally low in fertility, maize responds favourably to fertilizer application since it has exhausting effect on the soil. Kumar(1993), observed that maize fails to produce good grain yield in plots without fertilizer application. Kassam *et al.* (1975) also reported that the Northern Guinea savannah of West Africa has 50-60% higher yield potential for maize than the forest zone, because solar radiation is greater. Also diseases and insect problems are less severe than the humid zones. The maize grain can be harvested field dry because the rain cease shortly before the crop reaches maturity. Due to high yield potential, storability and multiple uses of the maize crop, it is now replacing the traditional cereal crops of the region, which were millet and sorghum in the grain economy of the nation (Elemo, 1993).Maize requires deep, dark, silt loam soil, good drainage, abundant moisture and moderately high temperatures for maximum yield. Therefore, a suitable environmental condition for successful maize production includes good soil type with adequate radiation, temperature and rainfall (Mc Donald and Copeland, 1997). Maize prefers well-drained fertile soils with good water holding capacity (Beck, 2002). Maize thrives in environments with abundant sunshine during the growing season and

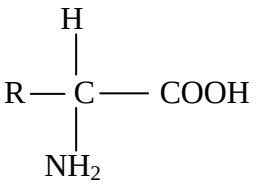
efficient but not excessive rainfall with good distribution particularly during the flowering period (Desai*et al.,* 1997).Though the moist savanna have the greatest potential for maize production, their soils are often fragile with low organic matter, poor buffering and water holding capacity, resulting in low levels of available nitrogen (IITA, 1992).

Maize has been known to be a major source of energy, protein and other mineral nutrients such as phosphorus, potassium, magnesium, sulphur and zinc (FAO, 1992). Maize seed contains three groups of proteins. The storage proteins, which constitute an amino acid reserve deposited early in seed development, the enzyme proteins involved in the plant metabolism and the structural proteins that are essential, ribosomal, chromosomal and membrane proteins. The predominant group of proteins in maize is a family of alcohol soluble prolamin proteins called zeins (Essen and Stetler, 1987) which accumulate in the protein bodies of maize endosperm during development (Lending and Larkins, 1989). The zein of maize store nitrogen, carbon and sulphur and supply these important elements to germinating seedling. The zein is more in the endosperm than in the embryo (Biston *et al.,* 1986). The compositions of starch, protein, oil, sugar, ash and others in the whole grain in percentage are 73.4, 9.1, 4.4, 1.9, 1.4 and 9.8. The endosperm has 87.6, 8.0, 0.8, 0.6, 0.3 and 2.7%. The germ contains 8.3, 18.3, 33.2, 10.8, 10.5 and 8.8%, the pericarp has 7.3, 3.7, 1.0, 0.3, 0.8 and 86.9% and lastly the tip cap contains 5.38, 9.1, 3.8, 1.6, 1.6 and 78.6% respectively (Nutrition and quality of maize, IITA Research Guide 33).

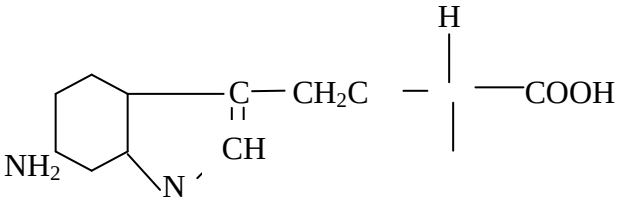
The zein proteins, which account for about 50% of the total endosperm protein at maturity in normal maize, are characterized by a high content of glutamine, leucine, and proline and low level of lysine and tryptophan. Osei *et al.* (1994) reported that overall content of these amino acids in normal maize are only 0.23 and 0.06% respectively compared with 0.36 and 0.10% respectively in Obatampa quality protein maize (QPM) variety.

2.6.2 Protein structure and functions

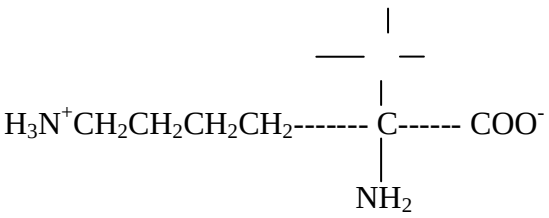
Proteins are the most versatile macromolecules in living systems and serve crucial functions in all biological processes. They act as catalysts, transport and store other molecules such as oxygen. They provide mechanical support and immune protection. Proteins also generate movement; transmit nerve impulses, control growth and differentiation (Berg *et al.,* 2001). Proteins are linear polymers built of monomer units called amino acids. It contains a wide range of functional groups such as alcohols, thiols, thioethers, carboxylic acids, carboxamides and a variety of basic groups (Berg *et al.,* 2001).



Amino Acid



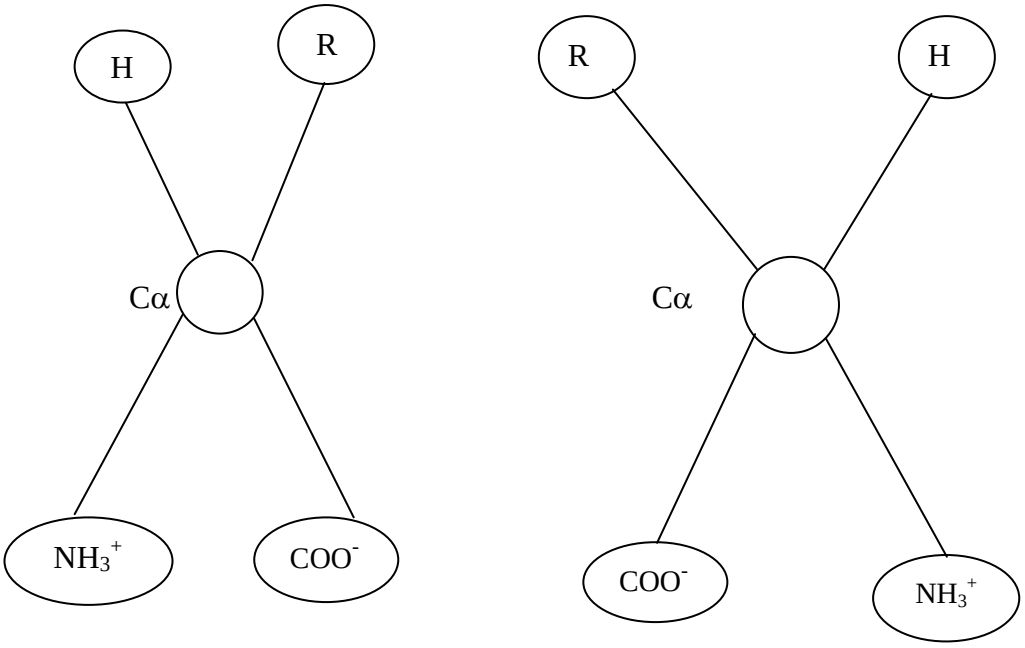
Tryptophan



Lysine

The combination of various sequences of these arrays of functional groups accounts for the broad spectrum of protein function. Proteins can interact with one another and with other biological macromolecules to form complex assemblies that makes some quite rigid while some display limited flexibility. Amino acids are the building blocks of protein and constitute a group of organic compounds containing two functional groups such as amino and carboxyl. The amino group (NH_2) is basic while the carboxyl group (COOH) is acidic in nature, the amino acid is termed α-amino acid if the carboxyl and amino groups are attached to the same carbon atom. An α-amino acid consists of a central carbon atom called the α-

carbon linked to an amino group, a hydrogen atom and distinctive R group. The R-group is often referred to as the side chain with four different groups connected to the tetrahedral α-carbon atom. Amino acids are chiral, the two mirror images formed are called the L-isomer and the D-isomer.



L-isomer D-isomer

The L-amino acids are the only constituents of proteins: it has S (rather than R) absolute configuration. Amino acids in solution at neutral pH exist predominantly as dipolar ions (also called zwitherions). In the dipolar form, the amino group is protonated ($-NH_3^+$) and the carboxyl group is deprotonated ($-COO^-$), the ionization varies with pH.

2.6.3 Factors affecting the amino acid composition of plants

Chromatographic techniques for the determination of amino acid and other organic components in plant tissue have stimulated the study of N-metabolism in plants. The proteins in plants are genetically controlled but there exists also a substantial and variable concentration of free amino acids at any stage of the development of the plant. Some works showed that the effects of the relative concentrations of the different free amino acids and of the proteins could be decisive factors in determining the nutritional quality of plants. Protein

is essential in the diet of man as a source of the amino acids he cannot synthesize from simple sources of N and energy for growth, reproduction and maintenance (Berg *et al.*, 2001).The low level of these amino acids, lysine and tryptophan in maize brought about the development of quality protein maize (QPM). Quality protein maize (QPM) is a cultivar that possesses higher quantity of lysine and tryptophan than the normal maize variety. Its protein has higher levels of lysine and tryptophan. Amino acid composition of normal and quality proteinmaize (Obatampa) are crude protein 9.8, 9.73, Threonine, 0.2and0.34, Valine, 0.33, 0.48, Methionine 0.17 and 0.15, Isoleucine 0.23 and 0.30 Leucine 0.77 and 0.88 Phenylalanine 0.31 and 0.39 Lysine 0.23 and 0.36 Tryptophan 0.06 and 0.10. (Osei *et al.*, 1994).

2.6.4 Protein content of maize

Osei *et al*. (1999) and Prasanna *et al*. (2001) reported 9.11% crude protein for quality protein maize, Ortega *et al.* (1986) and Aduku (2005) reported a value of 8% crude protein for normal maize and QPM. Pereira (1992) also reported a similar finding of 9.70% for QPM. Some studies even reported higher values of 11.3% CP for normal and QPM respectively (Rostango, *et al.*, 1990). Soh *et al* (1994) reported that differences may be due to varietal, soil and climatic conditions. Quality protein maize looks, grows and tastes like normal maize but has 70 – 100% more of the two essential amino acids, lysine and tryptophan than the normal type of maize. QPM are currently being cultivated in so many countries such as Benin, Guinea, Mali, and Nigeria etc. Many varieties have been adopted in the West African countries. The commonest ones are:

Susuma	-	Open pollinated
Obatampa	-	Open pollinated (Nursing Mother)
Da-daba	-	Hybrid
Mama – ba	-	Hybrid

Cida – ba	-	Hybrid
Nalongo	-	Mother of Twins

A lot of work had been done genetically in breeding an acceptable QPM (Prasanna, 2001). The QPM has also been reported to have higher protein quality and biological value than normal maize. The biological value of normal maize protein is 45% while that of opaque – 2 maize is 80% (Prassanna, 2001). Gaziola *et al.* (1999) studied the biochemistry of enzymes involved in lysine metabolism and reported that the modifier genes used to produce QPM varieties have induced increases in activity of enzymes involved in lysine catabolism, leading to a higher absolute level of soluble lysine. QPM has higher niacin availability due to a higher tryptophan, lower leucine content, higher calcium, carbohydrate (Graham *et al.*, 1989) and carotene utilization (Prassanna, 2001).The nutritional and biological superiority of QPM has also been amply demonstrated in model system such as rats (Mertz *et al.*, 1976), Pigs (Maner, 1975) infants and small children (Graham *et al.*, 1980) as well as adults. The quality protein maize has been introduced to Africa and Nigeria in particular but the QPM varieties introduced to the Nigeria savannah ecologies still have problems of adaptation when the levels of amino acid contents are concerned.

2.6.5 Effect of nutrients on protein content

Tsai *et al.* (1980) showed that nitrogen fertilization of maize increased total protein because of an increase in prolamin content and that there was a direct relationship between the soil and the nitrogen applied to the soil and the contents of crude protein, zein and leucine in maize grain. He concluded that variations in content of the amino acids suggest that nitrogen-fertilization in relation to plant population as well as variety has an important effect on protein composition. Potassium increases grain protein content of wheat thus improving quality while it increases the oil content of maize grain (Rejado, 1979). Whitehouse (1971)

also reported that the cause of high protein content in maize is a restriction on growth which is due to a shortage of water or some adverse condition during the later stages of grain-filling.

Mani and Dadari (2005) reported that increase in NPK fertilizer rate from 90:45:45 to 120:60:60 $Kgha^{-1}$ significantly enhanced growth and yield of quality protein maize. Hussaini *et al.* (2001) in their own work on performance of quality protein maize genotypes under different NPK fertilizer rates in Sudan and Northern Guinea Savannah zones in Nigeria reported that the response to fertilization shows that QPM can be fertilized within the same range as that normal maize and this is dependent on management and native soil fertility. Jones (1973) reported that water and nitrogen supplied to the soil early mainly increased total yield of both grain and protein but nitrogen supplied late in the life of maize although difficult to apply, often result in an increase in the protein content of the grain but the extra protein is of low biological value. Biological value is defined as the amount of absorbed nitrogen needed to provide the necessary amino acids for the different metabolic functions in the body.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Experimental Site

The study was conducted at the Institute for Agricultural Research (IAR) Experimental farm in Samaru, Zaria in the northern Guinea savanna ecological zone of Nigeria. Samaru as seen in fig 1 is at the northern fringe of the northern Guinea savanna (Ogunwole *et al.,* 2005; USDA., 2006) and is located at longitude 11^{o} 11$^{'}$N and latitude 7^{o} 38$^{'}$ E, at an elevation of 686m above sea level, with annual rainfall average of about 1060mm (Owonubi *et al.*,1991).

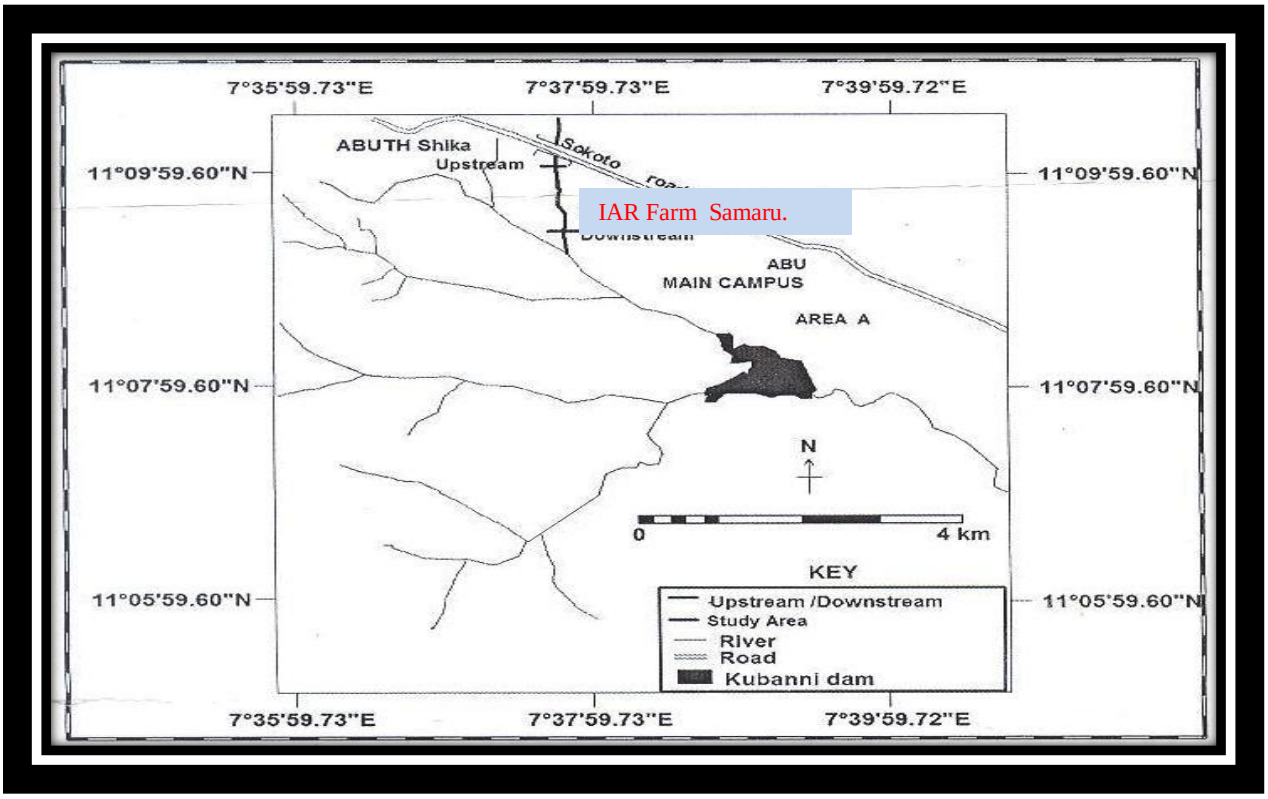


Fig. 1: Samaru map showing the IAR farm and the experimental site.
Source: Adapted and modified from Zaria SW topographic map.

The location has a mono-modal rainfall pattern with a mean annual rainfall of about 1060 mm per annum with high intensity within five (5) months from May to October (Uyovbisere and Lombin, 1991; Oluwasemire and Alabi, 2004).The area is characterized by

two seasons: the dry and wet seasons. The dry season comprise of a cold dry period otherwise known as the harmattan (Nov- Dec) and hot dry period (April - June) while the wet season consist of warm rainy season from July to October. Warm conditions and high relative humidity prevail during the rainy season. July and August are the months with highest rainfall while October and March constitutes transitional months between the rainy and cold dry season and between the hot and dry season.

The soil is classified as Alfisol in the USDA Soil Classification system and it is developed in deeply weathered pre-Cambrian, basement complex rock overlain by Aeolian drift materials of varying thickness (Moberg and Esu, 1989; Ogunwole, 2000).The main soil subgroup is typic Halplustalf (USDA Soil Survey staff, 2006). Average relative humidity level at Samaru is about 11-85%, indicating a wide variation over the season (Anosike, 1999). This reflects the extreme seasonal conditions influenced by the harmattan and the rainy seasons respectively. To achieve the objectives of the study, green house experiment and field trials were conducted on an Alfisol at the experimental farm of the Institute for Agricultural Research (IAR) at Samaru, Zaria.

3.2 Greenhouse Experiment

3.2.1 Soil sample collection and preparation

The soil sample used for the greenhouse experiment was collected from a fallow site of over 5 years, from the surface 0-20cm within the Institute for Agricultural Research (IAR) Farm Ahmadu Bello University (ABU), Zaria.

3.2.2 Preparation of the experimental pots, planting and measurements taken.

The soil samples were air dried and sieved through a 2mm sieve, composite sample was taken and kept in plastic bag for routine analysis. The greenhouse experiment consisted of four rates of nitrogen fertilizer (0, 50, 100 and 150kgNha^{-1}), two rates of micronutrients (0, cocktail mixtures) and four maize varieties (SAMMAZ 14 and SUSUMA (QPM), and

SAMMAZ 11 and SAMMAZ 12 (normal maize) that gave a total of thirty-two (32) treatments arranged in a completely randomized design replicated three times to give a total of 96 pots. Thereafter 4kg of the sieved soil were weighed out into each of the 96 plastic pots, perforated at the bottom to allow for free drainage and adequate root aeration. Plastic receivers were placed underneath to collect any seepage which was returned to the pots. The pots were watered to field capacity and left to equilibrate for a day. Eight maize seeds were planted symmetrically in the pots. They were thinned to four plants per pot a week after planting. The fertilizer treatments consisted of fertilizer K as K_2SO_4, P from $(NH_4)_2HPO_4$, Mg from $MgSO_4.2H_2O$ and combined micronutrients as Cu from $CuSO_4.5H_2O$, B from H_3BO_3, Mo from $(NH_4)_6Mo_7O_{24}.4H_2O$, Fe as $(NH_4)_2FeSO_46H_2O$, and Zn from $ZnSO_4.H_2O$. The fertilizer sources were reagent grade chemicals to supply the specific elements needed for the formulations. All were dissolved in $1000cm^3$ or one litre of de-ionised water and $20.8cm^3$ given to 48 pots each. These fertilizers were all applied at planting. The fertilizer N was split applied at 2 weeks after planting (2WAP) and at four weeks (4WAP). The pots were maintained at near field capacity through regular watering with de-ionised water. The parameters taken were stand count at germination and at harvest, plant height at two weeks interval, number of leaves per pot at two weeks interval and dry matter yield at harvest.

3.2.3 Soil and plant samples collection and preparation

At the termination of the trial at 6 weeks, the above ground part of the plant (1cm from the soil surface) was harvested for dry matter estimation. The plant biomass yield was weighed while fresh, rinsed with distilled water, placed in envelopes and then dried in an oven at 65^oC for 48hours to constant weight. The oven dried weight was taken and were ground with a stainless steel mortar and pestle, and then stored in small polythene bags for tissue analysis. Soil samples were also collected from each pot at harvest with auger and the samples were air dried and sieved through a 2mm sieve and then stored for chemical analysis.

3.3 Field Experiment

The response of the maize crop to N fertilizer treatments and micronutrient formulations were determined also in the field. Composite Soil samples were randomly taken with an auger from the field at two depths, 0-15cm and 15-30cm at the onset of the experiment and from each plots after harvest. The soils were air dried, crushed and sieved through a 2mm sieve. Sub-samples were analyzed for the physical and chemical properties.

3.3.1 Soil preparation and experimental design

The herbicide round-up was applied on the site which covered 2598m or 0.26ha and was left for two weeks before land preparation. The experimental field was prepared by ploughing, harrowing, ridging and marking out of plots. The site was divided into three blocks each consisting of 32 plots, giving a total of 96 plots and each plot measuring $12m^2$.There were 4 ridges in a plot, 5m long at 0.75m x 0.25m spacing on a row. The experiment was laid out in a randomized complete block design with three replications and treatments were factorially combined. Two maize seeds were sown per stand and thinned to one per stand at two weeks after germination. Weeding was done in each year with the use of the hand hoe.

3.3.2 Fertilizer application

Nitrogen was applied in 2 split doses at 2WAP and 4WAP at the rate of (0,50,100, 150$kgha^{-1}$) using Urea(46%). Basal application of phosphorus and potassium were done at 60$kgP_2O_5ha^{-1}$ as single super phosphate (SSP), and 60kgK_2Oha^{-1}potash (MOP), (60%) respectively. The micronutrients treatments (Fe, Zn, B, Mo, and Cu) were applied as cocktail of the mixture to half the number of plots at the rate of 22.85gha^{-1} and Mg at the rate of 10$kgMgha^{-1}$ as $MgSO_4$. The P, K, Mg and micronutrients were all applied 2 weeks after planting immediately after thinning to one plant per stand.

The Field treatment combinations layout:

Replicate I

V_1	V_3	V_4	V_2
N_4M_1	N_4M_2	N_1M_1	N_4M_1
N_1M_2	N_1M_1	N_4M_1	N_4M_2
N_2M_1	N_3M_1	N_2M_2	N_1M_1
N_3M_2	N_1M_2	N_4M_2	N_3M_1
N_2M_2	N_2M_2	N_3M_2	N_2M_2
N_3M_1	N_2M_1	N_1M_2	N_3M_2
N_1M_1	N_4M_1	N_2M_1	N_1M_2
N_4M_2	N_3M_2	N_3M_1	N_2M_1

Replicate II

V_4	V_2	V_3	V_1
N_4M_2	N_2M_1	N_4M_2	N_4M_2
N_2M_2	N_4M_2	N_2M_1	N_2M_2
N_3M_1	N_4M_1	N_1M_1	N_3M_1
N_1M_1	N_2M_2	N_1M_2	N_1M_1
N_3M_2	N_3M_2	N_3M_1	N_3M_2
N_1M_2	N_1M_1	N_3M_2	N_1M_2
N_4M_1	N_1M_2	N_2M_2	N_4M_1
N_2M_1	N_3M_1	N_4M_1	N_2M_1

Replicate III

V_2	V_1	V_4	V_3
N_1M_1	N_3M_1	N_2M_2	N_1M_1
N_3M_2	N_1M_2	N_1M_1	N_2M_1
N_3M_1	N_4M_2	N_1M_2	N_1M_2
N_4M_2	N_3M_2	N_2M_1	N_3M_2
N_4M_1	N_2M_2	N_4M_2	N_3M_1
N_2M_2	N_2M_1	N_3M_1	N_4M_1
N_1M_2	N_1M_1	N_3M_2	N_4M_2
N_2M_1	N_4M_1	N_4M_1	N_2M_2

Fig. 2: Field layout plan and treatment combinations
V_1 Variety 1 (Sammaz 14) ,V_2 Variety 2 (Susuma), V_3 Variety 3 (Sammaz 12), V_4 Variety 4 (Sammaz 11)
N--- Levels, N_1 0kg/ha, N_2 50kg/ ha, N_3 100kg/ha, N_4 150kg/ha
M---Micronutrients, M_0---no micronutrient, M_1---- cocktail micronutrients addition

3.3.3 Analysis of soil and plant samples

The particle size distribution was carried out using the standard hydrometer method as described by Gee and Bauder (1986). The sand, silt and clay fractions were dispersed using sodiumhexametaphosphate solution as dispersant. The textural class was obtained using the International Soil Textural Triangle. Soil pH was determined potentiometrically both in 0.01M $CaCl_2$ and water suspension in a soil/solution ratio of 1:2.5 using a glass electrode pH meter. Available P was extracted by Bray 1 method (Bray and Kurtz, 1945; Anderson and Ingram, 1989). The concentration of phosphorus in the extract was colorimetrically determined using a Spectrophotometer.

Organic carbon was determined by the dichromate wet oxidation method of Walkey Black as described by Juo (1979) and Nelson and Sommers (1982).

Total N was determined by the micro-Kjeldahl distillation procedure (Bremner and Molvaney, 1987). Exchangeable bases were extracted with 1N NH_4OAC buffered at pH 7 (Kundsen *et al.,* 1982). Sodium (Na^+) and potassium (K^+) in the extract were determined by flame emission photometer, while calcium (Ca^{2+}) and magnesium (Mg^{2+}) were determined by the atomic absorption spectrometer. The extractable micronutrients; copper (Cu), zinc (Zn), iron (Fe), boron (B) and molybdenum (Mo) in the soil were extracted with 0.1N HCl and read with the Atomic absorption spectrophotometer (Kundsen *et al*.,1982), while B was determined by the Morgan's solution extraction method and read on the colorimeter (Kudsen et al., 1982). The three concentrated acids mixture of HNO_3, $HClO_4$ and H_2SO_4 was used to digest the plant samples for analysis of N, P, K, Ca, Mg and the micronutrients Cu, Zn, Fe, Band Mo in the leaf of maize.

The total P from the digest was determined by the Vanadomolybdate method and the K was determined with the flame photometer. Cation exchange capacity (CEC) was determined by displacement with neutral ammonium acetate at a pH 7.0 followed by distillation as described by Thomas (1987).

3.3.4 Crop data collection.

Field observations were made in each plot. The response of maize varieties to the various treatments were evaluated by measuring the following parameters.

3.3.4.1 Plant height

Plant height was taken from 5 randomly selected plants from each plot every two weeks beginning from two weeks after planting (2WAP) up to the time tassels emerged.

3.3.4.2 Number of leaves/plot

Leaves from the randomly sampled plant stands per plot were determined by counting the leaves produced beginning from two weeks (2WAP) to tasselling stage.

3.3.4.3 Stalk diameter

Stalk diameter was determined on the randomly sampled plants by the use of the Venier caliper; the diameter was measured from the base of the stalk at two weeks interval from 2WAP up to tasselling stage.

3.3.4.4 Grain and stover yield

The grain/cob and stover yields were measured by weighing the grain/cob and the stalk of the net plot after harvest from the three replicates. Reports were given on per hectare bases.

3.4 Plant tissue analysis

Before 50% silking stage, leaf sampling was done. The index plant samples were oven-dried at 65^{o}C for 48 hours. The preparation was done in the same way as for the green house. The grain samples were oven-dried at 65^{o}C for 48hrs and then ground in a mill and stored for tissue analysis. N, P, K and micronutrients (Cu, Fe, Zn, B and Mo) were analyzed as done for the greenhouse experiment. The protein content of the leaves and grain sample was determined from total nitrogen and multiplied by a factor of 6.25. Soil samples were taken after the experiment and NPK and micronutrients (Cu, Fe, Zn, B and Mo) were determined as described in the greenhouse.

3.5 Amino Acid and Protein Analysis of Grain

Analysis of the maize grain was carried out on the endosperm of the maize seed (open pollinated and the quality protein maize varieties) as follows:

Random sample of 30 seeds were soaked in distilled water for 30 minutes. The pericarp was then peeled off and the germs were removed with scalpel and tweezers. The remaining endosperm was thereafter air-dried overnight, and ground in a mill to fine powder and this was used for the determination of grain N, crude protein and the amino acids.

3.6 Nitrogen Determination

Two gram (2g) of ground endosperm sample was weighed out into a Kjeldhal digestion flask to which concentrated sulphuric acid (10ml) was added. A catalyst mixture (0.5g) containing sodium sulphate ($NaSO_4$**),** copper sulphate ($CuSO_4$) and selenium oxide (SeO_2) in the ratio of 10:5:1 was added into the flask to facilitate digestion.

The flask was then put on the Kjeldhal digestion apparatus for 3hours until the liquid turned light green. The digested sample was allowed to cool and diluted with distilled water to 100ml in standard volumetric flask. Aliquot (10ml) of the diluted solution with 10ml of 45% sodium hydroxide solution was put into a distillation apparatus and distilled into 10ml of 2% boric acid containing 4 drops of bromocresol green/methyl red indicator until about 70ml of distillate was collected. The distillate was then titrated with standardized 0.01N hydrochloric acid to grey coloured end point, the percentage nitrogen in the original sample was calculated and the percentage of protein was also calculated by multiplying by the factor of 6.25 (Horwitz, 1980).

The amino acid profile in the known sample was determined using methods described by Benitez (1984). A known weight of the sample was dried to constant weight, defatted, hydrolyzed, evaporated in a rotary evaporator and loaded into the Technicon sequential Multi-Sample Amino Acid Analyzer (TSM).

3.7 Defatting Sample

A known weight of the dried sample was weighed into extraction thimble and the fat was extracted with chloroform/methanol (2:1) mixture using the soxhlet extraction apparatus as described by AOAC (2006). The extraction lasted for 15hrs. After defatting, a known weight of the defatted sample was hydrolsed using 6NHCl.

The filtrate was then evaporated to dryness at 40^0C under vacuum in a rotary evaporator. The residue was dissolved with 5ml to acetate buffer (pH 2.0) and stored in

plastic specimen bottles, which were kept in the freezer. About 5 to10 microlitre was dispensed into the cartridge of the analyzer. The TSM analyzer is designed to separate and analyze free acidic, neutral and basic amino acids of the hydrolysate.

3.8 Tryptophan and Lysine Determination

Tryptophan can be used as a single parameter for maize quality evaluation because of the relationship observed between tryptophan and lysine (Hernandez and Bates, 1969) in the maize endosperm protein. Relationship between lysine and tryptophan had been established by Hernandes and Bates (1969) and confirmed by Drochioiu *et al.* (2002) in Olakojo *et al.* (2007).

The percentage of tryptophan was calculated from the relationship:

% lysine= % tryptophan + 0.5 × 3.04

Where % tryptophan= % lysine– 0.5÷ 3.04

3.9 Contrast Analysis

The contrast analysis was used to differentiate between the effects of added micronutrients. That is, the effects of treatments between quality protein maize and normal maize, between QPM_A and QPM_B and generally with or without micronutrients application.

3.10 Principal Component Analysis

This was employed to reduce the number of the observed variables to a smaller number which account for most of the variance of the observed variables. Correlations and principal component analysis were used to determine the soil nutrient factors influencing the quality of the QPM and the normal maize varieties (SAS, 2005).

3.11 Statistical Analysis

All data collected were subjected to statistical analysis using SAS statistical computer software (SAS, 1999). Duncan Multiple Range Test (DMRT) was used to compare treatments means. Analysis of variance was employed to determine significant differences between means. The response of the grain yield to nitrogen and micronutrients were determined by Pearson's correlation method (Barr and Goodnight, 1972).

CHAPTER FOUR

4.0 RESULTS

4.1 Climatic Conditions of the Study Areas

The monthly weather data of the Institute for Agricultural Research Farm site used in this study are given in Figures 3- 6. They showed the rainfall distribution pattern and maximum and minimum temperatures over the `months in the years of study respectively while the climatic features in the trial years were summarized in Appendix 1 for 2008 and 2009 respectively. Rainfall amount and distribution during the growing periods and crop growth played significant role in the expression of plants potentials during flowering/ grain filling period especially in maize. The weather patterns (temperature and average soil moisture etc) during crops reproductive phase are very vital in stimulating plants to speed up the process of maturation. Generally in 2008, there was a drop in the amount of rainfall whereas in the year 2009 rainfall was evenly distributed and fairly continuous throughout the flowering/ grain filling periods of July-September (Figs. 3 & 4). Even that higher rainfall was recorded in 2009 than in 2008, 2008 was found to be warmer than 2009 with maximum temperature of 40^{o} C in the month of March while the temperature was lower in 2009 with a maximum of 38^{o}C (Figs 5 & 6).

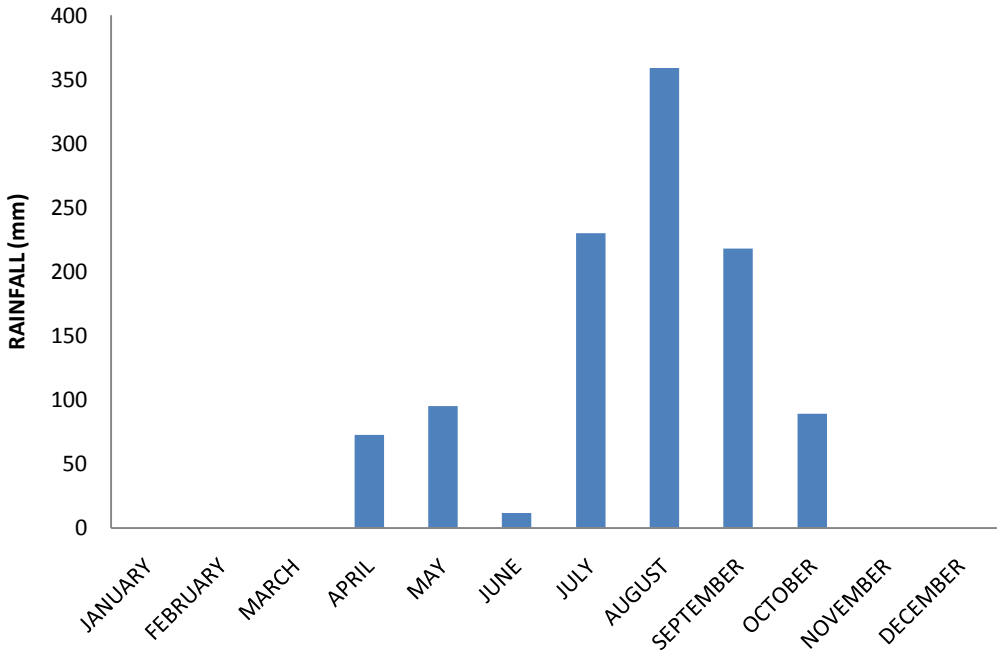


Figure 3: Mean rainfall (mm) of the study location for the year 2008

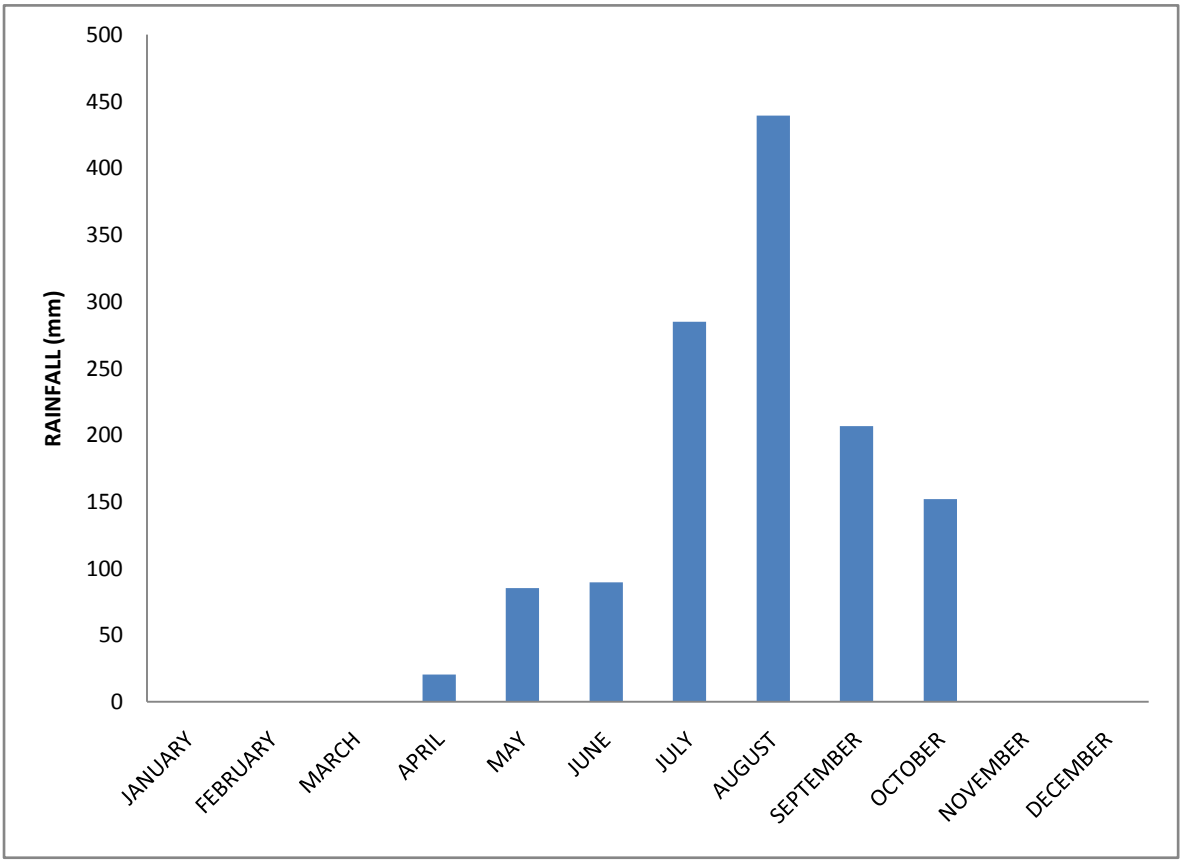


Figure 4: Mean rainfall of the study location for the year 2009

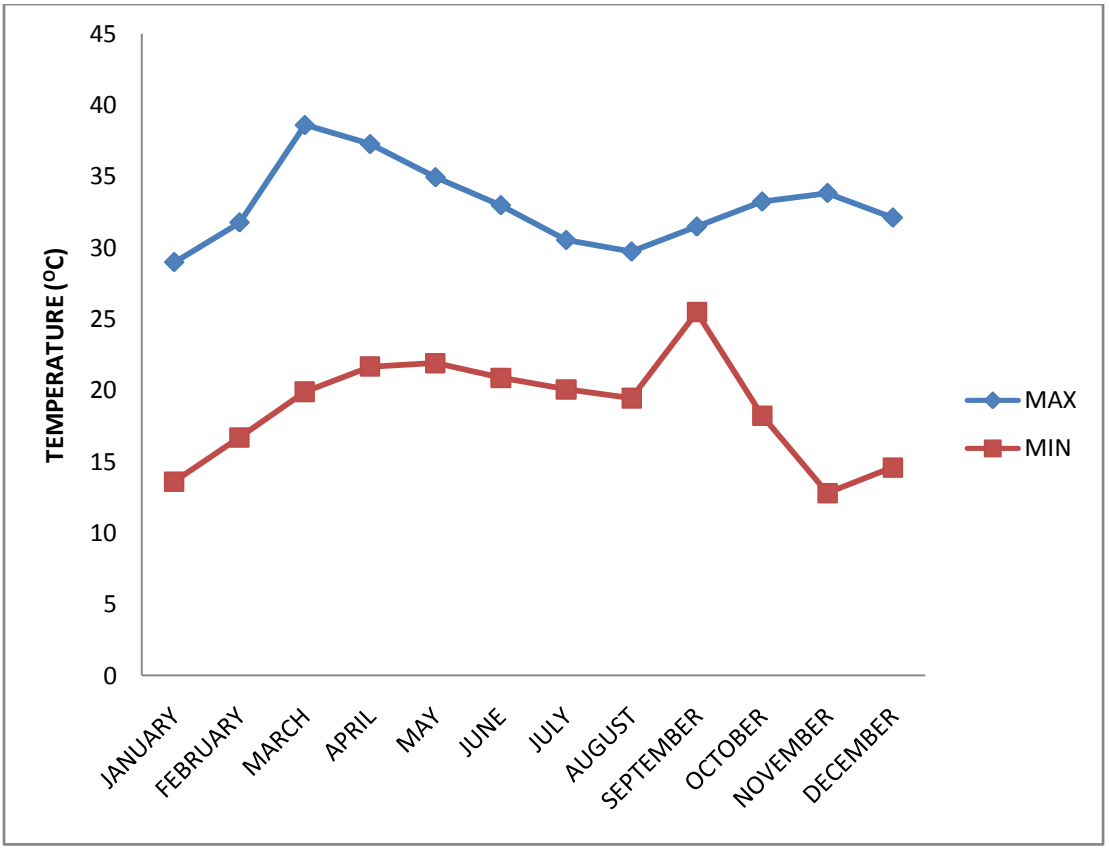


Figure 5: SAMARU Mean Monthly Temperature (^{0}C) 2008

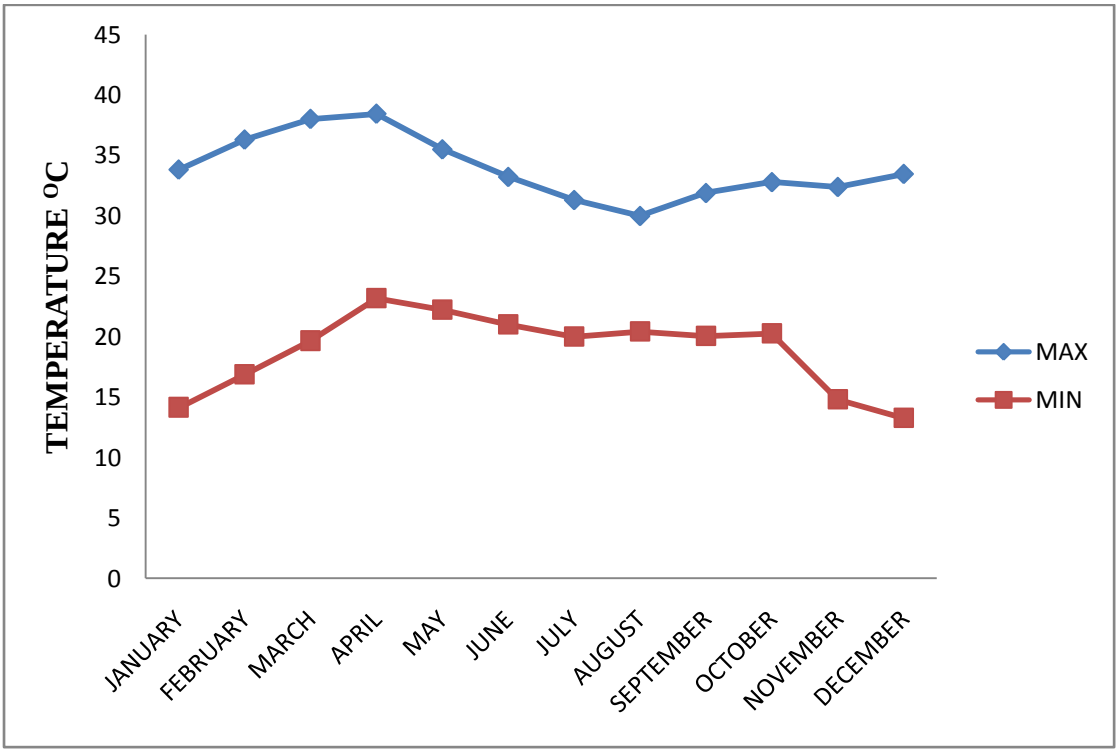


Figure 6: SAMARU Mean Monthly Temperature (^{0}C) 2009

4.1.1 Characterization of the soils used for the study

The soils used for the greenhouse and field trials were characterized for their physical and chemical properties as shown in Table 4.1.

4.1.2 Soil characteristics and geology

Soils of the experimental sites have been classified as Typic Haplustalf an Alfisol in the USDA Soil Classification system and it is developed in deeply weathered pre-Cambrian, basement complex rock overlain by aeolian drift materials of varying thickness (Moberg and Esu, 1991; Ogunwole, 2000). The soils were sandy loam in texture and low in clay contents ($123gkg^{-1}$) and ($120gkg^{-1}$) both in the greenhouse and field soils respectively.

Organic carbon contents of the soils were $5.40gkg^{-1}$ and $5.00gkg^{-1}$ which were low for the soils respectively. Some other workers have observed similar level of organic carbon in savanna soils, which implied low fertility status for the cultivated soil (Enwezor, 1989; Moberg and Esu, 1989).

The total nitrogen content of the soils ranged from 0.06%-0.12% with a mean of 0.08%. The low level of total nitrogen in the soil could be attributed to low organic matter contents of these typical savanna soils (Jones and Wild, 1975). The available P content of the soil was moderate with values of $8.90mgkg^{-1}$ and $6.80mgkg^{-1}$ for the greenhouse and field soils. The exchangeable site was dominated by calcium and magnesium as characteristic of savanna soils. These cations are the most abundant in the exchange complex of savannah soils. The K saturation of greenhouse and field soils was 7.8% and 5% respectively. Potassium fertility of the soil was in the range of $0.25cmolkg^{-1}$- $0.35cmolkg^{-1}$ with a mean of $0.35cmolkg^{-1}$. The sodium content was generally low $0.52cmolkg^{-1}$and 0.30 $cmolkg^{-1}$as may be expected for good arable soil although Na contents were higher than K in both soils. The higher Na content in the cultivated soils relative to K must have been introduced in fertilizer materials or other amendments employed over time for crop production. The effective CEC

values for the greenhouse and field top soils were 5.69 and 5.09 cmolkg^{-1} respectively, giving a Ca and Mg saturation of 56% and 20% and 54% and 24% respectively for both nutrients in the greenhouse and top soils. The micronutrient values were found to be low to moderate in the soils and have been recorded to be deficient in most savanna soils. These soils were therefore low in natural fertility and their productivity will decline quite rapidly under continuous cultivation, which by implication requires to be fertilized in order to sustain good crop yields (Lombin, 1987).

4.2 Greenhouse Experiment

4.2.1 Main effect of nitrogen fertilizer on the agronomic parameters

4.2.1.1 QPM varieties

The main effect showed that the parameters increased as nitrogen rates increased from 0-150kgNha^{-1} except SUSUMA variety that was more superior with the tallest plants (65.50cm) at 50kgNha^{-1} as shown in Table 4.2.

SUSUMA produced more leaves (12.75) than SAMMAZ 14(12.50) at nitrogen levels of (50kgha^{-1}N) and (150kgha^{-1}N) respectively. However, SAMMAZ 14 variety DMY increased with increasing rate of N while SUSUMA (QPM) had DMY of (6.67g) at (50kgha^{-1}N).

4.2.1.2 Normal varieties

The agronomic parameters of SAMMAZ 12 and SAMMAZ 11 were not far from the quality protein maize in that they produced more leaves and tallest plants at the highest level of nitrogen applied (150kgha^{-1}N) respectively as seen on Table 4.2. Dry matter yield increased with increased nitrogen rates although the increase was not significant. Maximum DMY for SAMMAZ 12 (6.28g/pot) and SAMMAZ 11 (6.17g/pot) were obtained when the crop was fertilized at 150kgNha^{-1}.

Table 4.1: Physico-chemical properties of the soil used for the study

Parameters	Greenhouse study	Field Study	
	0-20 (cm)	0-15 (cm)	15-30 (cm)
Sand (gkg^{-1})	540.0	530.0	525.0
Silt (gkg^{-1})	330.0	350.0	350.0
Clay (gkg^{-1})	130.0	120.0	125.0
Textural class	Sandy-loam	Sandy-loam	Sandy-loam
pH_{H20} 1:2.5	5.80	5.70	5.60
pH_{CaCl2} 1:2.5	5.30	5.40	5.20
Organic carbon (gkg^{-1})	5.40	5.20	5.00
Total nitrogen (%)	0.12	0.06	0.07
Available P ($mgkg^{-1}$)	8.90	7.58	6.80
Exchangeable acidity ($cmolkg^{-1}$)	0.47	0.60	0.52
Exchangeable bases ($cmolkg^{-1}$)			
Calcium	3.57	3.08	3.00
Magnesium	1.30	1.36	1.29
Sodium	0.52	0.40	0.30
Potassium	0.30	0.25	0.35
Effective CEC ($cmolkg^{-1}$)	5.69	5.09	4.94
Micronutrients ($mgkg^{-1}$)			
Extractable Zinc	18.50	10.75	12.40
Extractable Iron	55.80	52.00	45.50
Extractable Copper	0.60	0.58	0.55
Extractable Molybdenum	12.20	11.00	11.08
Extractable Boron	0.20	0.10	0.11

Table 4.2: Main effects of nitrogen on agronomic parameters in the greenhouse

Variety	Nitrogen ($kgha^{-1}$)	No of leaves/plot	Plant height(cm)	Dry matter Yield(g/pot)
SAMMAZ 14	0	8.25	34.75	5.39
	50	9.24	40.50	5.67
	100	9.81	41.62	5.89
	150	12.50	60.25	6.28
Mean		9.95	44.28	5.74
SUSUMA	0	9.16	42.36	5.72
	50	12.75	65.50	6.67
	100	9.80	50.54	5.84
	150	0.04	55.10	5.95
Mean		9.84	53.38	5.92
SAMMAZ 12	0	8.15	37.03	5.50
	50	8.25	40.67	5.61
	100	9.53	54.10	5.67
	150	10.50	56.30	6.00
Mean		9.11	47.03	5.28
SAMMAZ 11	0	8.24	36.49	5.57
	50	10.35	40.11	5.99
	100	10.65	52.45	5.89
	150	12.00	54.79	6.17
Mean		10.91	45.96	5.93
Mean		0.05	47.21	5.86
SE ±		6.97	2.23	0.28
CV (%)		48.25	14.67	11.81
CONTRAST				
QPM Vs normal		NS	**	NS
QPM_A Vs QPM_B		NS	NS	NS
With Vs without M/nut		NS	NS	NS

4.2.3 Response of agronomic parameters to micronutrient levels

Micronutrients application enhanced the performance of the quality protein maize in respect to the agronomic parameters because values were enhanced consistently with SUSUMA recording the tallest plant (60.35cm) and number of leaves (12.85) followed by SAMMAZ 14 with the height of (58.10cm) and number of leaves (12.55) as presented in Table 4.3. SAMMAZ 12 and SAMMAZ 11 were not far from the quality protein maize in that SAMMAZ 11 produced plants with height of 55.70cm and number of leaves 35.50 with added micronutrients while SAMMAZ 12 did with no micronutrients applications. The highest dry matter yield was recorded at micronutrient additions in all the varieties as seen on Table 4.3.

4. 2.4. Effects of nitrogen and micronutrients on the agronomic parameters of maize.

Combining nitrogen fertilizer and cocktail mixtures of micronutrients showed that the QPM (SAMMAZ 14 and SUSUMA) outperformed the normal maize in the utilization of micronutrients for the synthesis of various relevant products such as plant heights, number of leaf and in dry matter production. SAMMAZ 14 (QPM) was 60.25cm tall and had number of leaves (12.35) with added micronutrients and N rates of 150kgha^{-1} while SUSUMA variety had the tallest plant (67.75cm), highest number of leaves (12.67) with added micronutrients and fertilizer rate of 50kgNha^{-1}.The normal maize, SAMMAZ 12 and SAMMAZ 11 was 56.10cm, 55.65cm tall and produced 0.50 and 12.50 number of leaves respectively at 150kgNha^{-1} with no micronutrient applications (Table 4.4).

Table 4.3 Effect of micronutrients on agronomic parameters of the maize varieties (greenhouse)

Variety	Micronutrients level (gha^{-1})	No of leaves/plot	Plant height (cm)	DMY (g/pot)
SAMMAZ 14	-M	9.01	38.29	5.50
	+M	12.55	58.10	5.97
SUSUMA				
	-M	9.10	35.34	5.81
	+M	12.85	60.35	6.03
SAMMAZ 12	-M	2.50	55.70	5.89
	+M	8.35	35.50	5.83
SAMMAZ 11	-M	10.53	37.01	6.00
	+M	8.50	58.40	5.86
	Mean	10.42	50..21	5.86
	SE+	4.93	1.58	0.28
	CV (%)	48.25	14.67	11.81

-M= no micronutrient and +M= added micronutrient

SAMMAZ 14 and SUSUMA: Quality Protein Maize, SAMMAZ 12 and SAMMAZ 11: Normal maize.

Table 4.4: Interaction between nitrogen and micronutrients on agronomic parameters of maize in the greenhouse

Variety	Nitrogen ($kgha^{-1}$)	No of leaves		Plant Height(cm)		Dry matter yield g/pot	
		Micronutrients gha^{-1}					
		M_0	M_1	M_0	M_1	M_0	M_1
SAMMAZ 14	0	8.31	8.25	35.83	33.67	5.89	5.00
	50	8.67	9.24	38.89	35.55	5.11	5.66
	100	8.31	10.81	38.07	44.39	5.44	5.89
	150	8.67	12.35	40.32	60.25	5.56	5.89
Mean		8.49	10.20	38.28	43.47	5.50	5.97
SUSUMA	0	8.42	9.90	31.24	33.60	5.67	5.78
	50	8.44	12.67	30.67	67.75	6.44	6.78
	100	8.25	9.80	40.04	50.40	5.78	5.89
	150	8.33	10.84	37.17	50.10	5.89	6.00
Mean		8.36	10.72	34.78	50.46	5.81	6.03
SAMMAZ 12	0	8.25	8.03	37.34	37.34	5.78	5.55
	50	9.25	8.33	36.99	34.01	5.78	5.74
	100	9.53	8.61	40.67	40.12	5.56	5.54
	150	10.50	8.50	56.10	41.56	6.56	6.40
Mean		9.378	8.37	41.57	38.36	5.83	5.89
SAMMAZ 11	0	9.23	8.03	37.16	35.31	5.56	5.56
	50	11.65	8.36	40.00	33.43	5.78	6.22
	100	12.00	8.56	53.40	35.32	6.00	5.78
	150	12.50	6.96	55.65	40.72	6.67	5.89
Mean		11.38	7.98	46.55	36.22	6.00	5.83
Mean		8.42		37.21		5.86	
SE ±		9.87		3.15		0.39	
CV (%)		48.25		14.67		11.89	
		CONTRAST					
QPM vs Normal		NS	NS	NS	*	NS	NS
QPM_A vs QPM_B		NS	NS	NS	*	NS	NS

4.3 Combined Effects of Nitrogen Fertilizer and Micronutrients on the Chemical Properties of Cropped Greenhouse Soils.

The study was to give information on the effect of nitrogen and micronutrients on soil chemical properties in the greenhouse as presented in Table 4.5.

4.3.1 The pH in water (1:2.5)

The pH of the greenhouse soil was moderate to slightly acidic in water. The mean pH in water ranged from 5.2-6.0 with no micronutrients and 5.3-6.3 with micronutrients (Table 4.5).The contrast analysis showed no significant difference ($P< 0.05$) with or without micronutrients between quality protein maize and normal maize while there was a significant difference ($P< 0.01$) between quality protein maize A and B with added micronutrients.

4.3.2 Organic carbon

The interactive effect of treatments on soil organic carbon content of the soil was not significantly different in all the varieties. But the organic carbon content increases with increasing levels of nitrogen and with added micronutrient though the increase was not significant at ($P< 0.05$). The carbon content ranged from 0.7-1.1gkg^{-1} with no micronutrients application and 0.7-1.0gkg^{-1} was observed in the pots with added micronutrients for all the varieties. When the normal maize and QPM were compared, there was no significant difference between the mean values.

4.3.3 Total nitrogen

Effect of nitrogen fertilizer and micronutrients on nitrogen content of the soil as presented on Table 4.5 showed that nitrogen contents was highest in soils treated with nitrogen fertilizer at the highest rate of 150kgNha^{-1}. The treatment with the highest application of nitrogen and added micronutrients (N_4M_1) gave the highest N concentration. However there was no significant difference ($P< 0.05$) between the pots with no micronutrients application in N concentration. N content was generally low, with a range of 0.06-0.09 mg/kg as seen on Table 4.5.

4.3.4 Available soil phosphorus

The phosphorus concentration of the cropped soil although was not significant, but P increased as the nitrogen level applied increased (Table 4.5). The effect of treatments showed the highest P concentration (12.3mgkg^{-1}) was recorded at the highest rate of N with addition of micronutrients (N_4M_1). The quality protein maize and normal maize when compared were not significantly different from each other in their response to available phosphorus.

4.3.5 Exchangeable bases

The effects of nitrogen and micronutrients on exchangeable bases were not significant at ($P< 0.05$). However, K contents of soil ranged from 0.6-1.2 Cmolkg^{-1}, Na contents ranged from 1.3-2.0 Cmolkg^{-1}, 3.2-4.9 Cmolkg^{-1}for Ca and Mg contents ranged from 3.4-4.8 Cmolkg^{-1} with added micronutrients. With no micronutrients application, K content was in the range of 0.4-0.9 Cmolkg^{-1}, 1.2-1.9 Cmolkg^{-1}for Na, 3.1-4.8Cmolkg^{-1} Ca and 2.1-4.3 Cmolkg^{-1} Mg content as presented in Table 4.5.

4.4 Effects of Nitrogen and Micronutrients on Micronutrients Content of the Soil

The effects of nitrogen and micronutrients on the soil micronutrients content showed that the Cu contents of the soil ranged from 0.17-1.10 Cmolkg^{-1} with added micronutrients while pots with no micronutrients application recorded 0.17-1.00 Cmolkg^{-1} at 100kgNha^{-1}.The range of zinc contents of the soils was 12.22-19.52 Cmolkg^{-1}at the highest rate of N (150kgNha^{-1}) with added micronutrients while the range was 10.92-16.56 Cmolkg^{-1} with no micronutrients addition. The iron content range of the soil was 17.62-57.14 Cmolkg^{-1}with micronutrients and 20.59-47.62 Cmolkg^{-1} without micronutrients. Boron content of the soil was 3.69-7.39 Cmolkg^{-1} with micronutrients and 4.00-7.39 Cmolkg^{-1} with no micronutrients application while molybdenum contents of the soil ranged from 0.08-0.17 Cmolkg^{-1} with added micronutrients and 0.09-0.18 Cmolkg^{-1} with no micronutrients as presented on Table 4.6.

Table 4.5: The effects of N and micronutrients on some selected chemical properties of soil

Variety	Nitrogen level (kg/ha)	Micronutrients (gha^{-1}) pH H_2o		OC (gkg^{-1})		Total N (%)		Avail. P ($mgkg^{-1}$)		Exchangeable Bases K		Na $Cmolkg^{-1}$		Ca		Mg	
		M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1
SAMMAZ 14	0	5.9	5.5	1.1	0.7	0.07	0.06	7.9	6.1	0.6	0.8	1.4	1.8	4.8	4.9	4.0	3.4
	50	5.8	5.8	0.9	0.8	0.07	0.07	9.3	8.8	0.5	0.7	1.7	2.0	4.8	3.6	3.6	3.8
	100	5.8	5.9	1.0	0.7	0.06	0.08	9.0	10.2	0.5	0.8	1.7	1.6	3.8	3.7	3.7	3.5
	150	5.7	6.0	0.9	0.8	0.08	0.09	10.5	11.7	0.6	0.9	1.5	1.7	4.1	3.9	3.9	4.5
Mean		5.9	5.9	0.9	0.8	0.07	0.07	9.2	9.2	0.8	0.8	1.6	1.8	4.4	3.8	3.8	3.7
SUSUMA	0	5.9	5.5	0.7	0.9	0.06	0.08	4.7	5.5	0.9	0.9	1.6	1.3	3.8	3.9	4.3	3.7
	50	5.6	5.5	0.9	0.7	0.06	0.08	9.2	7.0	0.6	1.2	1.5	1.7	3.9	4.4	4.1	3.9
	100	5.7	5.6	0.8	0.8	0.08	0.08	7.6	11.1	0.8	0.8	1.9	1.5	3.5	5.2	3.1	3.7
	150	5.2	5.9	0.7	0.9	0.08	0.09	11.1	12.3	0.8	0.8	1.6	1.5	3.4	3.9	3.7	4.8
Mean		5.9	5.9	0.8	0.9	0.07	0.08	8.1	9.0	0.9	0.8	1.6	1.5	3.6	4.4	3.8	3.6
SAMMAZ 12	0	6.0	5.3	0.9	0.7	0.06	0.07	8.2	6.7	0.4	0.7	1.2	1.3	3.3	3.6	2.1	3.6
	50	5.6	5.9	0.9	0.9	0.07	0.07	5.8	8.2	0.4	0.7	1.3	1.5	3.2	3.6	3.3	3.9
	100	5.9	6.2	1.0	1.0	0.06	0.08	7.6	7.0	0.5	0.6	1.6	1.5	3.3	3.2	3.9	3.8
	150	5.2	6.3	0.9	1.0	0.09	0.08	9.6	9.0	0.4	0.7	1.3	1.4	3.1	3.4	3.5	3.8
Mean		5.9	6.1	0.9	0.9	0.07	0.07	7.8	7.7	0.8	0.8	1.5	1.6	4.0	4.3	3.7	4.1
SAMMAZ 11	0	5.9	5.7	0.9	0.9	0.08	0.06	7.9	8.2	0.1	0.5	1.4	1.3	3.2	3.0	2.9	3.6
	50	5.4	5.9	0.8	1.0	0.07	0.07	7.3	7.9	0.5	0.7	1.5	1.4	3.4	3.2	3.7	3.7
	100	5.7	5.9	1.0	0.9	0.08	0.08	3.5	6.4	0.7	0.7	1.5	1.4	3.3	3.4	3.6	3.5
	150	5.3	6.2	0.9	0.9	0.09	0.09	9.3	8.8	0.7	0.6	1.3	1.5	3.4	3.5	3.6	3.9
Mean		5.8	6.0	0.9	0.9	0.08	0.07	7.0	8.0	0.8	0.7	1.6	1.7	4.4	3.9	3.9	3.9
Mean		5.29		5.29		2.15		0.07		8.23		0.79		1.59		3.79	
SE ±		0.09		0.07		5.18		8.95		2.43		0.13		0.17		0.40	
CV (%)		2.76		2.26		4 8.02		21.38		51.21		28.12		21.31		18.29	
CONTRAST																	
QPM vs Normal		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
QPM_A vs QPM_B		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	*

Table 4.6:The effects of Nitrogen and micronutrient on macronutrient content of the soil

Variety	N level (kg/ha)	Extractable micronutrients ($Cmolkg^{-1}$)									
		Cu		Zn		Fe		M_o		B	
		M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1
SAMMAZ 14	0	0.67	0.83	12.04	16.67	43.33	31.91	0.11	0.12	5.85	4.00
	50	0.89	0.67	10.92	12.59	25.72	37.62	0.11	0.13	7.08	6.16
	100	1.00	0.33	12.59	12.22	43.29	17.62	0.11	0.11	5.08	7.08
	150	0.33	1.10	11.48	15.74	27.62	32.86	0.11	0.13	7.39	4.31
Mean		0.83	0.58	13.24	12.41	34.98	30.00	0.11	0.12	6.54	5.39
SUSUMA	0	0.50	0.83	13.71	16.11	47.62	34.76	0.12	0.17	7.39	3.69
	50	0.33	0.17	12.58	17.12	36.42	22.38	0.13	0.08	6.16	6.47
	100	0.67	1.00	14.57	18.11	57.14	32.86	0.11	0.09	4.31	5.85
	150	0.17	1.16	15.72	19.52	24.77	27.62	0.12	0.11	7.39	4.31
Mean		0.42	0.79	12.59	13.67	41.49	29.41	0.18	0.11	6.31	5.08
SAMMAZ 12	0	0.33	0.50	13.05	14.55	40.00	28.57	0.10	0.11	4.32	6.16
	50	0.50	0.50	12.35	12.89	29.05	43.80	0.11	0.16	4.00	6.16
	100	0.67	0.33	14.50	15.00	20.95	30.00	0.09	0.11	6.78	4.93
	150	0.98	1.00	16.00	17.21	21.42	40.02	0.09	0.15	4.93	4.31
Mean		0.54	0.79	11.99	14.77	27.86	35.59	0.09	0.13	5.01	5.39
SAMMAZ 11	0	0.67	0.67	14.65	13.75	35.24	56.19	0.11	0.09	6.16	6.16
	50	0.67	1.00	12.66	13.11	32.38	23.81	0.11	0.20	6.78	5.54
	100	1.00	0.50	15.70	14.15	23.67	47.14	0.10	0.09	6.16	7.39
	150	0.50	0.67	16.56	17.21	25.24	19.52	0.10	0.17	4.62	5.24
Mean		0.71	0.63	12.18	13.79	29.13	43.69	0.11	0.14	5.93	6.08
Mean		0.67		13.13		33.14		0.12		5.72	
SE ±		0.35		2.09		11.39		0.01		0.58	
CV (%)		89.98		21.31		59.54		25.69		35.02	
CONTRAST											
QPM vs Normal		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
QPM_A vs QPM_B		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.5 Effects of Nitrogen and Micronutrients on Nutrient Concentrations (N, P, K, Ca and Mg) of Maize Tissue in the Greenhouse

The effect of combined nitrogen and micronutrients on nutrient concentrations in maize plant tissue revealed higher N concentrations of 0.96gkg^{-1}at 150kgNha^{-1} with micronutrients application while the least concentration of 0.47gkg^{-1} was recorded at 50kgNha^{-1} with no micronutrients. The treatments increase N above the control at added micronutrients for SUSUMA, SAMMAZ 12 and 11 varieties respectively. The contrast analysis showed a significant difference in the nitrogen contents of the QPM and normal maize varieties with micronutrients while there was no significant difference between QPM and normal maize tissue where micronutrients were not applied. No significant difference recorded in nitrogen concentrations in the tissue of QPM_A and QPM_B. The highest phosphorus concentration in the tissue of SUSUMA variety was 0.96mgkg^{-1}at0kgNha^{-1} with no micronutrients and 0.78mgkg^{-1} at 50kgNha^{-1} with addition of micronutrients. There was a significant difference in P concentrations of the two quality protein maize SAMMAZ 14 and SUSUMA with no micronutrient additions while with added micronutrients there was no significant difference between QPM_A and QPM_B.

The highest K concentration of the leaves was 9.07gkg^{-1} by SUSUMA variety at 0kgNha^{-1} with no micronutrients and with micronutrients application the K concentration increased as nitrogen levels increased to the optimum (150kgNha^{-1}). The K content of the leaves increased also with treatments although the increase was not significant. When the QPM was compared with the normal maize varieties, there was significant difference between them in both micronutrients amended pots and where there was no micronutrient addition. There was no significant difference between the two QPM varieties. Calcium concentration in leaves with micronutrients was 0.41gkg^{-1} at 50kgNha^{-1} by SAMMAZ 12.Magnesium concentration was 0.55gkg^{-1} at 50kgNha^{-1} with micronutrients (SAMMAZ 12).

Table 4.7: The effects of nitrogen and micronutrients on nutrient concentration of tissues of maize varieties

Variety	Nitrogen level (kg/ha)	Total N (gkg^{-1})		Total P ($mgkg^{-1}$)		Total K ($cmolkg^{-1}$)		Total Ca ($cmolkg^{-1}$)		Total Mg ($cmolkg^{-1}$)	
		M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1
SAMMAZ 14	0	0.58	0.79	0.68	0.65	6.03	5.13	0.19	0.23	0.41	0.39
	50	0.70	0.47	0.63	0.49	6.30	5.80	0.21	0.27	0.34	0.39
	100	0.85	0.58	0.63	0.62	4.97	5.00	0.24	0.26	0.32	0.35
	150	0.76	0.82	0.70	0.68	5.70	6.47	0.22	0.31	0.29	0.46
Mean		0.72	0.66	0.66	0.61	5.75	5.85	0.22	0.27	0.34	0.39
SUSUMA	0	0.67	0.55	0.96	0.55	9.07	4.50	0.28	0.25	0.39	0.41
	50	0.82	0.88	0.65	0.78	6.40	5.13	0.27	0.41	0.32	0.41
	100	0.58	0.79	0.67	0.65	5.24	6.00	0.25	0.33	0.38	0.41
	150	0.64	0.93	0.78	0.62	5.37	6.43	0.27	0.28	0.40	0.39
Mean		0.68	0.79	0.77	0.65	6.52	5.52	0.28	0.29	0.37	0.41
SAMMAZ 12	0	0.69	0.82	0.65	0.60	6.33	5.24	0.27	0.24	0.35	0.31
	50	0.61	0.61	0.62	0.60	6.23	6.30	0.23	0.29	0.39	0.55
	100	0.61	0.85	0.63	0.63	5.96	4.26	0.33	0.25	0.43	0.40
	150	0.82	0.96	0.64	0.67	3.97	7.60	0.27	0.36	0.38	0.37
Mean		0.77	0.72	0.64	0.62	5.58	5.77	0.28	0.32	0.39	0.41
SAMMAZ 11	0	0.39	0.67	0.56	0.65	7.13	6.43	0.27	0.28	0.34	0.36
	50	0.61	0.70	0.64	0.75	6.40	6.43	0.19	0.35	0.31	0.46
	100	0.73	0.73	0.55	0.68	5.40	7.37	0.30	0.37	0.34	0.39
	150	0.55	0.89	0.62	0.68	4.37	5.90	0.30	0.39	0.44	0.49
Mean		0.57	0.70	0.59	0.69	5.83	6.53	0.27	0.32	0.36	0.40
Mean		0.71		0.07		5.95		0.28		0.39	
SE ±		0.14		81.77		0.76		0.05		0.06	
CV(%)		33.73		21.23		22.25		29.89		24.98	
CONTRAST											
QPM vs Normal		NS	*	NS	*	**	*	*	NS	NS	NS
QPM_A vs QPM_B		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.6 Effects of Treatments on the Tissue Micronutrients as Influenced by Crop Genotypes

The zinc content of the leaf increased with increase in nitrogen rates with or without micronutrients application by all the varieties as seen in Table 4.8. Iron concentration in leaves was not consistent without micronutrients application, the highest content was 292.76mgkg^{-1} by SAMMAZ 11 at 150kgNha^{-1}. When micronutrients were applied the highest concentration of iron in the leaves was 390.58mgkg^{-1} at 50kgNha^{-1} by SAMMAZ 11. Boron concentration in the leaves consistently increased with applied micronutrients and nitrogen 150kgNha^{-1}. Molybdenum concentration was highest in the leaf when micronutrients were not added to the soil (30.68mgkg^{-1}) at 100kgNha^{-1} in SAMMAZ 12.

4.7 Mean Response of Maize DMY to N Levels as Influenced by Micronutrients Application

The interaction between nitrogen fertilizer and micronutrient on dry matter yield of maize as seen on Table 4.9 showed that the general response was only up to 100kgNha^{-1} in soils supplied with adequate amounts of micronutrient.

Table 4.8: The effect of treatments on micronutrient concentrations in maize tissue as influenced by crop genotypes in the greenhouse

Variety	Nitrogen ($Kgha^{-1}$)	Zn		Fe		Mo		B	
				$mgkg^{-1}$					
		M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1
SAMMAZ 14	0	54.10	74.63	202.35	221.18	2.59	1.41	16.70	19.82
	50	65.29	78.36	169.41	274.70	0.77	1.78	27.09	16.37
	100	69.03	85.83	241.70	216.47	0.80	1.54	22.74	27.11
	150	72.76	86.62	221.17	207.25	0.78	1.98	21.01	30.34
	Mean	65.29	81.36	209.41	222.39	1.23	1.67	21.88	23.41
SUSUMA	0	59.70	59.70	263.53	221.17	1.05	1.24	9.87	16.54
	50	70.89	72.76	244.70	211.76	0.70	1.45	26.87	20.66
	100	87.69	73.96	254.11	197.64	0.53	1.56	24.77	21.54
	150	93.15	75.15	202.34	150.58	0.74	2.07	18.01	30.56
	Mean	77.86	70.39	241.17	195.29	0.75	1.58	19.88	22.32
SAMMAZ 12	0	59.70	73.63	160.19	188.23	0.75	1.62	18.23	18.35
	50	68.03	74.68	221.17	292.47	1.21	1.58	15.94	17.94
	100	69.04	69.03	188.43	221.17	1.32	1.72	30.68	28.80
	150	70.89	77.42	207.25	218.43	0.79	2.11	26.77	19.06
	Mean	66.91	73.69	194.26	230.59	1.02	1.76	22.90	21.04
SAMMAZ 11	0	46.51	64.29	225.88	272.95	0.74	1.46	16.21	13.19
	50	59.70	64.29	197.67	390.58	0.72	2.29	16.25	20.24
	100	61.57	67.41	292.76	263.64	1.00	1.80	29.83	19.53
	150	66.16	79.55	235.29	268.23	0.58	2.37	22.73	23.54
	Mean	58.48	70.54	237.65	285.88	0.76	1.95	21.25	18.76
Mean		70.36		28.69		1.35		21.48	
SE ±		12.78		46.23		0.50		3.92	
CV (%)		23.29		35.01		64.37		31.60	
CONTRAST									
QPM vs Normal		NS	NS	NS	NS	*	**	NS	NS
QPM_A vs QPM_B		NS	NS	NS	NS	NS	NS	NS	NS

Table 4.9: Effect of treatments on the dry matter yield of maize in the green house

Nitrogen level ($kgha^{-1}$)	Micronutrient (gha^{-1}) M_o	M_1
0	5.67	5.75
50	5.64	5.94
100	5.95	6.08
150	5.89	5.97
Mean	5.86	
SE±	0.19	
CV (%)	11.81	

4.8 Field Study

4.8.1 Grain Yield Response of Maize to Nitrogen

The response of maize grain to applications of varying rates of nitrogen fertilizers over the two years is given in Table 4.10. SAMMAZ 14 and SUSUMA (QPM) had yields of 2.6tha^{-1} and 2.7tha^{-1} respectively at 100kgNha^{-1} while normal maize variety SAMMAZ 12 and 11 had the combined yield of 1.93tha^{-1} and 2.3tha^{-1} at the highest rate of nitrogen application (150kgNha^{-1}).

The main effect of nitrogen in the combined analysis of the yield shows a significant ($P < 0.05$) effect between the yield of the quality protein maize varieties and the normal maize as seen in Table 4.10.

The pooled result of the yield response of the different varieties to nitrogen fertilizer was in the order SUSUMA> SAMMAZ 14 > SAMMAZ 11 >SAMMAZ 12 with percentage difference of 8.75% >4.59% > 27.74%.

The contrast analysis showed a highly significant difference between the yield of the QPM and normal maize varieties and between the two QPM varieties.

4.8.2 Effects of Micronutrients on Grain Yield of Maize

The combined yield showed SAMMAZ14 and SUSUMA (QPM) produced grain yield of 1.73tha^{-1} and 1.81tha^{-1} with addition of micronutrients (Cu, Zn, Fe, B and Mo) to the soil. The normal maize SAMMAZ 12 also produced grain yield of 1.4tha^{-1}without micronutrients application and SAMMAZ 11 had 1.67tha^{-1} with micronutrients application as seen in Table 4.11.

Table 4.10: Main effects of Nitrogen and different maize varieties on grain yield

		Grain yield (kg ha^{-1})		
Variety	Nitrogen (kg ha^{-1})	2008	2009	Combined
SAMMAZ 14	0	245.16	1111.09	678.05
	50	681.90	2776.94	1729.42
	100	2397.05	2708.82	2552.94
	150	1820.77	3082.32	2451.55
Mean		1096.31	2508.27	1802.34
SUSUMA	0	990.93	1354.11	1127.02
	50	368.01	2263.88	1315.94
	100	1809.09	3522.21	2665.65
	150	1231.87	2894.43	2063.15
Mean		707.22	2258.66	1632.94
SAMMAZ 12	0	515.22	1486.09	1000.65
	50	561.03	1805.55	1183.29
	100	981.89	2106.55	1571.22
	150	1366.63	2499.99	1933.31
Mean		865.19	1988.04	1422.12
SAMMAZ 11	0	690.23	1312.49	1012.75
	50	760.49	1944.44	1352.47
	100	1212.45	2129.58	1671.02
	150	1637.42	3062.16	2349.79
Mean		1265.06	2023.83	1644.45
Mean		975.37	2285.06	1639.45
SE ±		341.90	296.15	173.28
CV(%)		85.86	31.75	52.03
V x N		NS	NS	NS
CONTRAST				
QPM vs Normal		**	**	**
QPM_Avs QPM_B		**	**	**
With vs Without m/nuts		NS	NS	NS

Table 4.11: Effects of Micronutrients on Grain Yield of Maize

		Grain yield ($kgha^{-1}$)		
Variety	M/Nuts (gha^{-1})	2008	2009	Mean
SAMMAZ 14	-M	1113.83	2243.05	1678.44
	+M	1116.18	2357.45	1731.12
SUSUMA	-M	670.68	297.88	484.28
	+M	1386.01	2235.60	1810.81
SAMMAZ 12	-M	/908.28	1984.10	1446.19
	+M	797.87	1934.43	1336.15
SAMMAZ 11	-M	1077.72	2225.94	1651.83
	+M	744.38	2599.99	1672.28
Mean		975.37	2285.06	1639.45
SE+		241.76	209.41	246.24
CV (%)		85.86	31.75	52.03

4.8.3 Response of maize grain yield to nitrogen levels as influenced by micronutrients

The response of maize grain to applications of varying rates of nitrogen fertilizer as influenced by micronutrients application over the two years is presented in Table 4.12. When the yields were combined, the analysis showed SUSUMA variety had the yield of 3.2tha^{-1} (150kgN)and SAMMAZ 14 variety had the grain yield of 2.6tha^{-1} (150kgN) both with micronutrients application.

SAMMAZ 12 and SAMMAZ 11 (normal maize) though responded to nitrogen fertilization but responded poorly to micronutrient additions. SAMMAZ 12 had 2.2tha^{-1} when the yields were combined with no micronutrients. SAMMAZ 11, normal maize had the yield of 2.3tha^{-1} with added micronutrients. When the analysis was compared, the quality protein maize showed a highly significant difference ($P< 0.05$) from the normal maize at added micronutrients and the comparison between the QPM varieties was also significant ($P< 0.05$) with added micronutrients.

4.9 Main Effect of Nitrogen Fertilizer on Maize Stover Yield

The Stover yields for the two years 2008 and 2009 and when combined were significant at ($P< 0.05$) and it increased as nitrogen rates increased. SAMMAZ 11 (normal maize) performed best with the yield of 4.25tha^{-1} followed by SUSUMA with 4.045tha^{-1},SAMMAZ 14 produced Stover yield of 3.99tha^{-1} and SAMMAZ 12 had the yield of 3.6tha^{-1} respectively.

The contrast between the quality protein maize and the normal maize was highly significant at ($P< 0.05$) and also between the QPM_A and QPM_B was highly significant.

Table 4.12: Grain yield response of maize varieties to Nitrogen levels as influenced by micronutrients

	Micronutrient (gha^{-1})					
	2008		2009		Combined	
Varieties x N level (kg Nha^{-1})	-M	+M	-M	+M	-M	+M
SAMMAZ 14						
0	172.1	452.7	1111.1	1111.2	641.6	844.3
50	727.7	611.1	2138.9	1749.9	1445.8	1180.5
100	1263.8	2011.1	3277.2	2888.9	2270.8	2449.9
150	2261.1	1380.9	2902.2	3222.2	2301.3	2581.6
Mean	1106.2	1188.9	2357.3	2243.3	1784.0	1694.0
SUSUMA						
0	294.4	400.0	1236.1	1472.2	665.2	788.8
50	322.2	413.2	2222.2	2305.6	1313.9	1318.0
100	636.1	827.7	2469.4	3319.4	1552.8	2073.6
150	1333.3	1924.9	3777.8	4388.9	2194.4	3156.9
Mean	668.9	744.4	2600.0	2698.1	1593.7	1672.2
SAMMAZ 12						
0	405.5	624.9	972.2	1722.2	688.8	1312.5
50	538.8	583.3	1888.9	1999.9	1213.8	1152.7
100	930.5	622.2	2041.7	2279.4	1691.6	1450.8
150	1316.6	1802.7	2444.4	2555.5	2179.1	1687.5
Mean	797.8	908.3	1986.1	1934.4	1320.5	1523.8
SAMMAZ 11						
0	366.0	119.4	1430.6	1194.4	1333.3	669.4
50	891.6	913.9	2175.8	2083.3	1283.7	1498.6
100	1816.6	1533.3	2472.3	2583.3	1862.9	2058.3
150	1236.0	2977.5	2834.2	3081.7	2144.4	2329.7
Mean	1077.7	1385.9	2255.9	2235.0	1656.1	1814.0
SE ±	1057.89	194.22	2283.84	222.29	171.33	173.19
R^2	0.61	99.40	0.83	30.71	0.70	0.72
CV(%)	0.71	73.44	0.62	38.93	52.59	51.22
V x N	NS	NS	NS	NS	NS	NS
CONTRAST						
QPM vs Normal	* *	* *	*	* *	NS	* *
QPM_Avs QPM_B	NS	NS	NS	NS	NS	*

4.9.1 Effect of micronutrients on stover yield of maize

Micronutrient applications enhanced the yield of maize Stover in that the quality protein maize, SAMMAZ 14 and SUSUMA had the combined Stover yield of 3374.1kgha^{-1} and 2819.3kgha^{-1} with added micronutrients. SAMMAZ 11, normal maize produced the highest Stover yield of 3706.45kgha^{-1} also with added micronutrients while SAMMAZ 12 produced a yield of 2855.79kgha^{-1} without micronutrients application as seen in Table 4.14.

4.9.2 Effects of treatments on stover yield of the maize genotypes

When the two years were combined the highest Stover yield was 4208.0kgha^{-1} at 150kgNha^{-1} with micronutrients by SAMMAZ 14. SUSUMA produced Stover yield of 4388.7kgha^{-1} at the highest level of N applied with micronutrients as seen for both years. SAMMAZ 12 recorded highest Stover yield at the highest rates of N applied and without micronutrients. Although SAMMAZ 11 recorded the highest yield of 3722kgha^{-1} with applied micronutrients the yield was not statistically different from the yield of SAMMAZ 12 which was 3735.9kgha^{-1}. Comparing the varieties, the quality protein maize performed significantly better than the normal maize and there was significant difference between the QPM_A and QPM_B.

4.13: Main Effect of Nitrogen on Maize Stover Yield

		Stover yield ($kgha^{-1}$)		
Variety	Nitrogen ($kgha^{-1}$)	2008	2009	Combined
SAMMAZ 14	0	1684.62	2486.02	2085.32
	50	3138.63	3166.54	3152.58
	100	4347.08	3638.74	3867.92
	150	4152.47	3416.53	3895.61
Mean		3330.70	3176.96	3243.61
SUSUMA				
	0	833.35	2611.01	1722.18
	50	1854.00	3222.09	2531.15
	100	2458.24	3277.65	2867.95
	150	3569.29	4527.59	4048.44
Mean		2178.72	3409.59	2792.43
SAMMAZ 12	0	2479.09	1638.82	2058.95
	50	2923.49	2138.81	2531.15
	100	3665.06	2055.47	2860.26
	150	4555.37	2708.23	3631.80
Mean		3405.75	2135.33	2770.54
SAMMAZ 11	0	2326.29	3166.55	2746.42
	50	2879.05	3860.95	3370.00
	100	3944.29	3555.41	3749.85
	150	4645.65	3860.96	4253.31
Mean		3448.82	3610.97	3529.89
Mean		3090.99	3057.51	3070.56
SE ±		488.35	194.66	211.53
CV(%)		38.69	25.47	35.34
V x N		NS	NS	NS
CONTRAST				
QPM vs Normal		**	**	**
QPM_Avs QPM_B		**	**	**
With vs Without M/nut		NS	NS	NS

Table 4.14: Effects of Micronutrients on maize Stover yield

		Stover yield (kg ha^{-1})		
Variety	Micronutrients	2008	2009	Combined
SAMMAZ 14	-M	3013.77	3281.07	3147.42
	+M	3367.92	3380.33	3374.13
SUSUMA	-M	3402.64	2135.35	2768.99
	+M	3416.53	2222.09	2819.31
SAMMAZ 12	-M	2201.30	3510.27	2855.79
	+M	2069.36	3301.23	2685.29
SAMMAZ 11	-M	3513.75	3192.93	3353.34
	+M	3708.19	3704.71	3706.45
Mean		3086.68	3090.99	3070.56
SE+		213.68	345.32	313.29
CV (%)		23.98	38.69	35.34

Table 4.15: Effects of Treatments on Maize Genotypes Stover yield

	Micronutrient (gha^{-1})					
	2008		2009		Combined	
Variety x N level ($kg\ Nha^{1}$)	-M	+M	-M	+M	-M	+M
SAMMAZ 14 (QPM)						
0	2388.0	2358.0	1847.2	1522.1	2151.3	2052.6
50	2999.9	3333.0	2582.9	3694.3	2791.4	3513.7
100	3277.7	3667.5	3777.6	4916.6	4097.1	3722.6
150	3388.8	3888.7	3877.6	4527.3	3583.2	4208.0
Mean	3013.8	3368.1	3281.1	3380.3	3155.8	3374.2
SUSUMA (QPM)						
0	2833.2	2389.8	916.7	749.9	1840.0	1569.9
50	2944.3	3499.9	1916.3	1791.7	2430.3	2645.8
100	3555.4	2999.9	2916.6	1999.9	3236.0	2499.9
150	4277.6	4777.6	3138.8	3999.8	3708.2	4388.7
Mean	3416.8	3402.6	2222.1	2135.3	2803.6	2776.1
SAMMAZ 12						
0	1666.6	1611.1	2805.4	2152.7	2236.0	1881.9
50	1999.9	2277.7	2624.9	3222.1	2312.4	2749.9
100	1888.8	2222.1	3024.8	4305.4	2456.8	3263.8
150	2722.1	2694.3	4749.8	4360.9	3735.9	3527.6
Mean	2069.4	2201.3	3301.2	3510.3	2685.3	2855.8
SAMMAZ 11						
0	3444.3	3458.2	3458.2	1194.4	2326.3	3451.3
50	3888.7	2091.6	2091.6	3666.5	2879.1	2990.2
100	3777.6	3499.9	3499.9	4388.7	3638.8	3638.8
150	3722.1	3722.1	3722.1	5569.2	3520.1	3722.1
Mean	3708.2	3192.9	3192.9	3704.7	3448.8	3450.6
Mean	3044.3	3122.9	3110.9	3004.0	3077.7	3063.5
SE ±	224.25	264.97	159.43	154.48	217.50	207.14
CV(%)	36.0	41.57	25.11	25.19	34.62	36.23
V x N	NS	NS	NS	NS	NS	NS
CONTRAST						
QPM vs Normal	**	**	NS	**	NS	**
QPM_A vs QPM_B	NS	NS	NS	NS	*	*

4.10 Effect of Nitrogen Levels on the Cob Length and Cob Diameter of Maize as Influenced by the Crop Genotypes

4.10.1 Cob length

SAMMAZ 14 had the highest cob length of 15.86cm at 100kgNha^{-1} followed by SUSUMA variety with length of 15.01cm at 150kgNha^{-1}. The convectional maize SAMMAZ 11 followed the same trend with the highest cob length of 15.25cm at 100kgNha^{-1}. The contrast analysis showed that the QPM had the greatest cob length and was significantly different at ($P< 0.05$) from the normal maize while SAMMAZ 14 differed from SUSUMA variety and the difference was significant at ($P< 0.05$) as seen in Table 4.16.

4.10.2 Cob diameter

The combined analysis showed that the QPM had the greatest diameter 5.62cm and 5.51cm at 100kgNha^{-1} respectively while the conventional maize had the greatest diameter 5.29cm and 5.47cm at 150kgNha^{-1}as presented in Table 4.16.Comparing the QPM with the normal varieties showed that the QPM produced the greatest diameter (5.62) when the years were combined and the difference was highly significant at $P<0.05$.

4.10.3 Effect of micronutrients application on maize cob length and cob diameter

Micronutrients application was found to enhance the performance of all the varieties of maize as seen in Table 4.17. SAMMAZ 11 had the longest cob length of 14.69cm followed by SAMMAZ 14 (13.87cm) while the shortest cob length of 13.26cm was recorded by SAMMAZ 12. The cob diameter increased in all the varieties with micronutrients with largest diameter of 5.48cm in SAMMAZ 14.

Table 4.16: Effect of Nitrogen on Maize Genotypes Cob Length and Cob Diameter

Variety	Nitrogen level ($kgha^{-1}$)	Cob length (cm)			Cob diameter (cm)		
		2008	2009	Combined	2008	2009	Combined
SAMMAZ 14	0	8.57	13.37	10.97	3.29	6.28	4.78
	50	10.87	14.87	12.87	3.90	6.53	5.22
	100	13.97	16.95	15.86	4.26	6.87	5.62
	150	14.77	17.47	15.18	4.39	7.28	5.51
Mean		12.05	15.67	13.72	3.96	6.74	5.28
	0	7.54	13.77	10.69	2.98	6.55	4.82
SUSUMA	50	9.09	14.85	11.97	3.33	6.48	4.91
	100	11.97	16.28	14.13	3.07	7.15	5.51
	150	12.76	17.25	15.01	3.87	7.33	5.49
Mean		10.34	15.54	12.95	3.31	6.88	5.18
	0	10.03	13.17	11.59	3.37	6.22	4.79
SAMMAZ 12	50	10.85	14.45	12.65	3.71	6.58	4.96
	100	13.59	16.30	14.39	3.87	6.28	5.23
	150	11.22	16.67	14.94	4.21	6.25	5.29
Mean		11.42	15.15	13.39	3.79	6.33	5.07
	0	9.88	14.95	12.42	3.32	6.15	4.74
SAMMAZ 11	50	10.70	16.08	13.39	3.47	6.73	5.10
	100	14.24	17.42	15.25	4.00	6.65	5.33
	150	13.09	15.97	15.11	4.29	6.65	5.47
Mean		11.98	16.11	14.04	3.77	6.55	5.16
Mean	11.49		15.61	13.57	6.63	3.75	5.19
SE ±		0.78	0.64	0.37	0.20	0.23	0.11
CV (%)	16.67		9.99	13.25	8.65	14.73	10.78
V x N		NS	NS	NS	NS	NS	NS
CONTRAST							
QPM Vs Normal		**	**	**	**	**	**
QPM_AVs QPM_B		**	**	**	NS	*	**
With Vs Without		NS	NS	NS	NS	NS	NS

Table 4.17: Effect of Micronutrients application on maize cob length and cob diameter

Variety	Micronutrients	Cob length (cm)			Cob diameter (cm)		
		2008	2009	Mean	2008	2009	Mean
SAMMAZ 14	-M	12.05	15.54	13.82	6.58	3.96	5.27
	+M	12.00	15.74	13.87	6.98	3.97	5.48
SUSUMA	-M	10.21	15.03	12.62	6.86	3.43	5.15
	+M	11.68	15.28	13.48	6.90	3.49	5.19
SAMMAZ12	-M	11.61	15.01	13.31	6.26	3.78	5.02
	+M	10.47	16.04	13.26	6.44	3.82	5.13
SAMMAZ 11	-M	11.06	15.74	13.40	6.54	3.67	5.11
	+M	12.90	16.47	14.69	6.55	3.87	5.21

4.10.4 The interaction of nitrogen and micronutrients levels on maize cob length and diameter

The effect of the treatments on the cob length and diameter of the varieties of maize were shown in Table 4.18. Cob length and diameter of the varieties responded differently to the treatments applied. The combined analysis showed that the longest cob was 16.10cm at 150kgNha^{-1} without micronutrients application for SAMMAZ 14 (QPM). SUSUMA (QPM) maize also had the cob length of 15.29cm at the optimum rate of nitrogen with micronutrients application. SAMMAZ12 had 15.31cm at 100kgNha^{-1} with micronutrients while SAMMAZ 11 had 15.39cm at 150kgNha^{-1} with applied micronutrients. The combined analysis showed that SAMMAZ 14 had the longest cob length.

The combined analysis as seen on Table 4.18 showed that SAMMAZ 14 had the biggest cob diameter of 6.06cm at the optimum level of nitrogen applied with addition of micronutrients. SUSUMA variety recorded the greatest cob diameter of 5.77cm at 100kgNha^{-1} with micronutrients. SAMMAZ 12 and SAMMAZ 11 recorded cob diameters of 5.75cmat 100kgNha^{-1} of nitrogen with micronutrients formulation.

When the analysis was compared with each other, the contrast showed a highly significant difference ($P< 0.05$) between the quality protein maize and the normal maize varieties in the years of study and the combined with addition of micronutrients. The two QPM varieties also were significantly different from each other with added micronutrients. Comparing the cob diameter, the combined analysis showed significant difference ($P< 0.05$) between the QPM and normal varieties without micronutrients application while there was no significant difference between the quality protein maize varieties.

Table 4.18: Effects of treatments on maize varieties cob length and cob diameter

Variety	Nitrogen level ($kgha^{-1}$)	Cob length (cm)						Cob diameter (cm)					
		Micronutrient (gha^{-1})						Micronutrient (gha^{-1})					
		2008		2009		Combined		2008		2009		Combined	
		-M	+M	-M	+M	-M	+M	-M	+M	-M	+M	-M	+M
SAMMAZ 14	0	7.61	9.53	13.50	13.23	10.56	11.38	3.12	3.47	6.47	6.10	4.79	4.79
	50	11.23	10.47	15.57	14.17	13.40	12.32	4.06	3.74	6.63	6.43	5.35	5.09
	100	14.71	14.83	16.53	17.57	15.62	15.47	4.35	4.37	7.03	6.70	5.67	5.39
	150	14.45	13.36	17.37	17.37	16.10	15.91	4.30	4.28	7.77	6.80	5.59	6.06
Mean		12.00	12.05	15.74	15.05	13.87	14.15	3.95	3.97	6.98	6.51	5.47	5.22
SUSUMA													
	0	7.99	7.09	13.10	14.43	10.55	10.76	3.19	2.77	6.30	6.80	6.55	4.79
	50	8.75	9.43	14.30	15.40	11.53	12.42	3.41	3.25	6.50	6.47	4.96	4.86
	100	12.05	11.89	15.73	16.83	13.89	14.36	3.93	3.80	7.03	7.27	5.71	5.77
	150	12.43	13.09	17.00	17.50	14.72	15.29	3.17	4.14	7.60	7.07	5.10	5.44
Mean		10.31	10.38	15.03	16.04	12.7	13.21	3.57	3.85	6.86	6.90	5.63	5.14
SAMMAZ 12	0	9.20	10.85	13.90	12.43	11.55	11.64	3.22	3.52	6.23	6.20	4.73	4.45
	50	11.19	10.51	14.83	14.07	13.01	12.29	3.64	3.78	6.23	6.20	4.94	5.23
	100	14.21	14.21	16.40	16.93	14.95	15.31	3.97	3.76	6.60	6.57	5.29	5.75
	150	12.11	12.97	16.00	16.60	14.06	14.36	4.19	4.23	6.70	6.07	5.45	5.43
Mean		11.68	12.14	15.28	15.00	13.48	13.31	3.00	3.75	6.44	6.26	5.10	5.22
SAMMAZ	0	10.67	9.10	16.20	13.70	13.44	11.40	3.52	3.12	6.53	5.77	5.03	4.45
	50	8.51	12.89	15.53	16.63	12.02	14.76	3.19	3.75	6.77	6.70	5.42	5.23
	100	12.33	13.85	18.47	16.37	14.36	14.95	3.91	4.09	6.40	6.90	5.21	5.75
	150	12.71	15.77	15.67	16.27	14.06	15.39	4.06	4.54	6.50	6.80	4.53	5.45
Mean		11.06	12.90	13.71	15.74	13.71	13.87	3.67	3.88	6.55	6.54	5.05	5.22
Mean		11.49		15.61		13.47		3.75		6.63		5.20	
SE ±		1.11		0.90		0.37		0.32		0.33		0.13	
CV(%)		16.66		9.99		13.31		3.00		8.65		9.65	
V x N		NS		NS		NS		NS		NS		NS	
CONTRAST													
QPM vs Normal		NS	**	NS	**	NS	**	**	**	**	**	**	NS
QPM_A vs QPM_B		NS	*	NS	*	NS	*	NS	*	NS	NS	NS	NS

4.11 Main Response of Plant Height and 1000 Grain Weight of Maize Varieties to Nitrogen Fertilizer

The combined analysis of the plant height showed increase in plant height as nitrogen rates increases as presented in Table 4.19. Plots with highest nitrogen rate (150kg Nha^{-1}) produced taller plants (213.5cm) than lower nitrogen levels. The minimum plant height (150.5cm) was obtained with 50kgha^{-1} nitrogen rate. Although the interaction between nitrogen rates and the varieties was not significant at ($p< 0.05$), plant height increased as nitrogen fertilizer rates increased.

Increase in 1000 grain weight also followed the same pattern with the plant height. The combined analysis showed highest weight of grain was recorded by SAMMAZ 14 (224.52gha^{-1}) at 100kgNha^{-1} while other varieties SUSUMA recorded (220.73gha^{-1}), SAMMAZ 12 (211.32gha^{-1}) and SAMMAZ 11 (199.42gha^{-1}) had their 1000 grain yield at the highest rate of nitrogen applied (150kgha^{-1}) though the differences were not significant.

The comparisons between the QPM and the normal maize and between the quality protein maize A and quality protein maize B were highly significant ($P< 0.05$) both in plant height and grain weight. The QPM had significantly taller plant than the normal maize and QPM_A was significantly taller than QPM_B. The 1000 grain weight showed the same trend as in plant height when compared.

4.11.1 The effect of micronutrients on maize plant height and 1000 grain weight

SAMMAZ 14 and SUSUMA had the tallest plant (201.74cm), and (203.82cm) at micronutrients application. The interaction between the varieties and micronutrients applied was not significantly different at ($P< 0.05$) as presented in Table 4.20. The variations of the 1000 grain weight were not consistent with treatment in the years of experimentation although SAMMAZ 14 variety showed superior performance (205.21gha^{-1})with micronutrients as seen in Table 4.20.

Table 4.19: Effect of nitrogen rate on maize plant height and 1000 grain weight

Variety	Nitrogen level ($kgha^{-1}$)	Plant height (cm)			1000 grain weight (gha^{-1})		
		2008	2009	Combined	2008	2009	Combined
SAMMAZ 14	0	175.02	182.50	178.80	183.84	180.84	182.30
	50	185.25	199.17	192.20	191.78	196.84	194.31
	100	200.10	215.00	207.60	226.24	222.69	224.52
	150	198.23	213.33	205.80	216.45	219.99	218.21
Mean		189.65	202.5	192.25	204.58	205.07	204.83
SUSUMA							
	0	189.15	194.17	191.70	172.05	189.83	175.41
	50	183.33	188.33	185.80	166.69	188.66	177.72
	100	206.85	211.67	209.30	166.39	210.02	188.24
	150	212.00	215.00	213.50	209.75	231.61	220.73
Mean		197.83	202.29	139.11	178.72	205.03	150.38
SAMMAZ 12	0	153.18	155.83	154.50	152.59	185.19	168.92
	50	148.50	152.50	150.50	175.49	188.98	182.20
	100	165.95	170.83	168.40	220.11	188.06	204.14
	150	159.85	175.83	167.80	223.17	199.38	211.32
Mean		156.87	163.75	160.31	192.84	190.40	191.65
SAMMAZ 11	0	197.12	199.17	198.20	153.01	167.40	160.20
	50	195.25	199.17	197.20	172.39	169.37	170.91
	100	205.85	210.83	208.30	201.88	196.91	199.42
	150	210.25	214.17	212.20	193.33	183.65	188.51
Mean		202.12	205.84	203.98	180.15	179.33	179.75
Mean		193.59			183.75		194.96
SE ±		7.07			13.05		15.47
CV(%)		12.65			18.87		20.04
V x N		NS			NS		NS
CONTRAST							
QPM vs Normal		**	**	**	**	**	**
QPM_A vs QPM_B		**	**	**	**	**	**
With vs Without M/nut		NS	NS	NS	NS	NS	NS

4.20: The effect of micronutrients on maize varieties plant height and 1000 grain weight

Variety	M/nuts	Plant Height (cm)			1000 grain weight (gha^{-1})		
		2008	2009	Combined	2008	2009	Combined
SAMMAZ 14							
	-M	196.57	201.67	199.12	204.79	204.12	204.40
	+M	200.15	203.33	201.74	204.36	206.06	205.21
SUSUMA							
	-M	188.25	193.75	191.00	181.49	201.62	191.56
	+M	196.80	210.83	203.82	175.94	208.43	192.19
SAMMAZ 12							
	-M	160.35	164.17	162.26	201.43	192.03	197.22
	+M	158.30	163.33	160.82	184.26	188.77	186.52
SAMMAZ 11							
	-M	212.50	213.33	212.92	183.17	173.23	178.20
	+M	200.75	198.33	199.54	177.13	185.44	181.29
Mean		190.59	193.59	184.107.	189.07	194.96	
SE±		6.45	7.07	16	10.94	4.89	
CV (%)		10.95	12.65	13.47	20.04	8.68	
V xM		NS	NS	NS	NS	NS	

4.11.2 Interaction of N levels, micronutrients application and varieties on plant height and 1000 grain weight

4.11.2.1 Quality protein maize varieties

Plant height was observed to increase with increase in nitrogen application up to 150kgha^{-1}N for the quality protein maize varieties (Table 4.21). The increase in plant height with the highest rate of nitrogen and with micronutrients application was higher in the quality protein maize than in the normal maize. SAMMAZ 14 (QPM) was taller than the SUSUMA variety (QPM) and both varieties had positive response to increase in nitrogen levels up to 150kgha^{-1} and micronutrients. SAMMAZ 14 and SUSUMA were taller by 13.72% and 10.68% respectively at 150kgNha^{-1} than the control. SAMMAZ 14 produced the highest 1000 grain-weight of 295.0g at 100kgNha^{-1} while SUSUMA had 215.5g at 150kgNha^{-1}

4.11.2.2 Normal maize varieties

Effects of the factors on the normal maize varieties showed that SAMMAZ 11 produced the taller plant (216.1cm) with addition of micronutrients at the highest nitrogen levels of 150kgha^{-1} while SAMMAZ 12 was 180.5cm tall with micronutrients. The plant heights was not significantly different at ($P<0.05$) from each other but the combined analysis showed that SAMMAZ 12 and SAMMAZ 11 produced the highest plant height at the highest N application than the control.

When the data was averaged over the two years with increased rate of nitrogen and micronutrients, response of the 1000 grain weight of the varieties showed SAMMAZ 11 variety producing the lowest yield (206.5gha^{-1}) at100kgha^{-1} nitrogen with micronutrients.

In plant height, the contrast between quality protein maize and normal maize when combined was highly significant at ($P< 0.05$) while between quality protein maize A and B was significant ($P< 0.05$) with addition of micronutrients. The contrast analysis showed a highly significant ($P< 0.05$) difference in the combined analysis in one thousand grain weight

between the quality protein maize and the normal maize while there was no significant difference between the quality protein A and B.

4.12 The Effect of Treatments on Selected Chemical Properties of the Soil

4.12.1 Soil pH

Soil pH decreased with the application of nitrogen fertilizer and with added micronutrients in the two years of trials. The pH values ranged from 5.4- 6.6 (Table 4.22a).

4.12.2 Available phosphorus

Phosphorus application was not varied the available P content was observed to be low to moderate with the range of 9.33-12.97mgPkg^{-1} with increase in N fertilizer with no micronutrients application and was 10.38-12.45mgPkg^{-1}with addition of micronutrients at the highest level of nitrogen.

4.12.3 Organic carbon

The effects of treatment factors on organic matter as shown in Table 4.22b. The organic carbon content of the soils, had combined range of 0.53-0.75 with no micronutrients application and a range of 0.61- 0.91 with added micronutrients.

4.12.4 Total nitrogen in soil

The effects of nitrogen fertilizer on the nitrogen content of the soils are presented in Table 4.22b. Results showed that soil nitrogen was highest at the highest rate of nitrogen 150kgNha^{-1} applied. Combining the analysis, the N ranged from 0.04% - 0.07% with no micronutrients application and 0.04- 0.06% with addition of micronutrients.

Table 4.21: Effects of treatments and maize varieties on plant height and thousand grain weight

Variety	Nitrogen level($kgha^{-1}$)	Plant height (cm)						1000 grain weight (g)					
		Micronutrient (gha^{-1})						Micronutrient (gha^{-1})					
		2008		2009		Combined		2008		2009		Combined	
		-M	+M	-M	+M	-M	+M	-M	+M	-M	+M	-M	+M
SAMMAZ 14	0	175.0	190.0	182.0	198.5	158.3	172.9	173	188	180	187	176.5	187.5
	50	220.0	178.3	204.7	177.1	196.0	180.7	200	192	200	183	200.0	187.5
	100	205.0	220.0	215.6	222.2	201.6	221.1	224	221	213	238	218.5	295.0
	150	206.7	225.0	213.3	225.4	203.9	209.8	225	214	223	209	224.0	211.5
SUSUMA	0	173.3	200.0	178.5	206.6	159.7	160.3	189	190	174	169	181.5	179.5
	50	188.3	203.3	196.5	209.8	173,7	184.0	188	188	168	164	178.0	176.0
	100	205.3	215.0	215.4	219.5	190.3	197.2	193	226	165	166	179.0	196.0
	150	215.7	216.7	226.2	226.2	220.9	216.1	234	228	216	203	225.0	215.5
SAMMAZ 12	0	150.0	151.7	155.2	156.9	152.6	165.9	194	175	169	135	181.5	155.5
	50	160.0	155.0	168.9	160.2	164.5	158.8	196	181	178	172	187.0	176.5
	100	170.0	168.3	176.0	173.4	173.0	169.7	187	188	221	203	204.0	195.5
	150	173.3	181.7	181.5	178.2	177.4	180.5	189	209	236	224	212.5	216.5
SAMMAZ 11	0	206.7	191.7	211.7	200.5	209.2	159.2	167	167	169	136	168.0	151.5
	50	215.0	183.3	210.7	192.4	211.9	184.8	163	174	174	170	168.5	172.0
	100	213.2	205.0	219.1	214.7	216.0	196.2	187	206	196	207	191.5	206.5
	150	208.0	225.0	213.8	230.1	210.9	202.4	174	192	192	194	183.0	193.0
Mean		193.5		183.6		184.62		194.96		192.92		190.42	
SE±		14.14		4.57		5.52		9.77		6.25		6.44	
CV (%)		2.65		12.20		14.65		8.68		15.87		16.57	
V*N*MN		NS		NS		NS		NS		NS		NS	
CONTRAST													
QPM vs normal		NS	**	NS	**	NS	**	**	**	NS	**	**	**
QPM_A vs QPM_B		NS	NS	NS	**	NS	*	NS	NS	NS	NS	NS	NS

Table 4.22a: Effect of nitrogen and micronutrients on selected soil chemical properties (pH, and Available Phosphorus)

Treatments	pH_{H_2O}						Available P ($mgkg^{-1}$)					
	2008		2009		Combined		2008		2009		Combined	
	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1
SAMMAZ 14												
0	6.40	6.27	6.67	6.40	6.50`	6.47`	8.30	11.3	13.9	11.9	11.1	11.57
50	6.33	6.57	6.63	6.43	6.45	6.47	11.60	9.50	10.4	8.6	10.98	9.05
100	6.27	6.27	6.60	6.57	6.42	5.42	13.40	17.2	11.5	12.8	13.63	14.98
150	6.23	6.53	6.60	6.63	6.42	6.50	10.70	9.8	15.7	10.7	13.20	10.24
Mean	6.31	6.43	6.60	6.50	6.53	6.47	10.98	11.94	12.89	10.98	10.52	11.46
SUSUMA												
0	6.53	6.27	6.57	6.70	6.47	6.48	12.0	9.8	13.6	11.5	13.04	10.65
50	6.37	6.43	6.27	6.73	6.40	6.58	13.7	11.2	10.7	11.3	11.53	11.3
100	6.37	5.97	6.57	6.50	6.45	6.23	8.9	8.0	10.7	6.2	9.76	7.10
150	6.30	6.50	6.60	6.53	6.47	6.52	12.4	8.6	11.3	12.5	12.46	10.6
Mean	6.39	6.29	6.50	6.62	6.49	6.45	11.84	9.41	11.56	9.49	10.75	9.45
SAMMAZ 12												
0	6.40	6.50	6.57	6.66	6.48	6.60	10.4	9.5	9.8	10.4	10.79	9.95
50	6.80	6.37	6.57	6.47	6.55	6.42	8.9	10.7	8.3	11.6	8.60	11.13
100	6.40	6.27	6.53	6.60	6.47	6.43	9.5	10.1	13.6	13.6	10.68	11.85
150	6.13	6.57	6.53	6.70	6.33	6.62	11.8	14.2	11.9	9.8	10.81	12.02
Mean	6.43	6.43	6.48	6.61	6.38	6.52	10.14	11.12	10.30	11.35	11.05	11.23
SAMMAZ 11												
0	6.50	6.23	6.67	6.70	6.58	6.42	8.9	8.5	12.4	11.3	10.65	9.90
50	6.50	6.33	6.57	6.43	6.53	6.47	9.5	15.4	9.5	10.9	9.49	12.92
100	6.40	6.50	6.43	6.67	6.45	6.45	10.6	11.6	10.4	8.9	10.50	10.24
150	6.30	6.50	6.60	6.63	6.42	6.52	12.2	14.5	13.6	12.5	12.90	13.50
Mean	6.43	6.39	6.57	6.53	6.50	6.46	10.29	12.52	11.48	10.75	11.45	11.64
Mean	6.39	6.39	6.54	6.57	6.48	6.48	10.81	11.25	11.56	10.64	10.94	10.94
SE±	0.05	0.05	0.04	0.05	0.05	0.05	0.73	0.60	0.71	0.68	0.78	0.74
CV	4.39	4.17	2.76	3.09	4.07	4.07	33.03	26.12	30.17	30.92	33.32	33.32
CONTRAST												
QPM vs Normal	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
QPMA vs QPMB	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.22b: Effect of nitrogen and micronutrients on selected soil chemical properties (Organic carbon and Total nitrogen)

Nitrogen ($kgha^{-1}$)	Organic Carbon gkg^{-1}						Total Nitrogen gkg^{-1}					
	2008		2009		Combined		2008		2009		Combined	
	M_0	M_1	M_0	M_1	M_o	M_1	M_0	M_1	M_0	M_1	M_0	M_1
SAMMAZ 14												
0	0.83	.78	0.63	0.52	0.70	0.65	0.04	0.04	0.05	0.05	0.06	0.06
50	0.80	0.79	0.63	0.55	0.72	0.67	0.06	0.05	0.07	0.05	0.07	0.05
100	0.69	0.81	0.57	1.0	0.67	0.91	0.06	0.05	0.06	0.04	0.05	0.04
150	0.84	0.71	0.64	0.57	0.74	0.64	0.06	0.07	0.06	0.04	0.06	0.04
Mean	0.79	0.77	0.62	0.66	0.72	0.72	0.05	0.05	0.06	0.05	0.06	0.05
SUSUMA												
0	0.62	0.84	0.53	0.63	0.53	0.60	0.04	0.04	0.05	0.05	0.05	0.04
50	0.83	0.89	0.64	0.58	0.74	0.74	0.06	0.06	0.04	0.05	0.04	0.06
100	0.63	0.77	0.47	0.64	0.55	0.64	0.05	0.05	0.05	0.05	0.05	0.05
150	0.73	0.69	0.60	0.68	0.66	0.69	0.05	0.05	0.06	0.04	0.06	0.04
Mean	0.70	0.76	0.56	0.63	0.70	0.70	0.05	0.05	0.05	0.05	0.05	0.05
SAMMAZ 12												
0	0.80	0.75	0.60	0.71	0.74	0.73	0.04	0.04	0.05	0.06	0.04	0.06
50	0.78	0.69	0.63	0.47	0.71	0.69	0.05	0.06	0.05	0.05	0.05	0.05
100	0.76	0.77	0.60	0.57	0.68	0.66	0.04	0.05	0.05	0.05	0.04	0.05
150	0.86	0.91	0.74	0.79	0.77	0.85	0.06	0.06	0.06	0.05	0.05	0.06
Mean	0.80	0.78	0.65	0.63	0.70	0.70	0.05	0.06	0.05	0.05	0.05	0.05
SAMMAZ 11												
0	0.76	0.63	0.62	0.60	0.70	0.61	0.04	0.03	0.06	0.06	0.06	0.06
50	0.69	0.69	0.54	0.67	0.62	0.69	0.05	0.05	0.06	0.06	0.05	0.06
100	0.78	0.91	0.60	0.66	0.69	0.78	0.06	0.05	0.05	0.04	0.04	0.04
150	0.88	0.85	0.63	0.56	0.75	0.71	0.06	0.06	0.04	0.04	0.05	0.04
Mean	0.78	0.77	0.60	0.62	0.70	0.69	0.05	0.05	0.05	0.05	0.05	0.05
Mean	0.77	0.77	0.61	0.64	0.70	0.70	0.05	0.05	0.05	0.05	0.05	0.05
SE±	0.02	0.03	0.03	0.05	0.04	0.04	0.003	0.003	0.003	0.004	0.003	0.003
CV	14.72	19.96	26.28	32.03	28.78	28.78	32.39	35.34	23.70	29..14	32.13	32.13
CONTRAST												
QPM vs Normal	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
QPMA vs QPMB	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.13 The Effects of Nitrogen rates and Micronutrients on the Exchangeable Bases of the Cropped Soil

4.13.1 Ca content in soil.

The calcium content ranged from (3.23-3.93cmolkg^{-1}) with added micronutrients while the range of 3.15-4.47cmolkg^{-1} was obtained with no micronutrients application (Table 4.23a).

4.13.2 Magnesium content in soil

Magnesium contents of the soils ranged from 2.00-2.63cmolkg^{-1} with added micronutrients and 2.02- 2.98cmolkg^{-1} without micronutrients application.

4.13.3 Potassium content of the cropped soil

The combined potassium content of the soil ranged from 0.23-0.42 cmolkg^{-1} (Table 4.23b) with the addition of micronutrients and 0.25- 0.32cmolkg^{-1} with no micronutrients application.

4.13.4 Sodium content of soil

The sodium content of the soil ranged from 0.40-0.55cmolkg^{-1} with addition of micronutrients and 0.42-0.61cmolkg^{-1} with no micronutrients application.

Table 4.23a: Effects of nitrogen and micronutrients on exchangeable calcium and magnesium of the soil

Treatments	Exchangeable Calcium						Exchangeable Magnesium					
	← (Cmolkg^{-1})						→					
	2008		2009		Combined		2008		2009		Combined	
	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1
SAMMAZ 14												
0	3.33	3.87	3.50	3.97	3.42	3.92	2.13	2.67	2.50	2.53	2.32	2.60
50	3.27	3.63	4.47	4.13	3.87	3.88	1.93	2.27	2.93	2.40	2.43	2.33
100	3.73	3.07	3.40	3.40	3.57	3.23	2.13	2.07	2.23	2.80	2.18	2.43
150	2.93	3.07	3.37	3.40	3.15	3.23	1.63	1.80	2.40	2.20	2.02	2.00
Mean	3.32	3.41	3.68	3.73	3.50	3.57	1.96	2.20	2.52	2.48	2.24	2.34
SUSUMA												
0	3.67	4.33	3.70	3.53	3.68	3.93	2.40	2.53	2.40	2.47	2.40	2.50
50	3.00	3.73	3.73	4.00	3.37	3.87	2.00	2.20	2.47	2.73	2.23	2.47
100	4.87	3.73	4.0	3.67	4.43	3.70	2.90	2.33	3.07	2.67	2.98	2.50
150	3.27	3.47	3.37	3.70	4.40	3.58	2.20	1.93	2.40	2.67	2.30	2.30
Mean	3.70	3.82	3.70	3.73	3.70	3.77	2.38	2.25	2.58	2.63	2.48	2.44
SAMMAZ 12												
0	3.47	3.20	3.07	3.33	3.27	3.26	1.87	2.07	2.07	2.37	1.97	2.22
50	3.27	2.87	3.73	4.20	3.50	3.53	2.20	2.00	2.37	2.90	2.57	2.45
100	4.60	3.57	4.33	3.80	4.47	3.68	2.40	2.27	3.07	2.67	2.50	2.47
150	3.40	3.60	3.87	4.13	3.63	3.87	1.97	2.27	2.40	3.0	2.25	2.63
Mean	3.68	3.31	3.75	3.87	3.72	3.59	2.11	2.15	2.41	2.73	2.26	2.44
SAMMAZ 11												
0	3.33	3.67	4.07	4.00	3.70	3.83	1.93	2.27	2.73	2.63	2.23	2.15
50	4.47	3.33	4.13	3.87	4.30	3.60	2.80	2.07	2.33	2.47	2.28	2.27
100	3.60	3.47	3.73	4.13	3.37	3.80	2.73	2.00	2.27	2.67	2.50	2.30
150	3.40	3.20	3.90	3.53	3.65	3.37	2.13	2.07	2.60	2.23	2.37	2.45
Mean	3.70	3.42	3.96	3.88	3.83	3.65	2.40	2.10	2.48	2.48	2.44	2.29
Mean	3.60	3.49	3.77	3.80	3.69	3.64	2.21	2.18	2.50	2.58	2.35	2.38
SE+												
CV (%)	23.7	24.5	20.2	14.5	123.6	20.7	27.7	26.8	24.1	20.7	28.4	27.8
CONTRAST												
QPM vs Normal	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
QPM_A vs QPM_B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.23b:Effects of nitrogen and micronutrients on exchangeable potassium and sodium of the soil

Treatments	Exchangeable Potassium($Cmolkg^{-1}$)						Exchangeable Sodium					
	2008		2009		Combined		2008		2009		Combined	
	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1
SAMMAZ 14												
0	0.31	0.32	0.33	0.51	0.32	0.42	0.46	0.47	0.54	0.48	0.50	0.47
50	0.30	0.25	0.30	0.32	0.30	0.29	0.38	0.45	0.50	0.57	0.44	0.51
100	0.28	0.31	0.27	0.30	0.28	0.31	0.42	0.40	0.62	0.60	0.52	0.50
150	0.36	0.23	0.28	0.27	0.22	0.25	0.50	0.50	0.49	0.54	0.50	0.52
Mean	0.31	0.28	0.30	0.35	0.30	0.31	0.44	0.46	0.54	0.54	0.49	0.50
SUSUMA												
0	0.29	0.32	0.32	0.35	0.31	0.35	0.47	0.50	0.50	0.55	0.49	0.52
50	0.26	0.26	0.27	0.31	0.27	0.29	0.50	0.40	0.44	0.41	0.47	0.40
100	0.28	0.32	0.27	0.24	0.27	0.28	0.52	0.43	0.49	0.65	0.50	0.54
150	0.29	0.25	0.23	0.28	0.26	0.26	0.42	0.40	0.51	0.59	0.47	0.50
Mean	0.28	0.30	0.27	0.30	0.28	0.30	0.48	0.43	0.49	0.55	0.48	0.49
SAMMAZ 12												
0	0.33	0.31	0.31	0.28	0.32	0.32	0.46	0.46	0.37	0.63	0.42	0.55
50	0.34	0.27	0.23	0.26	0.28	0.27	0.46	0.47	0.52	0.43	0.47	0.45
100	0.25	0.29	0.24	0.28	0.25	0.29	0.48	0.57	0.46	0.44	0.47	0.51
150	0.26	0.37	0.32	0.23	0.29	0.30	0.36	0.41	0.81	0.53	0.59	0.47
Mean	0.30	0.31	0.28	0.27	0.29	0.29	0.44	0.48	0.54	0.51	0.49	0.49
SAMMAZ 11												
0	0.23	0.31	0.34	0.32	0.32.	0.31	0.43	0.43	0.55	0.59	0.49	0.51
50	0.29	0.27	0.26	0.27	0.28	0.27	0.51	0.44	0.61	0.58	0.56	
100	0.26	0.27	e0.29	0.25	0.28	0.26	0.57	0.33	0.64	0.64	0.61	
150	0.31	0.23	0.33	0.23	0.29	0.23	0.50	0.51	0.46	0.45	0.48	0.48
Mean	0.27	0.27	0.31	0.27	0.29	0.27	0.50	0.43	0.57	0.57	0.53	0.50
Mean	0.29	0.29	0.29	0.29	0.29	0.29	0.47	0.45	0.53	0.54	0.50	0.49
SE+												
CV (%)	21.2	17.1	15.1	42.4	23.2	38.5	20.4	22.2	27.9	20.1	27.8	23.0
QPM vs Normal	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
QPM_A vs QPM_B	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.14 Effect of Nitrogen levels on Soil Micronutrients Content of the Cropped Soils

4.14.1 Copper

The effects of nitrogen rates on soil micronutrients content showed the combined analysis had the highest copper content of the soil in the range of 0.82mgkg^{-1}- 0.92mgkg^{-1}(Table 4.24a).

4.14.2 Zinc

The soil zinc content of the cropped soils was found to increase consistently with increase in nitrogen with addition of micronutrients. The combined analysis showed zinc content in the soil ranged from 6.01- 9.17 mgkg^{-1} with addition of micronutrients while the range was 6.02-8.15 mgkg^{-1} with no micronutrients application.

4.14.3 Iron

The soil iron content of the cropped soils ranged from 8.09-12.38mgkg^{-1} with addition of micronutrients and 8.33-15.71mgkg^{-1}with no micronutrients.

4.14.4 Molybdenum

There was no progressive trend of molybdenum content with nitrogen rates (Table 4.25b). The range was 8.91-.15.09 mgkg^{-1} with addition of micronutrients and 10.98-14.47 mgkg^{-1}.

4.14.5 Boron

Boron content increased as nitrogen rate increased from the control to the highest level of nitrogen supplied with addition of micronutrients. The range was 0.16 mgkg^{-1}-0.24 mgkg^{-1} while with no micronutrients the range was 0.12mgkg^{-1}-0.17mgkg^{-1} (Table 4.25b).

Table 4.24a: Effects of nitrogen and micronutrients on copper and zinc concentrations of the cropped soils

Nitrogen kgha^{-1}	Copper						Zinc					
	mgkg^{-1}											
	2008		2009		Combined		2008		2009		Combined	
	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1
SAMMAZ 14												
0	0.90	0.73	0.95	0.80	0.93	0.77	7.41	4.63	10.93	7.39	6.20	6.01
50	0.78	0.85	1.22	0.82	1.00	0.83	4.44	4.07	7.96	8.89	6.21	6.48
100	0.85	0.63	0.70	0.97	0.78	0.80	4.82	6.69	8.89	7.41	6.85	7.05
150	0.68	0.72	1.05	0.93	0.87	0.83	6.85	4.26	7.59	10.74	7.22	7.50
Mean	0.80	0.73	0.94	0.88	0.89	0.88	5.88	4.91	8.19	8.61	7.36	8.61
SUSUMA												
0	0.63	0.47	0.82	0.88	0.73	0.68	5.93	4.81	7.79	8.15	6.86	6.48
50	0.55	0.72	0.93	1.07	0.74	0.89	4.81	4.26	9.44	8.70	7.13	6.48
100	0.45	0.62	0.90	1.00	0.68	0.81	5.74	5.57	10.57	8.52	8.15	7.04
150	0.52	0.75	0.88	1.02	0.70	0.88	6.48	5.37	7.96	7.04	7.22	9.17
Mean	0.54	0.64	1.13	0.99	0.71	0.99	5.74	5.00	8.47	8.10	7.34	8.10
SAMMAZ 12												
0	0.82	0.68	0.97	0.98	0.89	0.83	6.29	5.37	5.74	7.42	6.02	6.39
50	0.53	0.50	1.28	0.87	0.91	0.68	3.89	5.74	9.63	7.78	6.76	6.76
100	0.48	1.07	0.85	1.05	0.67	1.06	5.19	8.52	5.93	7.14	5.56	7.83
150	0.06	0.63	0.90	0.98	0.75	0.81	3.70	4.99	8.52	7.59	6.11	6.29
Mean	0.61	0.72	0.92	0.97	0.80	0.97	4.77	6.16	8.10	7.48	6.11	7.48
SAMMAZ 11												
0	0.92	0.47	1.02	1.02	0.97	0.74	4.63	5.56	10.37	9.26	7.50	7.41
50	0.50	0.90	1.08	1.13	0.79	1.02	5.37	4.07	6.85	10.56	6.11	7.32
100	0.87	0.82	1.22	0.72	1.04	0.77	3.89	6.67	5.00	10.37	4.45	8.52
150	0.92	0.58	0.83	0.83	0.88	0.71	6.29	5.37	8.52	8.15	7.41	6.76
Mean	0.80	0.69	0.92	0.93	0.92	0.72	5.05	5.42	8.15	9.58	6.37	9.58
Mean	0.69	0.69	0.98	0.94	0.83	0.93	5.36	5.37	8.23	8.44	6.79	6.91
SE-+	0.21	0.15	0.23	0.24	0.22	0.21	1.83	1.67	2.44	2.44	2.16	2.08
CV %	36.82	27.00	28.74	30.81	32.32	31.72	41.73	37.76	36.27	35.38	39.01	36.90
CONTRAST												
QPM vs normal	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
QPA_A vs QPM_B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.24b: Effects of nitrogen and micronutrients on iron and boron concentrations of the cropped soils

Nitrogen ($kgha^{-1}$)	Iron						Molybdenum						Boron					
	2008		2009		Combined		2008		2009		Combined		2008		2009		Combined	
	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_o	M_i	M_o	M_i	M_o	M_i	M_o	M_i	M_o	M_i
SAMMAZ 14																		
0	10.95	12.38	9.05	10.47	10.00	10.47	14.48	10.47	14.46	12.11	14.47	12.11	0.11	0.12	0.13	0.19	0.12	0.19
50	12.38	10.95	10.09	10.95	11.24	10.95	13.86	10.16	13.23	13.24	13.54	13.24	0.14	0.12	0.14	0.20	0.14	0.20
100	12.38	12.86	10.47	9.99	11.43	10.00	10.26	13.55	11.70	15.09	10.98	15.09	0.12	0.15	0.19	0.16	0.15	0.16
150	12.86	10.95	9.52	12.38	11.19	12.38	12.24	13.96	13.55	14.15	12.89	14.15	0.13	0.09	0.19	0.18	0.16	0.18
Mean	12.14	11.78	10.12	10.95	10.96	10.95	12.71	12.04	13.26	13.65	12.97	13.65	0.13	0.12	0.18	0.18	0.14	0.18
SUSUMA																		
0	10.47	10.95	10.00	6.66	10.24	6.66	11.70	12.62	12.01	13.86	11.86	13.86	0.11	0.12	0.19	0.16	0.16	0.16
50	14,76	10.46	12.38	11.90	13.57	11.90	13.22	15.39	14.47	14.26	13.85	14.26	0.14	0.14	0.19	0.17	0.16	0.17
100	11.89	9.04	14.29	8.09	13.09	8.09	14.47	15.09	14.15	8.91	14.31	8.91	0.12	0.11	0.21	0.14	0.17	0.14
150	8.09	13.34	8.57	10.95	8.33	10.95	13.84	9.55	15.09	11.70	14.47	11.70	0.12	0.14	0.18	0.16	0.15	0.16
Mean	11.31	10.95	11.21	9.40	11.31	9.40	13.31	13.17	13.65	12.18	13.62	12.18	0.12	0.13	0.19	0.16	0.16	0.16
SAMMAZ 12																		
0	13.33	11.90	9.52	8.57	11.43	8.57	15.38	12.63	12.63	14.26	14.00	14.26	0.12	0.14	0.18	0.15	0.15	0.15
50	6.19	19.05	10.48	10.48	8.33	10.48	12.93	11.99	13.03	12.61	12.98	12.61	0.13	0.16	0.19	0.24	0.16	0.24
100	11.43	14.29	10.00	9.52	10.72	9.52	14.78	14.17	13.24	10.78	14.01	10.78	0.15	0.11	0.19	0.22	0.17	0.22
150	19.04	10.47	12.38	11.43	15.71	11.43	12.32	12.32	14.47	12.01	13.39	12.01	0.11	0.14	0.18	0.13	0.14	0.13
Mean	12.49	13.93	10.72	9.99	11.55	10.00	13.85	12.78	13.57	12.42	13.59	12.42	0.13	0.14	0.19	0.19	0.16	0.19
SAMMAZ 11																		
0	9.04	9.52	11.91	7.14	10.48	7.14	11.09	13.86	13.97	11.09	12.52	11.09	0.12	0.11	0.19	0.20	0.16	0.20
50	11.90	13.33	11.90	11.42	11.90	11.42	9.55	12.63	13.86	10.47	11.70	10.47	0.10	0.11	0.23	0.19	0.17	0.19
100	11.43	14.76	8.10	8.57	9.77	8.57	9.55	14.47	15.19	12.01	12.37	12.01	0.13	0.12	0.17	0.22	0.15	0.22
150	9.04	10.48	10.00	9.52	9.52	9.52	12.61	11.99	13.55	11.07	13.07	11.07	0.16	0.13	0.26	0.17	0.21	0.17
Mean	5.05	12.02	10.12	9.16	10.42	9.16	10.69	13.24	14.17	11.16	12.42	11.16	0.13	0.12	0.20	0.19	0.17	0.19
Mean	11.58	12.17	10.54	9.88	11.06	11.02	12.64	12.80	13.66	12.35	52.83	12.58	0.13	0.12	0.19	0.18	0.16	0.15
SE-+	3.42	3.70	2.81	2.92	3.63	3.67	2.72	2.76	2.59	2.61	2.81	2.85	0.02	0.02	0.04	0.05	0.05	0.04
CV%	36.16	37.19	32.62	36.24	40.18	40.81	26.35	26.36	23.29	25.89	37.07	27.71	24.18	22.29	28.23	36.09	35.54	35.01
CONTRAST																		
QPM vs normal	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
QPA_A vs QPM_B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.15 The Effects of Nitrogen and Micronutrients on N, P, K, Ca and Mg Contents of the Maize Leaves

4.15.1 Nitrogen concentration of the maize leaf

The nitrogen concentration of the index leaf of the maize plant at harvest was evaluated. The nitrogen concentrations ranged from 0.96-1.44% in the combined analysis with no micronutrients and 0.81-1.28% with addition of micronutrients in SAMMAZ 14 (QPM) as presented in Table 4.25a. The nitrogen concentration of the index leaf of SUSUMA variety ranged from 0.90-1.13% with no micronutrients and 0.74-1.54% with additions of micronutrient. The contrast analysis between the QPM_A and QPM_B was not significantly different from each other. The concentration of nitrogen ranged from 0.99-1.99% in the normal varieties with no micronutrients and 0.92-1.18% with addition of micronutrients in SAMMAZ 12 while the nitrogen concentration of the index leaf of SAMMAZ 11 variety ranged from 1.11.-1.19% with no micronutrients and 0.86-1.09% with additions of micronutrient as presented in Table 4.25a. The contrast analysis showed a non significant difference between the quality protein maize and normal maize.

4.15.2 Phosphorus

The phosphorus concentration of the leaves ranged from 0.08-0.12% with no micronutrients addition and 0.09-0.11% with added micronutrients in SAMMAZ 14 while the concentration was 0.08-0.11% with or without micronutrients in SUSUMA variety.

Phosphorus concentration ranged from 0.99-1.11% when the analysis was combined with no micronutrients and 0.08-1.11% with addition of micronutrients in SAMMAZ 12 while in SAMMAZ 11 the P concentrations was 0.08-0.12% and 0.09-0.10% without micronutrients and with addition of micronutrients as presented in Table 4.25a. The contrast analysis showed a non significant difference between the quality protein maize and normal maize and between the QPM_A and QPM_B.

4.15.3 Potassium

The combined analysis showed the potassium concentration of the QPM (SAMMAZ 14 and SUSUMA) maize leaves ranged from 5.05-6.94% with no micronutrient while with addition of micronutrients, K concentration of the index leaf ranged from 5.89%- 7.03%.

Potassium concentrations of the normal maize (SAMMAZ 12 and SAMMAZ 11) showed an irregular trend with a combined analysis of 6.12-6.70% with addition of micronutrients. The contrast analysis showed the K content of the leaves was not significant at ($P<0.05$) between the quality protein maize and the normal maize and between the QPM_A and QPM_B.

4.15.4 Calcium

The calcium content in the leaves increased as the nitrogen levels increased from the control to 150kgha^{-1} although there was no significant increase at ($P<0.05$). The range concentration in the QPM was 0.41-0.55% with no micronutrient and with additions of micronutrients, the combined concentrations range was from 0.42-0.47%. The normal maize had a concentration range of 0.44-0.58% with no micronutrient and with additions of micronutrients ranged from 0.42-0.63% (Table 4.25b). The contrast analysis showed a significant difference between the quality protein maize and the normal maize with additions of micronutrients when combined but there was no significant difference between the QPM_A and QPM_B.

4.15.5 Magnesium

The concentration of magnesium in the QPM leaves, one of the most dominant exchangeable bases was not consistent. However, the combined values showed a range of 0.31-0.36% with no micronutrients while with additions of micronutrients had a range of 0.32-0.36%. The normal maize showed a combined range of 0.24-0.34% with no micronutrient and 0.31-0.39% with additions of micronutrients as presented in Table 4.25b.

Table 4.25a: Effect of nitrogen and micronutrients on N, P, K concentrations of leaves of maize varieties

Nitrogen ($kgha^{-1}$)	Nitrogen						Phosphorus						Potassium					
							%											
	2008		2009		Combined		2008		2009		Combined		2008		2009		Combined	
	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_o	M_i	M_o	M_i	M_o	M_i	M_o	M_i	M_o	M_i
SAMMAZ 14																		
0	0.73	1.08	1.45	1.37	1.09	1.22	0.10	0.07	0.13	0.14	0.12	0.10	7.20	7.13	5.57	5.42	6.38	6.28
50	0.55	1.66	1.37	0.90	0.96	1.28	0.06	0.06	0.16	0.11	0.11	0.09	5.80	6.63	4.30	5.15	5.05	5.89
100	0.87	0.66	1.31	0.96	1.09	0.81	0.05	0.07	0.10	0.15	0.08	0.11	6.30	7.36	5.90	4.80	6.10	6.08
150	1.43	1.34	1.45	1.13	1.44	1.23	0.08	0.08	0.14	0.11	0.11	0.09	8.70	7.96	5.18	5.42	6.94	6.69
Mean	0.89	1.19	1.40	1.09	1.15	1.14	0.08	0.07	0.14	0.13	0.11	0.10	7.00	7.28	5.24	5.20	6.12	6.24
SUSUMA																		
0	0.67	1.60	1.13	1.25	0.90	1.43	0.07	0.09	0.13	0.13	0.10	0.11	7.06	6.80	5.18	5.45	6.12	6.12
50	0.90	0.70	0.96	0.78	0.93	0.74	0.86	0.07	0.11	0.13	0.10	0.10	7.33	6.60	5.70	5.15	6.51	5.87
100	0.81	1.43	1.19	1.31	1.00	1.37	0.56	0.06	0.12	0.11	0.08	0.08	7.23	7.93	5.00	5.45	6.11	6.69
150	0.79	1.22	1.48	1.86	1.13	1.54	0.07	0.07	0.15	0.13	0.11	0.10	8.13	9.00	4.97	5.07	6.55	7.03
Mean	0.79	1.24	1.20	1.31	0.99	1.27	0.07	0.08	0.13	0.13	0.10	0.10	7.44	7.58	5.22	5.28	6.33	6.43
SAMMAZ 12																		
0	0.96	0.84	1.16	1.10	1.06	0.97	0.06	0.07	0.16	0.15	0.11	0.11	7.46	7.56	6.05	5.20	6.75	6.38
50	0.99	0.70	0.99	1.13	0.99	0.92	0.07	0.05	0.12	0.14	0.09	0.09	6.46	5.76	5.95	6.40	6.21	6.08
100	1.02	1.13	1.22	1.22	1.12	1.18	0.06	0.06	0.17	0.10	0.11	0.08	6.96	8.16	5.70	5.52	6.33	6.84
150	1.13	1.25	1.25	1.10	1.19	1.18	0.07	0.07	0.11	0.11	0.09	0.09	8.20	6.60	4.90	6.21	6.55	6.40
Mean	1.03	0.99	1.16	1.15	1.09	1.07	0.07	0.06	0.14	0.13	0.11	0.09	7.28	7.03	5.65	5.84	6.46	6.43
SAMMAZ 11																		
0	0.74	0.84	1.51	0.87	1.12	0.86	0.09	0.08	0.14	0.13	0.12	0.10	8.26	6.56	5.43	5.80	6.84	6.18
50	1.34	0.81	1.05	1.28	1.19	1.05	0.06	0.07	0.11	0.13	0.08	0.10	8.50	6.26	6.08	4.75	7.29	5.50
100	1.14	0.87	1.14	1.31	1.14	1.09	0.07	0.07	0.11	0.11	0.09	0.09	6.83	7.23	5.30	7.08	6.06	7.16
150	0.85	0,76	1.38	1.13	1.11	0.94	0.06	0.07	0.13	0.14	0.09	0.10	8.26	6.63	5.38	6.40	6.82	6.51
Mean	1.02	0.83	1.28	1.15	1.15	0.99	0.07	0.07	0.13	0.13	0.10	0.10	7.96	6.68	5.55	6.01	6.76	6.34
Mean	0.93	1.06	1.26	1.17	1.10	1.12	0.07	0.07	0.13	0.13	0.10	0.10	7.42	7.14	5.41	5.58	6.42	6.36
SE-+	0.41	0.46	0.29	0.33	0.85	0.46	0.22	0.01	0.04	0.03	0.02	0.02	0.86	0.86	0.71	0.58	0.97	0.73
CV%	53.21	52.85	28.33	34.78	47.52	50.92	23.09	22.07	20.19	26.19	24.95	26.77	19.03	14.78	15.97	12.77	18.49	14.03
CONTRAST																		
QPM vs normal	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS
QPA_A vs QPM_B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.25b: Effect of nitrogen and micronutrients on Ca and Mg concentrations of maize leaf

Nitrogen (Kg/ha)	Calcium						Magnesium					
	%											
	2008		2009		Combined		2008		2009		Combined	
	M_o	M_i	M_o	M_i	M_o	M_i	M_o	M_i	M_o	M_i	M_o	M_i
SAMMAZ 14												
0	0.31	0.33	0.50	0.54	0.41	0.43	0.21	0.22	0.41	0.50	0.31	0.36
50	0.37	0.29	0.52	0.56	0.44	0.42	0.23	0.23	0.41	0.43	0.32	0.33
100	0.32	0.36	0.58	0.53	0.45	0.45	0.26	0.21	0.43	0.42	0.34	0.32
150	0.39	0.32	0.70	0.55	0.55	0.43	0.26	0.27	0.35	0.43	0.31	0.33
Mean	0.35	0.33	0.58	0.55	0.46	0.44	0.24	0.24	0.40	0.45	0.32	0.34
SUSUMA												
0	0.26	0.34	0.58	0.59	0.42	0.46	0.26	0.22	0.47	0.43	0.36	0.32
50	0.37	0.36	0.58	0.49	0.47	0.43	0.25	0.21	0.47	0.44	0.36	0.32
100	0.33	0.34	0.59	0.56	0.46	0.45	0.24	0.22	0.42	0.42	0.33	0.32
150	0.37	0.33	0.61	0.61	0.49	0.47	0.24	0.23	0.47	0.43	0.36	0.33
Mean	0.34	0.35	0.59	0.57	0.46	0/.46	0.25	0.22	0.46	0.43	0.36	0.33
SAMMAZ 12												
0	0.34	0.58	0.55	0.68	0.44	0.63	0.26	0.37	0.43	0.41	0.34	0.39
50	0.36	0.35	0.62	0.54	0.49	0.45	0.22	0.24	0.45	0.42	0.34	0.33
100	0.44	0.61	0.57	0.54	0.50	0.58	0.25	0.33	0.41	0.42	0.33	0.38
150	0.48	0.40	0.63	0.50	0.56	0.45	0.28	0.24	0.39	0.40	0.34	0.32
Mean	0.41	0.49	0.60	0.57	0.50	0.53	0.26	0.30	0.43	0.42	0.34	0.36
SAMMAZ 11												
0	0.48	0.33	0.62	0.59	0.55	0.46	0.27	0.23	0.35	0.38	0.31	0.30
50	0.32	0.34	0.56	0.50	0.44	0.42	0.20	0.18	0.35	0.35	0.27	0.26
100	0.53	0.36	0.64	0.52	0.58	0.44	0.16	0.19	0.33	0.40	0.24	0.29
150	0.27	0.34	0.55	0.67	0.41	0.50	0.19	0.21	0.37	0.41	0.28	0.31
Mean	0.40	0.35	0.60	0.57	0.50	0.46	0.21	0.20	0.35	0.39	0.28	0.29
Mean	0.37	0.38	0.59	0.56	0.48	0.47	0.24	0.24	0.41	0.42	0.33	0.33
SE-+	0.06	0.08	0.08	0.08	0.09	0.10	0.04	0.04	0.05	0.04	0.04	0.04
CV %	20.99	28.13	17.37	17.93	22.69	24.77	19.32	18.27	13.95	11.73	15.98	14.43
CONTRAST												
QPM vs normal	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
QPA_A vs QPM_B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.16 Effects of Nitrogen and Micronutrients on the Micronutrients Concentration of Maize Index Leaf

4.16.1 Copper

The highest content of copper (3.23mgkg^{-1}) was produced in the maize leaves at low rate of nitrogen and no micronutrients as seen in Table 4.26a while with micronutrients additions concentration of copper in the maize leaves was (3.19mgkg^{-1}) at 100kg Nha^{-1}.

4.16.2 Zinc

In the QPM varieties, the combined analysis showed that the highest concentration of zinc in the ear leaf was 60.13mgkg^{-1} and obtained with no micronutrient at 0 kgNha^{-1} while zinc concentrations was 67.29mgkg^{-1} with additions of micronutrients and 100 kgNha^{-1} in SAMMAZ 14. SUSUMA variety obtained 57.84mgkg^{-1} with additions of micronutrients at 150kgNha^{-1} and 55.16mgkg^{-1} with no micronutrients additions at 50kgNha^{-1}.

The normal maize, SAMMAZ 12 recorded the higher concentration of zinc 57.80mgkg^{-1}) with additions of micronutrients and with 50kgNha^{-1} and 53.17mgkg^{-1}with no micronutrient and 50kgNha^{-1}. SAMMAZ 11 recorded 55.47mgkg^{-1} with additions of micronutrients and 48.51mgkg^{-1} with no micronutrient and 150kgNha^{-1}. The contrast analysis was not significant between the QPM and the normal varieties.

4.16.3 Iron

Iron content in the ear leaf of Sammaz14 variety was 294.12mgkg^{-1} and 211.76mgkg^{-1} in the combined analysis at 150kgNha^{-1}and 0kgNha^{-1} of nitrogen with additions of micronutrients and no micronutrient respectively. SUSUMA recorded iron concentration of 230.59mgkg^{-1} and 181.19mgkg^{-1}in the combined analysis at 100kgNha^{-1}and 0kgNha^{-1} with additions of micronutrients and with no micronutrient.

The normal maize recorded a range of 155.29- 216.47mgkg^{-1}mgkg^{-1} and 178.82-216.47mgkg^{-1}in the combined analysis with additions of micronutrients and no micronutrient respectively.

4.16.4 Boron

The concentration of boron was at optimum rate for both formulations, with or without micronutrients with mean values of 2.38mgkg^{-1} for no micronutrients formulation and 2.80mgkg^{-1} with micronutrients formulation.

4.16.5 Molybdenum

Molybdenum as measured by the concentration in the leaves showed that the highest concentration was at zero level of nitrogen for both with or without micronutrients formulation. When micronutrients were not added to the soil, the combined analysis value was 0.59mgkg^{-1} and with micronutrient additions, rate was 0.57mgkg^{-1} respectively.

4.26a: Effect of nitrogen rates and micronutrient on copper, zinc and iron concentrations of the leaves of maize varieties

Nitrogen (kgha^{-1})	Copper						Zinc						Iron					
	%																	
	2008		2009		Combined		2008		2009		Combined		2008		2009		Combined	
	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_0	`M_1	M_0	M_1	M_0	M_1	M_o	M_1	M_o	M_1
SAMMAZ 14																		
0	1.32	1.87	0.93	1.85	1.13	3.23	53.10	43.73	67.16	54.10	48.94	60.13	159.99	188.23	263.53	235.29	211.76	211.76
50	1.10	2.22	1.85	1.85	1.48	2.04	52.51	50.37	54.10	48.51	53.31	49.44	150.59	197.64	221.17	160.00	185.88	178.82
100	1.23	1.81	2.78	2.76	2.01	2.29	40.87	80.47	55.97	54.10	50.37	67.29	155.29	169.41	235.29	282.35	195.29	225.89
150	2.25	2.32	3.70	3.48	2.98	2.90	59.70	50.37	57.84	61.57	58.77	55.97	202.35	282.35	207.05	305.88	204.70	294.12
Mean	1.48	2.06	2.32	2.56	1.90	2.31	49.65	59.17	58.03	55.04	53.98	57.08	167.06	209.41	231.76	245.88	199.41	227.64
SUSUMA																		
0	0.93	2.20	0.83	0.93	0.88	1.57	37.31	48.51	35.45	57.84	36.38	53.17	197.67	164.70	164.70	211.76	181.19	188.23
50	1.40	3.19	0.93	1.67	1.17	2.43	58.08	42.91	52.24	46.64	55.16	44.78	178.82	121.96	160.03	207.05	169.42	164.51
100	1.85	2.28	1.85	2.59	1.85	2.44	54.97	50.37	44.77	33.58	49.87	41.98	160.03	207.06	183.52	254.11	171.78	230.59
150	2.56	3.70	2.78	3.70	2.67	3.70	38.18	57.84	41.05	57.84	39.61	57.84	164.70	221.17	188.23	169.41	176.47	195.29
Mean	1.89	2.84	1.39	2.32	1.64	2.58	47.14	49.91	43.38	48.97	45.26	49.44	175.31	178.72	174.12	210.58	174.71	194.65
SAMMAZ 12																		
0	1.06	1.10	1.85	1.85	1.46	1.48	41.04	44.77	61.57	35.48	51.31	40.11	141.17	164.70	216.47	150.59	178.82	157.65
50	1.56	2.23	3.70	2.78	2.63	2.51	44.78	70.83	57.84	44.78	51.31	57.80	188.23	169.41	211.76	188.23	199.99	178.82
100	1.57	2.56	2.78	3.70	2.18	3.13	61.57	57.84	44.78	46.64	53.17	52.24	183.52	202.35	244.70	225.88	214.11	214.11
150	1.95	2.32	1.85	3.07	1.90	3.01	50.37	46.64	44.78	52.24	47.57	49.44	192.94	211.76	169.41	207.05	181.17	209.41
Mean	1.54	2.06	2.55	3.01	2.05	2.54	49.44	55.02	52.24	44.78	50.84	49.89	176.47	187.06	210.58	192.94	193.53	189.99
SAMMAZ 11																		
0	1.12	2.11	1.10	0.93	1.11	1.52	52.24	44.78	39.18	59.70	45.71	52.24	211.76	174.12	183.53	258.82	197.64	216.47
50	1.34	3.21	0.93	3.72	1.14	3.47	48.51	50.37	44.78	39.18	46.64	44.78	221.17	174.11	145.88	136.47	183.52	155.29
100	0.98	1.67	0.93	2.78	0.96	2.23	51.24	54.10	33.58	50.37	42.41	52.24	202.35	183.52	230.58	188.23	216.47	185.88
150	1.13	2.19	0.95	3.07	1.04	2.63	57.84	53.10	39.18	57.84	48.51	55.47	207.05	197.64	183.52	202.35	195.29	199.99
Mean	1.14	2.30	0.69	2.78	1.50	2.54	52.46	50.59	39.18	51.77	45.82	51.18	210.58	182.35	185.88	196.47	198.23	189.41
Mean	1.27	2.80	1.74	2.64	2.21	3.13	52.04	51.29	47.46	50.96	49.75	51.12	182.35	189.38	200.58	211.17	199.17	200.43
SE-+	0.35	0.41	0.42	0.45	0.31	0.35	15.55	13.06	9.69	12.54	14.90	15.85	30.48	51.42	32.08	79.62	45.23	67.18
CV%	103.2	110.3	119.8	105.1	100.7	123.5	36.61	31.19	24.99	30.14	36.69	37.99	20.47	33.26	33.92	46.11	28.93	41.05
CONTRAST																		
QPM vs normal	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
QPA_A vs QPM_B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.26b: Effect of nitrogen rates and micronutrient on molybdenum and boron concentrations of the leaves of maize varieties

Nitrogen (Kg/ha)	Molybdenum						Boron					
	%											
	2008		2009		Combined		2008		2009		Combined	
SAMMAZ 14	M_0	M_1	M_0	M_1	M_0	M_1	M_0	M_1	M_o	M_1	M_o	M_1
0	43.12	43.12	80.07	59.27	61.59	51.19	0.53	1.45	3.29	3.75	1.91	2.60
50	46.19	27.72	64.67	43.11	55.43	35.42	1.20	1.79	3.51	3.88	2.36	2.84
100	33.88	70.83	64.67	52.35	49.27	61.59	0.87	1.06	2.82	4.17	1.85	2.61
150	46.19	49.27	43.12	52.35	44.66	50.81	1.42	1.24	3.96	3.28	2.69	2.26
Mean	42.35	47.73	63.13	51.77	52.74	49.75	1.01	1.39	3.39	3.77	2.20	2.58
SUSUMA												
0	64.67	30.79	46.19	61.59	55.43	46.19	0.64	1.19	2.69	2.61	1.67	1.90
50	58.51	43.12	76.99	83.15	67.75	43.13	0.31	1.56	2.93	3.78	1.62	2.67
100	55.43	46.19	67.75	46.19	61.59	46.19	0.50	0.95	3.64	3.64	2.07	2.29
150	52.35	55.43	49.27	58.51	50.81	56.97	0.42	2.03	2.96	4.30	1.69	3.17
Mean	57.74	43.89	60.05	54.71	58.89	53.12	0.59	1.48	3.08	3.45	1.83	2.47
SAMMAZ 12												
0	58.51	43.12	49.27	55.43	53.89	49.27	1.55	1.66	3.24	3.06	2.39	2.36
50	21.56	58.51	40.04	67.75	30.79	43.13	0.92	2.24	3.04	3.77	1.98	3.01
100	40.04	67.75	46.19	49.27	43.12	58.51	0.37	2.56	3.27	4.12	2.07	2.85
150	46.19	46.19	70.83	46.19	58.51	46.19	0.67	1.97	3.43	4.33	2.05	3.15
Mean	41.58	53.89	51.58	55.94	46.58	54.28	0.88	1.81	3.22	3.95	2.05	2.88
SAMMAZ 11												
0	58.51	49.27	67.75	67.75	63.13	58.51	1.00	0.50	3.59	4.01	2.29	2.26
50	52.35	33.88	61.57	43.12	56.96	38.49	0.39	1.56	3.41	3.46	1.90	2.51
100	67.75	36.97	43.09	46.19	55.42	41.58	0.68	1.57	2.85	3.38	1.70	2.33
150	33.88	40.04	40.01	55.43	36.92	47.73	1.63	1.21	3.96	4.30	2.79	2.76
Mean	53.12	40.04	53.10	49.48	53.11	46.58	0.93	1.11	3.45	3.79	2.19	2.46
Mean	48.69	46.39	56.97	55.48	52.83	50.93	0.85	1.45	3.29	3.74	2.07	2.59
SE-+	13.39	12.42	18.06	16.04	15.99	14.85	0.61	0.65	2.83	10.65	0.83	0.74
CV%	33.68	32.79	38.82	35.39	37.07	35.70	88.31	54.59	31.08	21.26	49.13	34.86
CONTRAST												
QPM vs normal	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
QPA_A vs QPM_B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.17 The Main Effect of Nitrogen Fertilization on Nitrogen Concentration of the Maize Grain, Crude Protein, Lysine and Tryptophan Content.

4.17.1 Grain nitrogen content

Increase in nitrogen rates increased the concentration of N in the grain from the control to the highest level of nitrogen applied (150kgNha^{-1}). The combined analysis also showed that grain N increased as the nitrogen rates increased from the control to 150kgNha^{-1} in the QPM varieties - SAMMAZ 14 (2.78%) and SUSUMA (2.80%) while for the normal maize varieties (SAMMAZ 12 and SAMMAZ 11) though N increased to the highest rate of N applied (150kgNha^{-1}) the N content was lower than it was for quality protein maize varieties. SAMMAZ 12 and SAMMAZ 11 produced (2.52%) and (2.64%) nitrogen in the grains respectively (Table 4.27).

4.17.2 Crude protein content

The application of N at the rate of150kgha^{-1} gave maximum crude protein contents of 17.45% for SAMMAZ 14, (17.36%) for SUSUMA, (15.72%) for SAMMAZ 12 and (14.94%) for SAMMAZ 11 (Table 4.27). The protein content of SAMMAZ 14 (QPM) was 19.31% > SAMMAZ 12 and 24.47% > SAMMAZ 11. SUSUMA had protein content of 24.59% > SAMMAZ 12 and 24.08% > SAMMAZ 11.

4.17.3 Lysine and tryptophan contents of the maize varieties

When the lysine and tryptophan contents of the maize varieties were combined for the two years, SUSUMA recorded 3.14% and tryptophan contents 0.72% at (100kgN) while SAMMAZ 14 had maximum lysine content of 3.06% and tryptophan content of 0.55% at (150kgN). SAMMAZ 11 had lysine content of 2.96% and 0.48% tryptophan and SAMMAZ 12 had maximum lysine content of 2.87% and tryptophan content was 0.43% both at the highest nitrogen applied (150kgN).

Table 4.27: The effect of nitrogen on nitrogen, crude protein, lysine and tryptophan contents of different maize varieties grains.

Variety	Nitrogen ($Kgha^{-1}$)	Nitrogen in grains (%)			Crude protein in grains (%)			Lysine (%)			Tryptophan (%)		
		2008	2009	Combined	2008	2009	Combined	2008	2009	Combined	2008	2009	Combined
SAMMAZ 14	0	2.14	2.79	2.46	13.39	17.41	15.40	2.85	2.66	2.76	0.47	0.38	0.42
	50	2.28	2.95	2.62	14.22	18.41	16.32	3.14	2.78	2.96	0.45	0.42	0.44
	100	2.42	2.95	2.69	15.13	18.59	16.86	2.73	2.99	3.00	0.49	0.47	0.44
	150	2.45	3.09	2.78	15.31	19.33	17.36	3.19	2.93	3.06	0.53	0.47	0.55
	Mean	2.32	2.97	2.64	14.51	18.50	16.51	3.04	2.76	2.87	0.50	0.41	0.45
SUSUMA	0	2.14	2.93	2.54	13.39	18.29	15.84	3.11	3.12	3.12	0.48	0.53	0.51
	50	2.11	2.93	2.52	13.22	18.32	15.77	3.00	3.28	3.00	0.52	0.58	0.44
	100	2.38	3.08	2.73	14.85	18.23	16.54	3.11	3.41	3.14	0.48	0.61	0.72
	150	2.46	3.14	2.80	15.40	19.59	17.45	2.97	3.42	3.13	0.52	0.58	0.55
	Mean	2.27	3.01	2.64	14.22	18.54	16.38	2.95	3.25	3.06	0.47	0.57	0.52
SAMMAZ 12	0	1.69	2.67	2.18	12.21	14.14	13.18	2.75	3.08	2.79	0.31	0.42	0.37
	50	1.95	2.69	2.32	14.39	17.14	14.54	2.68	2.89	2.84	0.41	0.35	0.43
	100	1.69	2.48	2.09	10.57	18.61	14.59	2.47	2.78	2.68	0.38	0.48	0.38
	150	2.06	2.98	2.52	12.21	16.68	14.94	2.65	3.08	2.87	0.39	0.47	0.43
	Mean	1.97	2.71	2.34	12.35	16.98	14.63	2.64	2.96	2.79	0.37	0.47	0.42
SAMMAZ 11	0	1.94	2.78	2.36	12.12	16.04	14.08	2.69	2.98	2.79	0.39	0.48	0.43
	50	2.03	2.81	2.42	12.12	15.04	14.36	2.84	2.81	2.82	0.45	0.49	0.47
	100	2.04	2.83	2.44	12.76	17.98	15.37	2.88	2.82	2.85	0.45	0.42	0.44
	150	2.30	2.98	2.64	12.85	18.59	15.72	3.14	2.78	2.96	0.45	0.42	0.48
	Mean	2.00	2.79	2.41	12.62	17.47	15.04	2.87	2.94	2.90	0.45	0.47	0.49
Mean		2.15	2.87	2.51	13.42	17.88	15.64	2.87	2.97	2.91	0.44	0.48	0.47
SE+		0.28	0.31	0.11	1.77	1.89	0.67	0.27	0.26	0.10	0.03	0.02	0.03
CV(%)		22.81	8.74	21.19	22.82	18.37	20.89	16.51	15.35	16.83	11.63	8.50	32.03
V*N		NS	NS	NS	NS	NS	NS	NS	NS	NS	**	* *	**
Contrast													
QPM vs Normal		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
QPM_A vs QPM_B		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.18 Effects of Micronutrients on Nitrogen, Crude protein, Lysine and Tryptophan Contents of the Maize Grain

SUSUMA (QPM) had N content of 2.74% with micronutrients application while SAMMAZ 14 (QPM) produced combined N content of 2.67% in the grain. The normal maize, SAMMAZ 12 recorded N content of 2.40% without micronutrients application while SAMMAZ 11 (normal maize) had 2.55% Nin the grain with micronutrients application.

The application of micronutrients increased the crude protein of the QPM varieties in that SUSUMA had the highest crude protein of 17.09% followed by SAMMAZ 14 with 16.67% and SAMMAZ 11 had 15.93% all with micronutrients application while SAMMAZ 12 produced crude protein of 14.97% without micronutrients application.

QPM varieties SUSUMA had the lysine and tryptophan contents of 3.20% and 0.53%, SAMMAZ 14 had lysine and tryptophan contents of 3.01% and 0.49% and SAMMAZ 11 produced lysine and tryptophan contents of 2.93% and 0.47% all with micronutrients application. SAMMAZ 12 had lysine content of 2.84% and tryptophan content of 0.44% without micronutrients application as presented in Table 4.28.

Table 4.28: The effect of micronutrients on nitrogen in grains, crude proteins, lysine and tryptophan content of the maize varieties.

Variety	Micronutrients (gha^{-1})	Nitrogen in grains		Crude protein in Grains		Tryptophan (%)		Lysine (%)	
		2008	2009	2008	2009	2008	2009	2008	2009
SAMMAZ 14									
	-M	2.03	2.88	12.67	18.03	0.47	0.36	2.94	2.62
	+M	2.31	3.02	14.45	18.89	0.53	0.45	3.13	2.89
SUSUMA									
	-M	1.91	2.66	11.94	16.77	0.43	0.59	2.83	3.16
	+M	2.39	3.08	14.95	19.23	0.51	0.54	3.07	3.33
SAMMAZ 12									
	-M	2.04	2.75	14.08	17.77	0.39	0.48	2.69	2.99
	+M	2.00	2.71	12.53	16.96	0.35	0.46	2.59	2.92
SAMMAZ 11					.				
	-M	2.11	1.99	13.00	16.18	0.42	0.47	2.79	2.96
	+M	2.25	2.85	12.76	17.18	0.47	0.46	2.94	2.92
Mean		2.15	2.87	13.42	17.88	0.44	0.48	2.87	2.97
SE±		0.28	0.31	1.77	1.89	0.03	0.02	0.27	0.26
CV(%)		22.81	18.74	22.82	18.37	11.63	8.50	16.51	15.35
V*N		NS	NS	NS	NS	**	**	**	**

4.19 The Effect of Treatments on Nitrogen, Crude Proteins, Lysine and Tryptophan Contents of the Maize Grain

The effect of treatments on the grain parameters as presented in Table 4.29 showed grain N generally seemed to increase with N rates in the QPM varieties and decrease in the normal maize varieties, with or without the application of micronutrients. SAMMAZ 14 had 2.54kgNha^{-1} and 2.53kgNha^{-1} nitrogen content with or without micronutrients application. SUSUMA had a nitrogen content of 2.90kgNha^{-1} and 2.77kgNha^{-1} with added micronutrients or without micronutrients application. The normal maize SAMMAZ 12 and 11 recorded 2.85 kgNha^{-1}, 2.74 kgNha^{-1}, 2.83 kgNha^{-1} and 2.68kgNha^{-1} with or without the application of micronutrients respectively.

The results also showed that the crude protein content varied from 16.78% to 19.60% among the varieties. SAMMAZ 14 had crude protein content of 16.78% at 150kgNha^{-1} with micronutrient addition and had 14.27% at 150kg Nha^{-1}without micronutrients. Also SUSUMA had the highest crude protein of 17.91% at 50kgNha^{-1} with no micronutrient addition, but had 19.60% at 50kgNha^{-1} with addition of micronutrients. SAMMAZ 12 had crude protein content of 18.32%with micronutrients and 17.23% without micronutrient at 150kgNha^{-1}. For SAMMAZ 11, (normal maize) recorded the crude protein of 17.24% and 16.41%withand without micronutrients at150kgha^{-1}N respectively. The mean crude proteins content among the varieties were 14.45% - 18.90% for both years respectively as presented on Table 4.29a.

The lysine and tryptophan contents of the different varieties were presented in Table 4.29b. The lysine content was3.19% and 2.82% for SAMMAZ 14 with or without micronutrients. SUSUMA had highest lysine content of 3.30% and 3.24% with or without micronutrients with 50kgNha^{-1}. SAMMAZ 12 recorded a lysine content of 3.02% and 2.89%

with or without micronutrients while SAMMAZ 11 had lysine content of 3.20% and 2.93% with or without micronutrients respectively.

The mean values for tryptophan in the two years were highly significant, $p<0.05$ with the highest value of 0.59% (SUSUMA) and the lowest value of 0.39% (SAMMAZ 14).The tryptophan content of 0.55% ($100kgNha^{-1}$) and 0.43% ($0kgNha^{-1}$) were recorded with or without micronutrients application by SAMMAZ 14 while SUSUMA variety had tryptophan content of 0.59% and 0.52% at $50kgNha^{-1}$with or without micronutrient application. SAMMAZ12 had tryptophan content of 0.46% ($0kgNha^{-1}$) without micronutrients and 0.45% ($150kgNha^{-1}$) with micronutrient applications. SAMMAZ11 recorded 0.50% and 0.50% ($50kgNha^{-1}$) with or without micronutrients.

Table 4.29a: The effect of treatments on nitrogen and crude proteins contents of different maize grains.

Variety	Nitrogen ($kgha^{-1}$)	Micronutrients (gha^{-1})											
		Nitrogen in grains						Crude protein in grains					
		2008		2009		Combined		2008		2009		Combined	
		-M	+M	-M	+M	-M	+M	-M	+M	-M	+M	-M	+M
SAMMAZ 14	0	2.68	2.97	2.01	2.10	2.35	2.07	16.77	18.59	12.57	13.48	13.03	16.04
	50	3.06	2.71	2.04	1.84	2.48	2.28	18.23	16.93	12.76	11.48	14.67	14.21
	100	3.12	2.82	1.84	2.25	2.48	2.54	19.51	17.68	14.04	13.03	15.50	15.36
	150	2.80	2.33	2.25	1.84	2.53	2.54	17.50	14.58	11.04	11.48	14.27	16.78
	Mean	2.88	2.71	2.03	2.01	2.26	2.36	18.00	16.95	12.67	12.53	15.34	14.74
SUSUMA	0	2.92	3.04	2.13	2.08	2.53	2.56	15.68	18.59	12.58	11.85	14.13	15.22
	50	2.51	3.12	2.74	2.19	2.77	2.90	19.32	19.50	13.67	16.31	17.91	19.60
	100	2.51	2.83	1.43	1.95	1.97	2.39	15.68	17.68	8.93	12.21	12.31	14.95
	150	3.06	1.89	2.48	1.84	2.66	1.87	19.14	11.85	13.31	11.49	16.23	11.62
	Mean	2.75	2.66	1.91	2.02	2.33	2.34	17.18	16.78	11.94	12.62	14.56	14.23
SAMMAZ 12	0	3.06	2.51	1.87	2.42	2.47	2.47	19.14	15.68	11.66	15.13	15.40	15.41
	50	2.98	2.98	2.30	2.54	2.64	2.46	18.59	18.59	14.40	15.87	16.50	17.23
	100	2.77	3.12	2.48	2.07	2.63	2.60	17.32	19.50	15.49	12.94	16.41	16.20
	150	3.12	3.15	2.36	2.54	2.74	2.85	19.51	14.76	19.68	15.86	17.23	18.32
	Mean	3.08	2.84	2.25	2.39	2.67	2.62	19.23	17.77	14.08	14.95	16.64	16.36
SAMMAZ 11	0	2.77	3.08	1.72	2.57	2.25	2.39	17.32	19.27	10.75	16.04	14.04	17.66
	50	3.09	2.77	2.19	2.04	2.64	2.41	19.14	17.32	11.05	12.76	14.64	15.08
	100	3.05	3.12	2.30	2.45	2.26	2.83	16.95	19.51	14.39	13.67	15.67	17.01
	150	2.92	2.89	2.01	2.08	2.68	2.79	18.98	18.98	17.14	15.49	16.41	17.24
Mean		2.99	3.02	2.24	2.31	2.62	2.67	18.18	18.90	13.99	14.45	16.09	16.98
Mean		2.92	2.81	2.11	2.18	2.52	2.50	18.15	17.50	13.17	13.64	15.66	15.62
SE±		0.11	0.12	0.09	0.11	0.10	0.12	0.55	0.77	0.55	0.69	0.55	0.74
CV (%)		15.13	21.43	20.32	24.96	19.00	23.01	14.87	21.53	20.32	24.96	18.19	23.06
Contrast													
QPM vs Normal		NS	NS	*	NS	NS	*	NS	NS	**	NS	*	NS
QPM_A vs OPM_B		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.29b: The interactive treatments on grain lysine and tryptophan contents of the maize varieties

Variety	Nitrogen(kgha^{-1})	Micronutrients (gha^{-1})											
		Lysine						Tryptophan					
		2008		2009		Combined		2008		2009		Combined	
		-M	+M	-M	+M	-M	+M	-M	+M	-M	+M	-M	+M
SAMMAZ 14	0	3.00	3.38	2.63	2.66	2.70	2.85	0.49	0.61	0.37	0.38	0.43	0.50
	50	2.90	2.79	2.66	2.90	2.78	2.95	0.45	0.42	0.38	0.45	0.41	0.44
	100	2.90	3.01	2.50	3.36	2.82	3.19	0.45	0.49	0.32	0.61	0.39	0.55
	150	2.95	3.33	2.68	2.63	2.82	3.50	0.47	0.59	0.38	0.37	0.43	0.48
	Mean	2.94	3.13	2.62	3.13	2.78	3.13	0.47	0.53	0.36	0.45	0.42	0.49
SUSUMA	0	3.01	2.93	3.25	2.98	3.13	2.96	0.49	0.46	0.57	0.48	0.53	0.47
	50	3.19	3.03	3.41	3.44	3.24	3.50	0.55	0.49	0.62	0.53	0.52	0.59
	100	3.17	2.77	3.40	3.36	2.89	3.07	0.54	0.41	0.61	0.61	0.58	0.51
	150	2.90	2.60	3.20	3.17	3.05	3.29	0.45	0.36	0.55	0.54	0.50	0.45
	Mean	3.07	2.83	3.32	3.24	3.20	3.04	0.51	0.43	0.54	0.59	0.55	0.49
SAMMAZ 12	0	2.66	2.68	3.04	3.01	2.85	2.85	0.38	0.38	0.53	0.49	0.46	0.44
	50	2.77	2.58	3.01	2.87	2.75	2.73	0.41	0.35	0.49	0.53	0.45	0.44
	100	2.74	2.20	2.90	2.66	2.82	2.43	0.40	0.22	0.45	0.38	0.43	0.30
	150	2.60	2.90	2.90	3.14	2.89	2.02	0.36	0.45	0.45	0.44	0.41	0.45
	Mean	2.69	2.59	2.96	2.92	2.83	2.76	0.38	0.35	0.48	0.46	0.43	0.41
SAMMAZ11	0	2.63	2.74	3.01	2.95	2.82	2.85	0.37	0.40	0.49	0.47	0.43	0.44
	50	2.68	3.33	3.01	3.07	2.85	2.25	0.38	0.59	0.49	0.44	0.41	0.50
	100	2.87	2.88	2.77	2.87	2.82	2.88	0.44	0.45	0.39	0.44	0.42	0.45
	150	2.98	2.79	2.87	2.98	2.93	2.89	0.48	0.42	0.51	0.48	0.50	0.45
Mean		2.79	2.94	2.92	2.97	2.86	2.96	0.42	0.47	0.47	0.46	0.45	0.47
Mean		2.99	2.17	2.87	2.87	2.89	2.92	0.44	0.52	0.44	0.44	0.46	0.48
SE±		0.11	0.09	0.10	0.10	0.11	0.09	0.01	0.06	0.01	0.02	0.01	0.04
CV (%)		18.13	14.72	17.19	16.34	17.95	15.45	10.22	10.22	12.86	10.22	11.32	12.96
CONTRAST													
QPM vs Normal		NS	NS	NS	*	NS	*	NS	NS	NS	**	NS	**
QPM_A vs OPM_B		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.20 Correlation Studies

4.20.1 Correlation studies of agronomic parameters and grain parameters

The relationships between agronomic parameters and grain parameters were derived by simple correlation and presented in Table 4.30. Grain yield was significantly related with Stover yield and 1000 grain weight with r values of 0.67^{**} and0.62^{**} respectively. The grain yield showed a significant but negative (P< 0.05) correlation with nitrogen and protein contents of the grain (r= -0.36**) and (r=-0.36**).

The nitrogen content of the grain was positively and highly correlated (r= 0.99^{**}) with crude protein content of the maize. While lysine was highly and positively correlated (r= 0.48**) with tryptophan.

4.21 The Correlation Matrix between Grain Yield, Grain Parameters and some Soil Chemical Properties.

The correlation matrix between grain and soil parameters is shown in Table 4.31. The pH (r= 0.26*), soil N (r=0.19*), zinc (r=0.24*), and copper (r=0.31*) were positively correlated (P< 0.01) with the grain yield while the grain yield was positively and highly significantly correlated (P< 0.05) with boron (0.49**) and calcium (0.17**) contents of the soil respectively. The grain N contents exhibited positively and highly significant correlation (P< 0.05) with crude protein (r= 0.99**) and organic carbon (r= 0.24**) contents of the soil while it had a significant positive correlation (P< 0.01) with exchangeable acidity (r= 0.14*) and pH (r= 0.02*) of the soil. Grain N was highly significant but negatively correlated with boron (r= -0.40**), copper (r= -0.45**) and sodium(r= -0.16*) contents of the soil.

The crude protein was positively and significantly correlated with exchangeable acidity (r=0.14*), soil pH (r= 0.19*) and organic carbon (r=0.24*)and was significantly and negatively correlated (P< 0.05) with sodium (r= -0.16*), boron (r= -0.40**) and copper (r= -0.45**) contents of the soil. Lysine content of the grain increased as tryptophan contents and soil N increased with r values of 0.19** and 0.07* and decreased with exchangeable acidity

(r= -0.16**), sodium (-r=0.16**) and copper (r= -0.17**) contents of the soil while tryptophan increased with soil N (r= 0.15*) and decreased with exchangeable acidity (r= -0.05*) and exchangeable copper (r= -0.23**).

The pH of the soil was highly and positively correlated (P< 0.05) with exchangeable acidity(r =0.30**) and available phosphorus (r =0.30**) while it was positively correlated (P< 0.01) with exchangeable sodium (r =0.17*), extractable zinc (r=0.04*) and extractable boron (r =0.16*). The pH of the soil was negatively correlated with organic carbon (r =-0.14*) and exchangeable magnesium (r =-0.15*). The exchangeable acidity was positively correlated with available phosphorus (r =0.34**) and negatively correlated with soil N (r =-0.22*), extractable copper (-0.15*) and boron (r =-0.17*). Organic carbon content of the soil was significantly (P<0.05) and positively correlated with available phosphorus (r =0.20**) and significantly correlated (P<0.01) with exchangeable potassium (r =0.19*) but negatively correlated with extractable zinc (r =-0.20**), copper (-0.14*) and boron (r =-0.17*). Soil N was positively and significantly correlated with lysine (r =0.07*) and tryptophan content (r =0.15*) of the soil with a negative correlation with exchangeable acidity (r =-0.22*) and extractable boron (r =-0.15*) content of the soil. Available phosphorus of the soil was positively correlated with exchangeable potassium (r=0.27*) and negatively correlated with exchangeable calcium (r =-0.25*).

The exchangeable calcium was highly and positively correlated with exchangeable magnesium (r =0.80**). Magnesium was highly and significantly correlated with boron (0.22**) and copper (0.14**) while zinc was positively and highly significantly correlated (P< 0.05) with boron (0.29**) and copper (0.23**) as presented on Table 4.31.

Table 4.30 Correlation coefficient (r) between agronomic parameters and some grain parameters

	Grain yld	Stover yld	1000gr wt	Plt ht	TN in grain	Crude protein	Lysine	Tryptophan
Grain yld	1.000							
Stover yld	0.669**	1.000						
1000 gr.wt	0.617**	0.627**	1.000					
Plt ht.	0.308	0.077	0.049	1.000				
TN in grain	-0.363**	0.017	0.004	0.032	1.000			
Crude protein	-0.364**	0.011	0.003	0.025	0.993**	1.000		
Lysine	0.083	0.027	-0.009	-0.025	0.022	0.021	1.000	
Tryptophan	-0.131	0.034	-0.095	-0.056	0.081	0.088	0.480**	1.000

** = Significant at 5%
* = Significant at 1%

4.31 Correlation Coefficient (r) between grain yield, grain parameters and some chemical properties of the soil

	G. yld	TNg	CP	Lys	Tryp	pH	Exacidity	OC	TNsoil	AvP	K	Na	Ca	Mg	Zn	B	Cu
G. yld	1.00																
TNg	-0.36**	1.00															
CP	-0.36**	0.99**	1.00														
Lys	-0.06	0.02	0.21	1.00													
Tryp	0.11	0.08	0.09	0.19**	1.00												
Ph	0.26*	0.20*	0.19*	-0.07	-0.08	1.00											
Exacidity	-0.11	0.14*	0.14*	-0.16**	-0.05*	0.30**	1.00										
OC	-0.04	0.24**	0.24**	0.02	-0.02	-0.14**	-0.16	1.00									
TNsoil	0.19*	0.05	0.07	0.07*	0.15*	-0.05	-0.22*	0.12	1.00								
AvP	0.05	0.03	0.03	0.09	-0.01	0.30**	0.34**	0.20**	-0.01	1.00							
K	-0.11	-0.05	-0.04	-0.04	0.13	-0.02	0.12	0.19*	--0.05	0.27*	1.00						
Na	0.18	-0.16*	-0.16*	-0.16**	-0.08	0.17*	-0.21	0.03	0.04	0.05	0.15*	1.00					
Ca	0.17**	0.01	0.01	-0.08	-0.00	-0.19	-0.06	-0.04	0.05	-0.25*	0.14	0.05	1.00				
Mg	0.04	-0.14*	-0.15	-0.08	-0.03	-0.15*	-0.12	-0.04	0.10	-0.24	0.10	0.03	0.80**	1.00			
Zn	0.24*	-0.38**	-0.37	0.17	0.25	0.04*	-0.04	-0.20*	0.04	-0.05	0.10	0.15	0.04	0.10	1.00		
B	0.49**	-0.41**	-0.40**	-0.02	-0.10	0.16*	-0.17*	-0.17*	-0.15*	-0.09	0.03	-0.01	0.11	0.22**	0.29**	1.00	
Cu	0.31*	-0.44**	-0.45**	-0.16*	-0.23*	0.09	-0.15*	-0.14*	-0.07	-0.10	-0.03	0.10	0.03	0.14*	0.23**	0.38	1.00

**** = Significant at 5%**
*** = Significant at 1%**

KEY

G. yld–Grain yield TNg—Total nitrogen in grain CP—Crude protein Lys--Lysine Tryp—Tryptophan pH—pH soil Exacidity OC—Organic Carbon TNsoil AvP—Available phosphorus Exch K Exch Na Exch.Ca Exch Mg Extrac Zn Extrac B Extrac Cu

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4.22 Correlation Matrix between Grain and Plant Tissue Parameters

Results of the correlation matrix between grain and plant tissue parameters are shown on Table 4.32. The grain N and crude protein contents of the grain were negatively but significantly correlated with phosphorus (r= - 0.50**), potassium (r= - 0.32*), calcium (r= -0.42**), magnesium (r= -0.50**), zinc (r= -0.17*), boron (r= -0.42**) and molybdenum (r= -0.15*) concentrations of the plant tissue. The amino acids (lysine and tryptophan) only increased as potassium (r= 0.14*) concentration in the tissue increased but was negatively correlated with calcium (r= -0.16*), copper (r= -0.15*) and boron (r= -0.19*). Phosphorus was positively correlated with calcium (r= 0.62**), magnesium (r= 0.60**), copper (r= 0.51**), zinc (r= 0.15*), iron (r= 0.19*), boron (r= 0.55**) and molybdenum (r= 0.21*) and negatively correlated with potassium (r= -0.47**). Potassium concentration in the plant tissue was negatively correlated with calcium (r= -0.37**), magnesium (r=-0.50**), copper (r=-0.40**) and boron (r=-0.50**). The calcium concentration in the plant tissue was positively correlated with magnesium (r= 0.60**), boron (r= 0.45**) and molybdenum (r= 0.23*). Magnesium was positively correlated with iron (r= 0.17*), boron (r= 0.65**) and molybdenum (r= 0.24*) and iron was positively correlated with boron (r= 0.157*). Copper concentration increased with zinc (r= 0.24*) and boron (r= 0.38*) and iron increased with boron (r= 0.16*) content of the maize tissue.

Table 4.32: Correlation matrix between grain and plant tissue parameters

	TNin grain	Crude Protein	Lysine	Tryptophan	TNinplant	TP	TK	TCa	TMg	TCu	TZn	TFe	B	Mo
TNg	**1.00**													
CP	**0.99****	**1.00**												
Ly	**-0.02**	**0.08**	**1.00**											
Try	**0.08**	**0.09**	**0.19****	**1.00**										
TNpl	**0.03**	**0.03**	**-0.02**	**-0.07**	**1.00**									
P	**-0.50****	**-0.50****	**-0.05**	**-0.62**	**0.06**	**1.00**								
K	**-0.32***	**- 0.32***	**-0.02**	**0.14***	**-0.10***	**-0.47****	**1.00**							
Ca	**-0.42****	**-0.44****	**-0.10**	**-0.16***	**0.07**	**0.62****	**-0.37****	**1.00**						
Mg	**-0.50****	**-0.50****	**-0.06**	**-0.12**	**0.20***	**0.60****	**-0.50****	**0.60****	**1.00**					
Cu	**-0.26****	**-0.26***	**0.04**	**-0.15***	**-0.08**	**0.51****	**-0.40****	**0.48**	**0.39***	**1.00**				
Zn	**-0.17**	**-0.17***	**0.04**	**-0.01**	**-0.27****	**0.15***	**0.06**	**0.09**	**-0.09**	**0.24***	**1.00**			
Fe	**-0.06**	**0.07**	**-0.04**	**-0.01**	**0.16***	**0.19***	**0.04**	**0.04**	**0.17***	**0.13**	**0.06**	**1.00**		
B	**-0.42****	**-0.41****	**-0.08**	**-0.19***	**0.29****	**0.55****	**-0.50****	**0.45****	**0.65****	**0.38***	**-0.08**	**0.16***	**1.00**	
Mo	**-0.15***	**-0.15***	**0.08**	**0.01**	**0.04**	**0.21***	**-0.12**	**0.23***	**0.24***	**0.04**	**-0.10**	**-0.02**	**0.11**	**1.00**

**** = Significant at5%**
*** = Significant at 1%**
KEY
Gyld –Grain yield Syld—Stover yieldTNg –Total nitrogen in grain. CP—Crude protein Ly –Lysine content of grain Try–Tryptophan content TNpl--- Total nitrogen P –Total P K –Total K Ca—Total Ca Mg –Total Mg Cu–Total Cu Zn - Total Zn Fe-- Total Fe B---- Total B Mo--- Total Mo

4.23 The Relationships between Micronutrients in the Soil and Plant Tissue Micronutrients Content

Results are shown in Table 4.33, there was a positive and highly significant relationship between the extractable copper, zinc ($r=0.232^{**}$) and boron ($r=0.383^{**}$) contents of the soil while there was a positive and significant relationships between the soil copper and copper ($r=0.358^{**}$) zinc ($r=0.201^{**}$) and boron ($r=0.309^{**}$) concentrations of the plant tissue. Zinc contents of the soil increases boron ($r=0.290^{**}$) uptake from the soil and therefore increased the concentration of copper ($r=0.280^{**}$) and boron ($r=0.362^{**}$) in the plant tissue.

Increased in soil iron contents decreased the copper ($r= -0.155^{*}$) and iron ($r= -0.208$) contents in the leaves of the maize varieties while uptake of boron in the soil increased the copper ($r=0.379^{**}$), zinc ($r=0.229^{**}$) and boron ($r=0.336^{**}$) concentrations in the plant tissue. Copper concentration in plant tissue also increases the zinc ($r=0.243^{**}$) and boron ($r=0.383^{**}$) concentration in the plant tissue while iron only increased with boron ($r=0.169^{*}$) concentration.

Table 4.33: Correlation coefficient (r) between soil micronutrients and tissue micronutrients of the maize varieties

Soil micronutrients Tissue micronutrients

	Cu	Zn	Fe	B	Mo	TCu	TZn	TFe	TB	Mo
Cu	1.000									
Zn	0.232**	1.000								
Fe	-0.045	-0.111	1.000							
B	0.333**	0.290**	-0.094	1.000						
Mo	0.015	0.082	-0.127	0.029	1.000					
TCu	0.358**	0.280**	-0.155*	0.379**	0.017	1.000				
TZn	0.201**	0.017	0.034	0.229**	0.033	0.243**	1.000			
TFe	0.018	0.018	-0.208**	-0.118	0.035	0.131	0.061	1.000		
TB	0.309**	0.367**	-0.115	0.336**	-0.090	0.383**	-0.077	0.169*	1.000	
TMo	0.042	-0.098	-0.019	0.087	0.087	0.042	-0.098	-0.019	0.102	1.0000

**= significant at 5%

* = significant at 1%

4.24 Principal Component Analysis (PCA)

Principal Component Analysis was carried out on the soil chemical properties, tissue nutrients and grain parameters for the treatments to identify the soil fertility indicators that most importantly explained the variability in the grain yield and the soil nutrient factors influencing the nutritional quality of the maize varieties. The principal components (PC) with Eigen values > 1 were retained, since Eigen values < 1 indicated that the factor could explain less variance than individual soil, plant and grain properties. A high communality estimate suggests that high portion of the variance was explained by the factor components; therefore, it would get higher preference over low communality estimate (Garson, 2007). High Eigen values were selected to best represent the variation in the soil fertility management practices (Litchner *et al*., 2008; Eche, 2011).

4.24.1 Principal component analysis (PCA) of the soil nutrients

Seven principal components were greater than one (>1) and cumulatively explained 71.68% of the variation within the soil fertility treatments (Table 4.36.). All the twenty- four retained chemical properties clustered together and cumulatively explained 71.68% of the variations within the soil fertility treatments. Principal components one (PC1) or cluster 1 demonstrates the influence of soil pH on Cu (- 0.497), B (-0.629), Na (0.436) Mg (-0.537) and P (0.573) availability and these can be interpreted as soil reaction. Clusters 2 and 3 can be interpreted as soil exchange site furnishing the soil solution with exchangeable K, Ca and Mg as a function of soil acidity. The second loading which contributed 12.91% of the total variance had positive loadings for exchangeable K, Ca and Mg. These exchangeable bases were the dominant bases in the soil used especially (Ca and Mg).

Cluster 4 consists of extractable boron, exchangeable potassium (0.433), exchangeable calcium (-0.394), organic carbon (0.352), extractable Mo (0.426) and soil nitrogen (-0.442). This cluster is purely organic colloid responsible for furnishing the soil with micronutrients (Brady and Weil, 2004). PC 5 had an additional 7.70% of the total variance and had a positive loading for organic carbon (0.752), exchangeable sodium (0.505) and soil nitrogen (0.358). Cluster 6 and 7 had an additional 6.94% and 6.74% respectively of the total variance with positive loading for extractable zinc (0.763), copper (0.431), molybdenum (0.466) and soil nitrogen (0.573) respectively as presented on Table 4.34.

4.24.2 Principal components analysis for tissue properties

Four principal components were greater than one, and cumulatively explained 62.37% of the variation within the soil fertility treatments (Table 4.35). The principal components analysis of the tissue properties showed the principal component one (PC1) which explains 25% of the variance was dominated by phosphorus (0.717), zinc (0.724), calcium (0.647) and copper (0.651) with a negative loading for total nitrogen (0.686). PC 2 was dominated by molybdenum (0.680), copper (0.362), iron (0.395) but had a negative loading for calcium (-0.373) and boron (-0.650). The third and fourth PC showed a positive loading for magnesium (0.685), iron (0.745) and potassium (0.863) concentrations in the leaves of the maize crop.

The positive loading for nitrogen in the tissue showed that increase in the N fertilization of soil increases the nitrogen in the tissue and subsequently an increase of N content of the grain. This report was in agreement with that of Deosthale and Visweswar (1972) who reported that the level of nitrogen fertilizer influences the quantity and quality of protein maize.

4.34: Principal Component Analysis of Soil Chemical properties

Measurement	**Principal Components**						
Soil chemical Properties	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**
Eigen values	2.66	1.94	1.56	1.38	1.16	1.04	1.01
% contribution	17.72	12.94	10.41	9.23	7.70	6.94	6.74
Cumulative percent	17.72	30.63	41.04	50.30	58.00	64.94	71.68
	Rotated score of seven retain Eigen vectors						
NTRG SOL	0.0259	-0.062	0.315	**-0.442**	**0.358**	0.268	**0.573**
pH_{H_2O}	0.217	**0.349**	**-0.659**	-0.101	0.278	0.258	0.194
pH $CaCl_2$	**-0.511**	0.263	**-0.548**	0.193	0.067	0.153	0.129
Extrac Cu	**- 0.497**	-0.059	0.337	0.205	0.072	-0.055	**0.431**
Extrac Zn	0.099	-0.086	0.302	0.313	-0.145	**0.763**	-0.004
Extrac Fe	0.221	0.086	0.340	0.343	-0.019	0.149	0.035
Extrac B	**0.629**	0.228	0.131	**0.362**	-0.189	0.099	0.066
Av P	**0.573**	**0.425**	-0.200	0.013	-0.176	-0.066	0.258
Exch acidity	**0.703**	0.344	0.092	-0.033	-0.072	0.026	-0.014
Exch K	0.257	**0.638**	-0.072	**0.433**	-0.145	-0.023	-0.041
Exch Na	**0.436**	0.181	**0.392**	0.174	**0.505**	-0.086	-0.346
Exch Ca	-0.343	**0.689**	0.314	**-0.394**	-0.011	-0.070	-0.132
Exch Mg	**0.537**	**0.647**	0.230	-0.273	0.086	-0.035	0.037
OC	-0.236	-0.004	-0.130	**0.352**	**0.752**	-0.001	-0.115
Extrac Mo	0.204	-0.028	0.122	**0.426**	0.019	**-0.493**	**0.466**

4.35: First four Principal Components analysis for Tissue Properties

Measurement	**Principal Components**			
Tissue Properties	**PC1**	**PC2**	**PC3**	**PC4**
Eigen values	2.51	1.49	1.22	1.02
% contribution	25.11	14.87	12.17	10.22
Cumulative percent	25.11	39.99	52.15	62.37
	Rotated Score of Four Retain Eigen Vectors			
TNPLT	**0.686**	0.040	-0.026	**-0.372**
TK	-0.288	-0.123	0.129	**0.863**
TP	**0.717**	-0.025	0.231	-0.064
TCa	**0.647**	**-0.373**	-0.191	-0.175
TMg	-0.122	-0.294	**0.685**	-0.180
TCu	**0.651**	**0.362**	-0.029	-0.045
TZn	**0.724**	0.270	0.089	0.230
TFe	-0.001	**0.395**	**0.745**	-0.083
TB	-0.228	**0.650**	0.049	0.062
TMo	0.098	**-0.680**	0.275	0.076

4.24.3 Principal components analysis of grain nutrients

Two principal components were greater than one and cumulatively explained 84.6% of the variation of the grain quality parameters as seen in Table 4.36. The principal components one (PC 1) explained 51.56% of the total variance and was strongly correlated with total nitrogen in the grain (0.978), crude protein (0.978), lysine (0.364) and tryptophan (0.356) contents of the grain. The PC 2 explained loading for the grain analysis showed that two principal components were greater than 1 (> 1) and cumulatively explained 84.59% of the variation within the quality of the maize varieties and was dominated by lysine (0.830) and tryptophan (0.743) respectively (Table 4.36).

4.24.4 Gross margin analysis

The main objective of the analysis of any production enterprise is to determine the costs and returns of operations and associated level of profit. The result of gross margin analysis (Table 4.37) indicated that the highest profit of N 2, 960 was obtained by variety two (SUSUMA) at 50kgNha-^{1} with micronutrients application while the profit of N2,430 obtained by variety one (SAMMAZ 14) was similar at 50 kgNha-^{1} with micronutrients application.

Table 4.36: Principal components analysis of the nutrients in grain

Measurement	**Principal components**	
Grain parameters	PC 1	PC 2
Eigen values	2.06	1.32
% contribution	51.56	33.03
Cumulative percent	51.56	84.59
	Rotated Score of Two Retained Eigen Vectors	
TN Grain	**0.978**	0.201
Crude protein	**0.978**	0.201
Lysine	**0.364**	**0.830**
Tryptophan	**0.356**	**0.743**

Table 4.37 : Gross benefit analysis of quality protein maize and normal maize to nitrogen fertilizer and micronutrients application from 2008-2009 rainy season in Samaru.

NITROGN Kg ha^{-1}	VAR	Micro Nutr	Prod Cost	YIELD t ha^{-1}	Unit Price	Gross Revenue	Gross Margin	GM/ N invested
0	1	1	38250	1.11	4000	49997.85	11747.85	0.31
0	1	2	42250	1.11	4000	49999.95	7749.95	0.18
0	2	1	38250	2.14	4000	96249.30	57999.30	1.52
0	2	2	42250	1.75	4000	78750.45	36500.45	0.86
0	3	1	38250	2.00	4000	89999.40	21379.40	0.31
0	3	2	42250	2.89	4000	115555.33	73305.33	1.74
0	4	1	38250	2.90	4000	116083.87	77833.87	2.03
0	4	2	42250	2.22	4000	88888.67	46638.67	1.10
1	1	1	52630	1.24	4000	55626.00	2996.00	0.06
1	1	2	56630	1.47	4000	66244.95	9614.95	0.17
1	2	1	52630	2.31	4000	103750.05	51120.05	0.97
1	2	2	56630	4.22	4000	189999.75	133369.75	2.96
1	3	1	52630	2.47	4000	98777.87	46147.87	0.88
1	3	2	56630	3.32	4000	132777.73	76147.73	1.34
1	4	1	52630	4.39	4000	175554.93	122924.93	2.34
1	4	2	56630	3.06	4000	122221.33	65591.33	1.16
2	1	1	64620	0.97	400s0	43747.95	-20872.05	-0.32
2	1	2	68620	3.83	4000	131110.67	92860.67	2.43
2	2	1	64620	3.89	4000	174999.15	110379.15	1.71
2	2	2	68620	4.72	4000	212499.30	143879.30	2.10
2	3	1	64620	2.04	4000	81666.00	17046.00	0.26
2	3	2	68620	2.28	4000	91178.13	22558.13	0.33
2	4	1	64620	2.44	4000	97777.87	33157.87	0.51
2	4	2	68620	2.56	4000	102221.60	33601.60	0.49
3	1	1	76500	1.43	4000	64373.85	-12126.15	-0.16
3	1	2	80500	1.19	4000	53749.20	-26750.80	-0.33
3	2	1	76500	2.18	4000	97911.90	21411.90	0.28
3	2	2	80500	2.08	4000	93749.55	13249.55	0.16
3	3	1	76500	2.83	4000	113372.93	36872.93	0.48
3	3	2	80500	2.58	4000	103332.93	22832.93	0.28
3	4	1	76500	2.47	4000	98888.53	22388.53	0.29
3	4	2	80500	3.08	4000	123266.27	42766.27	0.53

Key: No= 0kgNha^{-1}, N1=50kgNha^{-1}, N2 = 100kgNha^{-1}, N3= 150kgNha^{-1}, M_O= without micronutrient application, M_1 = with micronutrients application, V_1= SAMMAZ 14, V_2 = SUSUMA, V_3 = SAMMAZ 12, V_4= SAMMAZ 11

CHAPTER 5

5.0 DISCUSSION

5.1 Physico-Chemical Characteristics of the Soils of the Experimental Site

The pH of the soil measured in water (H_2O) indicated moderate to mild acidity. This is typical of savanna soils with pH range of 4-6.5 (Jones and Wild, 1975). The pH value in water was 5.80 indicating that exchangeable aluminum toxicity may not be a problem in these soils (Dauda, 2004).

The low level of organic carbon content and organic matter in the soil of the experimental site was probably as a result of high proportion of sand content of the soil. Jones and Wild (1975) reported that organic matter content decreased latitudinal from the south to the north as the amount of rainfall received and vegetation cover decreases. Low organic carbon is attributed to inadequate supply of organic litter, bush burning, long dry season and intensive mineralization during the raining season (Dugje *et al*., 2008). The low level of organic carbon coupled with the sandy texture associated with the soils would normally encourage a rapid leaching of cations (Jones, 1973, Enwezor *et al.*, 1989) and consequently the soil would be low in CEC (Iwuafor, 1979), exchangeable bases and micronutrients.

The total nitrogen content of the soils was low. This low value was closely linked with low organic content of the soils which is typical of tropical savanna soils (Jones and Wild, 1975). Furthermore, the low N levels observed in the soil can be attributed to continuous cropping and increased land use intensity. Manyong *et al*. (1996) caution that soil depletion would be a serious problem in areas where land used intensification was on the increase. The low available P agrees with the report of Jones and Wild (1975) and Dugje *et al*. (2008), that P is one of the limiting nutrients to crop production in the northern savanna of Nigeria. This can be attributed to the low OM contents of these typical savannah soils. These levels were consistent with what was

observed in the soils of the northern Guinea savannah (Lombin *et al.*, 1985; Uyovbisere and Lombin, 1991). The exchangeable site was dominated by calcium and magnesium as characteristic of savanna soils. These cations are the most abundant in the exchange complex of savannah soils. The potassium fertility of the soil was rated medium to high with a mean of 0.64cmolkg^{-1}. The average range of soil K values for the Nigeria savanna soils is 0.5 – 0.25cmolkg^{-1} and this is rated as medium while value greater than 0.3 cmolkg^{-1} are regarded as high (Jones and Wild, 1975). The sodium content was generally low as may be expected for good arable soil. The ECEC values were low for both the greenhouse and field soils.

The micronutrient values were found to be low to moderate in the soils. These soils are therefore low in natural fertility and their productivity will decline quite rapidly under continuous cultivation, which by implication requires to be fertilized in order to sustain good crop yields (Lombin, 1987).

5.2 Greenhouse Experiment

5.2.1 Effects of nitrogen and micronutrients on the agronomic parameters

Response to nitrogen increased as nitrogen rates increased from the control to 150kgNha^{-1} SUSUMA (QPM) variety outperformed other varieties since it was taller, had more number of leaves and produced more biomass at low level of nitrogen applied (50kgha^{-1}). This implied that SUSUMA variety was more vigorous and efficient in the utilization of applied nitrogen and therefore would be more economical to manage profitably than SAMMAZ 14 (QPM).

The agronomic parameters of SAMMAZ 12 and SAMMAZ 11 (normal varieties) were not far from the quality protein maize in that they produced more number of leaves and tallest plants at the highest level of nitrogen applied (150kgha^{-1}N) respectively.

This result was supported by Ogunlela *et al.*, 1988 who reported that plant height and dry matter yield increased as the rate of nitrogen increases. The authors observed that with increase in nitrogen application up to 100 or 150kgha^{-1}, there was increase in plant height and dry matter production. Onasanya *et al.*(2009) in their findings reported that application of nitrogen enhanced vegetative growth of maize as expressed by the increase observed in number of leaves, plant height, leave area index, total dry matter per plant and relative growth rate of maize.

The orthogonal contrast showed a significant difference in plant height between the quality protein maize and the normal maize varieties.

Micronutrients application enhanced the performance of the quality protein maize in respect to the agronomic parameters because values were enhanced consistently with the application of micronutrients. This implies that QPM has the capacity to utilize high levels of micronutrients for the synthesis of the various relevant products and so may determine the differences in maize quality. However, this consistency was not seen in the normal maize, which means that their capacity to utilize high amount of micronutrients was low.

5.2.2 Effects of nitrogen fertilizer and micronutrients combinations on some selected chemical properties of the greenhouse soil

Soil pH decreased with nitrogen levels when micronutrient was not added to the soil. At low pH solubility, micronutrients cations is high and as pH is raised their solubility and availability to plants decreased especially in copper, zinc, iron, manganese and boron (Graham *et al*., 2002 and Fagbola and Ogunbe, 2007). On the other hands, the increase in soil pH with increase in nitrogen rates may be due to availability of micronutrients added to the soil. The pH range which was moderate to slightly acidic could be due to increase in iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) and aluminium oxide and hydroxide clay minerals in the soil.

The significant difference between the QPM_A and QPM_B suggested that one of the varieties is more qualitative than the other and both differ in the use of micronutrients.

The organic carbon content obtained was generally low compared to literature values and can be attributed to the inherent low carbon content of savanna soils (Ogunwole *et al.,* 2001). The nitrogen levels had no effect on the organic carbon content of the soil. This signified that nitrogen fertilizer in particular or chemical fertilizers in general did not increase organic matter content of the soil. This was in agreement with the reports of Bationo and Mokunye (1991) and Kwari *et al*. (1998). Kwari *et al*., 1998 stated that the use of mineral fertilizer generally resulted in high yield but are not sustainable under the environmental condition of the Sudan- Sahelian savanna sub-region.

There was a significant increasing trend in the content of total nitrogen with the addition of nitrogen fertilizer. The low total N of the soil may be due to plant uptake, runoff and leaching processes in the soil. This is in agreement with Jones and Wild (1975) who reported that soils of the savanna are generally low in N with values ranged from 0.08 to 0.29% with a mean of 0.05%. Comparing the two quality protein maize showed no significant difference in their response to nitrogen fertilizer.

The low P content observed may be due to low availability of P status in savanna soils which is a function of P content of the parent material which is low for most savanna soils of Nigeria (Uyovbisere, 1979). In spite of a blanket application of phosphorus, the levels were low to moderate which means more phosphorus is required for the management of grain legumes and for good crop yield.

5. 2.3 Effect of treatments on exchangeable bases

The micronutrients application may have enhanced the performance of the quality protein maize in respect to the exchangeable bases more than in the normal maize. This showed that the QPM varieties have the capacity to utilize high levels of micronutrient for the synthesis of the exchangeable bases more than the normal maize. It has been widely reported that plant species differ widely in their requirement for calcium and magnesium (Fageria, 1984). Calcium is an important nutrient in quality protein maize because higher calcium and higher niacin availability leads to higher tryptophan (Graham *et al.,* 1980) while potassium is essential in the synthesis of amino acids and proteins from ammonium ions.

5.2.4 Effects of nitrogen and micronutrients on extractable micronutrients

The effects of nitrogen and micronutrients on the soil micronutrients content of the soil shows that increased in the amount of micronutrients Cu, B and Zn in the soils were attributable to the soil acidity associated with the use of NPK fertilizer since the micronutrients cations are most soluble and available under acid conditions. In very acid soils, there is relative abundance of Cu, Fe, Zn and Mn (Brady and Weil, 2004). Zinc being an important micronutrient, since it has been found to be a constituent of dehydrogenase, proteinase and peptidase. It also has a specific role in the synthesis of tyrosine, tryptophan and phenylalanine (Brady and Weil, 2004). The contrast showed no significant difference in the varieties response to micronutrients.

5.3 Effect of Treatments on Nutrient Concentration of the Maize Plant Tissue

The treatments increase N above the control at added micronutrients for SUSUMA, SAMMAZ 12 and 11. The trend observed in the P concentration of the leaves suggests that P may have been well supplied in the soil and henceforth do not need both nitrogen and micronutrients fertilization. Phosphorus concentrations decreased with the application of

micronutrients since P fixation takes place at low pH while availability of micronutrients was more pronounced at low soil acidity. There was a significant difference in P concentrations of the two quality protein maize SAMMAZ 14 and SUSUMA with no micronutrient additions while with added micronutrients there was no significant difference between QPM_A and QPM_B.

The K content of the leaves increased also with treatments although the increase was not significant while the application of nitrogen fertilizer increases Ca and Mg concentration in the leaves of all the varieties (Tanimu *et al.*, 2007). From the above, both the quality protein maize and normal maize had different responses to the treatments.

The contrast analysis showed no significant difference between the quality protein maize and normal maize in their response to micronutrients except in molybdenum which was significant with or without micronutrients. There was no significant difference between QPM_A and QPM_B in the nutrients.

5.4 Field Experiment

5.4.1 Effects of nitrogen and micronutrients on grain and stover yields of maize

SUSUMA **(**QPM**)** maize was more superior in performance than all the other varieties, the trend of performance was SUSUMA > SAMMAZ 14> SAMMAZ 11>SAMMAZ 12.The combined grain yield estimation showed that the QPM varieties out yielded the normal maize by 17.93%. Similar results were obtained by (Ajayi *et al*., 1998 and Mani and Dadari, 2005). The response of the maize to nitrogen fertilizer is known to be related to the level of OM, the total nitrogen content of the soil and the variety of the maize used (Singh and Singh, 1979).

The contrast analysis revealed a highly significant difference ($P< 0.05$) in performance between the QPM and the normal varieties.

The significantly higher grain yield obtained in the QPM varieties was a product of variety effect. This was contrary with the report of Hussaini *et al.* (2001) which in their own work on performance of quality protein maize genotypes under different NPK fertilizer rates in Sudan and northern Guinea savanna zones in Nigeria, reported that the response to fertilization showed that QPM can be fertilized within the same range as normal maize and this is dependent on management and native soil fertility. The contrast analysis showed the two quality protein maize (QPM) varieties were significantly different from each other. This was supported by Dowsell *et al.*(1996) who reported that maize varieties differ in their yield potential, maturity period and canopy architecture.

The added micronutrients (Cu, Fe, Zn, B and Mo) enhanced the yield performance of quality protein maize (SAMMAZ 14 and SUSUMA) with SUSUMA being more superior with 1.81t ha^{-1} (Rogo *et al.*, 2001 and Kanwal *et al.*, 2010). This shows the synergistic role of micronutrients in improving plant growth and other biochemical and physiological activities. Bishnu *et al.* (2010) in their findings recorded highest grain yield with the crop supplied with all the micronutrients (B, Zn, S, Mn and Mo) applied in combination with NPK fertilizers at 120: 60:60kg/ha. Kanwal *et al*. (2010) found that zinc application to soil had a positive significant effect on grain yield and Rogo *et al.* (2001) reported an increase in grain yield of maize to zinc application.

The normal maize SAMMAZ 12 was not enhanced by the added micronutrients. This implied that both the QPM and the conventional maize when subjected to the same environmental factors can utilize micronutrients differently for yield increase. This result also shows that when the QPM and the conventional maize varieties were subjected to the same environmental conditions will supply and inherent soil micronutrients differently for yield increase.

The combined effects of the treatments showed that the QPM varieties were more superior in performance with addition of micronutrients. SAMMAZ 12 and SAMMAZ 11 (normal maize) though responded to nitrogen fertilization but responded poorly to micronutrient additions since they do not have the capacity to utilize high levels of micronutrients. QPM varieties had higher yields when suitable micronutrients levels were added to the soil and when nitrogen rate was at the maximum tested. This shows that the QPM varieties were more efficient in the utilization of micronutrients for optimum yield. This is supported by the correlation studies which showed that grain yield was positively correlated with zinc, boron and copper.

There was an increase in the Stover yield as nitrogen rates increased from the control to the highest rate of N ($150kgNha^{-1}$). This is in accordance with Tanimu *et al*, (2007), who recorded an increase in Stover yield as nitrogen rates increased in an experiment in Samaru. Daudu (2004) also observed an increase in the Stover yield of maize in SAMARU with increasing nitrogen rates 0-120kg Nha^{-1}. This increase showed that increase in nitrogen rates increased the dry matter yield. Onasanya *et al.*(2009) in their findings reported that application of nitrogen enhanced vegetative growth of maize as expressed by the increase observed in number of leaves, plant height, leave area index, total dry matter per plant and relative growth rate of maize.

This increase in growth parameters confirmed the importance of nitrogen as a constituent of protein and also as an integral component of many other compounds essential for plant growth processes including chlorophyll and enzymes.

The contrast analysis between the quality protein maize and the normal maize and also between the QPM_A and QPM_B was highly significant indicating that the varieties differ in their utilization of nitrogen fertilizers. When the Stover yield were combined for both years, it showed that the

QPM (SAMMAZ 14 and SUSUMA) responded to micronutrients addition in that the micronutrients enhanced maize growth performance which was an indication that QPM varieties have the capacity to utilize high levels of micronutrient for the synthesis of the biomass than the normal maize. This indicated that nitrogen application had pronounced effect in increasing vegetative growth of crop plants.

Micronutrients application enhanced the Stover yield of SAMMAZ 14 and SUSUMA varieties. SAMMAZ 14, SUSUMA and SAMMAZ 11 conventional maize responded to micronutrient fertilizers. This implied that SAMMAZ 14, SUSUMA and SAMMAZ 11 varieties were more vigorous and efficient in the utilization of applied micronutrients while SAMMAZ 12 did not respond to micronutrients application.

5.5 Effect of Nitrogen on Growth Parameters of Maize

The result indicated that nitrogen application had pronounced effect in increasing vegetative growth of crop plants. Ogunlela *et al.* (1988) reported increase in plant height and dry matter production of maize while some workers also reported that application of nitrogen significantly increase plant height, number of grain per ear and grain yield of maize (Mohammed *et al.*, 1978; Mahmood *et al.*, 2001 and El-Gizawy, 2009).

Ayub *et al*. (2002) also observed that growth parameters like plant height, number of leaves per plant, stem diameter; leaf area/plant green fodder yield, dry matter yield and dry matter percentage were influenced by the application of nitrogen.

Wajid *et al.* (2007) evaluated the effect of three nitrogen levels and three maize cultivars, and observed that nitrogen rates significantly affected plant height, 1000grain weight, grain yield and harvest index. Jaliya *et al.* (2008) observed that increase in fertiliser rate from 0:0:0 to 150:26:50kgNPKha^{-1} significantly increased the number of grains per cob and 100 grain weight

of quality protein maize while further increase to 180:35:66kgNPKha^{-1} significantly reduced it in both years for number of grains per cob and 100 grain weight only in one year.

The increase in plant height in response to micronutrient application may be due to its active role in metabolic processes including carbohydrate metabolism (Bishnu *et al;* 2010). Micronutrient applications enhanced the quality of maize varieties especially for good growth and adequate level of substrates for proper physiological functions. This may be expressed in plant vigour.

5.6 Effects of Treatments on some Chemical Properties of the Soil

The pH of the cropped soil was found generally to be moderate to slightly acidic and fell within the pH of most Alfisols in the Nigerian savanna which is 5.5-6.8 (Jones and Wild, 1975). The pH decreases over the years with increase in nitrogen application. This is consistent with acid producing nature of fertilizer due to its nitrogen and phosphorus content (Pestov, 1994). This implies that continuous use of inorganic nitrogen fertilizer will increase soil acidity and would ultimately result in reduction in yield of crops. The remarkable decreased of the pH over the years is consistence with the findings of Kang and Wilson, (1987) who reported that the savanna soils are generally acidic and poorly buffered with respect to most nutrients. Increase in pH normally decrease solubility and availability of micronutrients especially Cu, Zn, Fe, Mn and B in soils.

This implies that P supply was improved with increase in nitrogen rate and with the application of micronutrients. Available P contents was low to moderate, this inferred that available P was better build up with highest nitrogen rate and micronutrients formulation. However, the mean values were not significant from each other. Mokwunye (1974) also reported a range of 0.01-0.04% in the savanna zone. Increased plant vigour would definitely

increase rhizospheric activities and root secretion of organic acids that may have rendered soil P more available. The organic matter values were low and good fertilization will be crucial for maintaining a good level of organic matter content in the soils, which is a primary index factor of soil fertility and responsible for furnishing the soil with micronutrients (Brady and Weil, 2004).

The total N was low (Jones and Wild, 1975). The lower total nitrogen recorded may be due to the rapid growth of maize which made the maize plant capture more nitrogen which is already in the plant available form. This would have enhanced higher rate of nitrogen uptake by plants resulting in the depletion of nitrogen in the soil at a much faster rate (Eche, 2011). The low nitrogen could also be related to an effective microbial degradation of organic matter resulting in low fertility characteristics of the soils of northern Guinea savanna (Eche, 2011). The treatments did not significantly increase the nitrogen content of the soil (Brady and Weil, 2004). This may be due to solubility, volatility and leaching aside from plant uptake.

Calcium has been the element most prevalent as component compound of the nutrients in fertilizers and the most abundant basic cations in tropical soils system (Raji and Owootomo, 2007). The increase in exchangeable calcium and magnesium could be attributed to the high rate of nitrate uptake which is favoured by low pH conditions created by high levels of nitrate absorption by plants. The amount of potassium was low to moderate. It has been reported that higher amount of K allowed for the efficient use of more N which resulted in better early vegetative growth and higher grain and straw yield as K and N rates increased. Crops respond to higher K levels when N is sufficient and greater yield response to N fertilizer occurs when K is sufficient. Interaction between K and micronutrients shows an increase in utilization of Cu, Mn

and Zn while with B, Fe and Mo had resulted in decreased uptake when K was added. K also interferes with uptake of Mg and this is common in corn.

The rate of copper is not low compared to the range of 0.2-0.3 $mgkg^{-1}$ which is termed low. When copper is low in soil, it may contribute to low grain yield (Tisdale *et al.,* 1993). The rate of Cu uptake in plants is among the lowest of all the essential elements (Kabata-Pendias and Pendias, 1992). This suggests that the extractable zinc content of the soil is high and available in the soil since the pH of the soil was moderately acid (pH 6.6). These values show that the iron content of the soil is moderate and adequate for crop production. Iron is an important micronutrient although present in large quantities in most soils but its deficiency is a common nutritional disorder in many crop plants causing chlorosis, poor yields and reduced nutritional quality (Aref, 2011).

Boron content increased as nitrogen rate increased from the control to the highest level of nitrogen supplied the range of boron was $0.14mgkg^{-1}$ -$0.20mgkg^{-1}$. The report is in accordance with Lombin (1985), who reported the levels of available boron in the savannah soils to be in the range of 0.14-$0.25mgkg^{-1}$ which is sub-optimum for the growth of boron sensitive crops. Daudu (1989) got a range of 37.9-$44.5mgkg^{-1}$B in some savannah soils developed from loess. Kparmwang (1993) obtained a range of 19-$160mgkg^{-1}$B in basaltic soils in Northern Guinea Savannah soils of Nigeria. Oyinlola (1997), reported a range of 0.05-$0.18mgkg^{-1}$ with a mean of $0.105mgkg^{-1}$ extractable boron. Boron deficiency is one of the most widespread micronutrient deficiencies in the Northern Nigeria savannah region. Boron is among those elements for which many plants have low range of tolerance and the amount of boron required for plants is so small that critical limits of boron toxicity and deficiency are very narrow (Oyinlola and Chude, 2004). The concentration of boron in soils and plants not only varies with soil type, plant species and

environmental conditions, but also its excess or deficiency may affect the plant growth and production, because there is small concentration range between deficiency and toxicity in soil-plant system (Tariq and Mott, 2007). The increased availability of micronutrients: Cu, Fe and Zn are attributable to reduced soil pH and acidity associated with the use of NPK fertilizer. The micronutrients cations are most soluble and available under acid conditions (Ayeni and Adetunji, 2010). Brady and Weil (2004) postulated that there is a relative abundance of Fe, Mn, Zn and Cu in very acid soils. Molybdenum is essential for nitrogen metabolism in corn where it is needed for the function of nitrate reductase. Molybdenum is deficient at low pH but it helps in utilization of nitrogen. Mo deficiency in maize has been found to shorten internodes, increase leaf area and reduce pollen development (Yermiyahu *et al*., 1995).

5.7 The Effect of Nitrogen and Micronutrients on N, P, K, Ca and Mg contents of the Maize Leaves

The N concentration in the leaves generally increased with increase in nitrogen levels in the years and in the combined analysis but the nitrogen contents of the index leaf of the maize was low. The additions of micronutrients helped the nitrogen concentrations in the leaf of plants to increase with increase in fertilizer rate, which is an indication of improvement in soil fertility although the difference was not significant (Tisdale *et al.,* 2007). The K content of the leaves increased also with treatments although the increase was not significant. Tanimu *et al,* (2007) in an experiment carried out in Samaru reported that increase in application of nitrogen fertilizer tend to increase the leaf concentration of calcium and magnesium although calcium accumulation is always low in the shoot than in the root.

5.8 Effects of Nitrogen and Micronutrients on the Micronutrients Concentration on the Maize Index Leaf

The rate of Cu uptake in plants is among the lowest of all the essential elements (Kabata-Pendias and Pendias, 1992). This is in accordance with Fiel et al., (2005), who observed the shortage of N or P caused low maize yield but enhanced micronutrient contents in plants except that of Cu in stalks. The zinc leaf concentration was adequate and the varieties differ in the absorption of zinc in the ear leaf although the contrast analysis showed no significant differences between the varieties. In an experiment that looked at the response of maize to zinc fertilization it was reported that plant height, cob length, number of seeds/cob and 1000-seed weight responded positively to Zn fertilization (Hossain *et al*., 2011). Iron is an important micronutrient although present in large quantities in most soils but its deficiency is a common nutritional disorder in many crop plants causing chlorosis, poor yields and reduced nutritional quality (Aref, 2011).

Many root crops, leguminous crop and many fruit and forest trees have a relatively large boron demand while the cereals and legumes are more tolerant to a low boron supply in the soil. Boron requirement varies with soil type, plant species and environmental conditions but also its excess or deficiency may affect the plant growth and production because there is small concentration range between deficiency and toxicity in soil- plant system (Tisdale *et al.*,1985; Muzzammil *et al.*, 2009). Boron is an essential micronutrient that facilitates the translocation of sugars, ensures proper seed set, increases yield and modifies the nutritional quality of crops (Gupta,1993).

5.9 Effect of Nitrogen Fertilizer on Nitrogen, Crude Protein, Lysine and Tryptophan contents of the Maize Grain

The nitrogen concentration in the grain increased as amount of nitrogen increased from the control or zero level to the highest level of nitrogen supplied ($150kgNha^{-1}$).This was supported by Thomison *et al.* (2004) who reported that grain protein concentration showed more consistence response to increasing nitrogen rates than did yield. The grain crude protein also significantly increased with increase in nitrogen rates. Since N is a major constituent of protein, applying N fertilizer would enhance protein synthesis or build up in cereal grains like maize. The highest crude protein recorded in this work was 17.45% for SUSUMA (QPM) and 15.72% for SAMMAZ 11 (normal maize) these were high compared to 9.11% recorded by Osei *et al.* (1999) and Prasanna *et al.* (2001) for QPM. Aduku (2005) reported a value of 8.0% crude protein for normal maize and QPM. The variation in the quantity and quality of the crude protein in the grain maize could be attributed to the level of nitrogen in the soil since the level of nitrogen fertilizer influences the quantity and quality of protein in maize (Deosthale and Visweswar, 1972).

Micronutrients application increased the lysine and tryptophan content of the QPM varieties since values were increased by the application of micronutrients. This suggests in clear terms that QPM varieties had higher capacity to utilize applied micronutrients for the synthesis of the relevant amino acids. It can be inferred from this that though normal maize and QPM varieties could be exposed to the same environmental conditions and take up same amounts of micronutrients, the QPM varieties have genetic capacity to synthesize high levels of amino acids and so would have nutritionally higher quality grains.

This infers that SAMMAZ 11 though a normal maize responded to micronutrients application although at the highest application of N fertilizer which subsequently increased the protein content. This infers that the micronutrients content of the QPM varieties are similar to the normal maize. This report was in agreement with (Brown et al., 1998) who reported in their works that micronutrient and lipid content of high lysine maize are similar to normal maize.

In the study, SUSUMA (QPM) had highest crude protein, lysine and tryptophan contents with nitrogen fertilizer and micronutrients while SAMMAZ 14 performed better at no micronutrients but with optimal level of nitrogen. The conventional maize had protein, lysine and tryptophan contents at the highest application of nitrogen. SUSUMA, quality protein maize had just lysine content of 1.23% and 11.21% with or without micronutrient better and tryptophan content of 3.85% and 15.25% better than SAMMAZ 11 a normal maize variety. This implies that giving the normal maize variety same environment by exposing them to same management practices and soil factors can help the normal maize pick up more essential amino acids.

The QPM and the normal maize differed significantly from each other with respect to lysine and percentage tryptophan ($P<0.05$). This probably suggests a high variability that exists in maize genotypes with respect to these biochemical components. Plant breeders may therefore found this attribute useful in genetic manipulation and cultivar development for enhance protein biochemical components. Forages and some cereals other than maize support the view that nitrogen fertilization up to and beyond the point of maximum yield increases the concentration of nitrogen in the tissue (Andersen and Koie, 1975). Lysine and tryptophan values in this study were comparable with Vassal *et al*. (1979) who reported range of lysine content of 1.8- 2.0% and tryptophan content of 0.9-1.06%. Sema and Rooney (1994) reported higher lysine content of 4.08 g/100g protein and tryptophan content of 0.75 g/100g protein in QPM. They reported lysine

contents of 3.04 g/100g protein and tryptophan contents of 0.59 g/100g protein in the normal maize.

SUSUMA had higher marginal protein, lysine and tryptophan contents with micronutrients application than the normal maize which infers that QPM cultivars had greater lysine and tryptophan contents than the normal cultivars and that lysine and tryptophan contents increased in both the QPM and normal varieties as the N level in the soil increased. This shows that given the set of conditions that influenced quality in QPM, the quality of the normal maize may be improved. This is consistent with the results of Pixley and Bjamason (1993) and Bhatnajar et al. (2003) who reported the superiority of QPM cultivars over non- QPM cultivars for protein quality. The contrast analysis showed no significant difference in all the parameters however this may indicate there is genotypic variation in grain protein content in both the QPM and the normal cultivars.

Santayehu (2008) reported that the protein content of the kernels of corn increased with increasing nitrogen supply in the soil. Potassium increases grain protein content of wheat thus improving quality while it increases the oil content of maize grain (Rejado, 1979). Whitehouse (1971) also reported that the cause of high protein content in maize is a restriction on growth which is due to a shortage of water or some adverse condition during the later stages of grain-filling.

Anonymous (2004) showed that there was a direct relationship between the soil and the nitrogen applied to the soil and the contents of crude protein, zein and leucine in maize grain. He concluded that variation in content of the amino acids suggest that nitrogen-fertilization in relation to plant population as well as variety has an important effect on protein composition. The contrast analysis showed no significant difference in all the parameters however this may

indicate there is genotypic variation in grain protein content in both the QPM and the normal cultivars.

5.10 The Correlation Coefficient between Agronomic Parameters and Grain Parameters

There was a positive relationship between the grain yield and Stover yield, 1000grain-weight and plant height indicating that all these growth parameters increases or affects the grain yield of the maize. This is expected as a vigorous plant would invariably yield good harvest. The grain yield was negatively correlated with the nitrogen and protein contents of the grain which means the protein concentration in the grain decreased as grain yield increases. This is in accordance with Orit- Monasterio (2001) who reported same in their work. The protein content of the grain was positively influenced by the grain nitrogen. The lysine and tryptophan contents of the maize were not significantly affected by the grain yield which suggests that there was no particular pattern of relationship established between yield and quality. Lysine had a positive influence on the tryptophan content of the grain which means that increase in lysine content increases the tryptophan content of the maize.

5.11 The Correlation Matrix between Grain Yield, Grain Parameters and some Soil Chemical Properties.

The grain yield increases as nitrogen content of the soil increased and soil pH was favorable to support the growth and yield of the maize since the pH of the soil was moderately acidic. Micronutrients such as zinc and boron supply from the soil also increased grain production since they are constituent of protein synthesis. This is in accordance with Osiname *et al* (1973) who reported that low zinc in the soil have been found to reduce maize yield in several parts of Africa. Tahir *et al.* (2009) inferred that Zn fertilization in maize significantly improved plant height, 100 grain weight and protein content of the maize. The grain yield was negatively

correlated with exchangeable calcium. The soil pH increases with exchangeable acidity, available phosphorus and boron while it was negatively correlated with organic carbon, exchangeable magnesium and extractable zinc. The availability of zinc decreases as soil pH increased which implies that at low pH (moderately acidic), there was availability of micronutrients and macronutrients such as Zn, B, Cu, Ca and N contents in the soil and this also implies that within allowable limits for conducive crop performance, increase in soil pH, soil N, Ca, Zn, B and Cu would increase grain yield. Gromove *et al*. (1994) reported that the efficiency of utilization of nutrients from fertilizers applied to soils depends on weather conditions, biological characteristics of the crops and fertilizer rates.

There was a negative and significant relationship between the grain yield and the protein content of the maize in that as grain yield increases the protein content of the grain decreased. This infers that the quantity of grain produced do not determine the quality of the maize. Increased nitrogen content of the grain is strongly associated with increased crude protein, exchangeable acidity, pH and organic carbon contents of the soil and uptake in sodium, magnesium, zinc, boron and copper contents of the soil increased the content of grain N. The crude protein content of the maize increases as the organic carbon and pH contents of the soil increased with negative correlation with Na, B and Cu. This shows that increase in uptake of these nutrients from the soil will increase the crude protein contents of the maize. Lysine and tryptophan contents of the grain maize varieties are positively affected by N, Na, Cu contents of the soil and exchangeable acidity. This infers that the amino acids increase with soil N and shows that all protein fractions in the grain are reduced when N in the soil is limiting (Pixley and Bjamason, 1993).

The increase in soil pH demonstrates a strong association with phosphorus, sodium, zinc and boron contents of the soil while availability of zinc decreases as soil pH increases. Organic carbon and magnesium contents of the soil increased as soil pH decreases. This infers that pH of the soil was favorable to support the growth and yield of the maize since the pH of the soil was moderately acid while increase in acidity of the soil increase phosphorus contents of the soil. Increase in nitrogen, boron and copper contents of the soil takes place at decrease soil acidity. Phosphorus is positively and significantly correlated with potassium and negatively correlated with calcium. This indicated that increase in phosphorus increases the potassium content and decreased the calcium content of the soil. This is called calcium induced P. K interacts with P and together they can interact with other nutrients in soil

5.12 Correlation with Plant Parameters

Zinc and potassium content of the index leaf increased as grain yield increased while calcium, magnesium, potassium, phosphorus, boron and molybdenum in the index leaf decreased the grain yield. The nitrogen content of the leaf increased as magnesium, boron and iron contents increases while it negatively decreased with zinc. This indicates that decrease of these nutrients in the plant tissue due to uptake will increase the grain and protein contents in the plant tissue.

The relationships between the micronutrients in the soil and plant tissue micronutrients implied that application of micronutrients (Cu, Zn and B) to the soils increased the micronutrients concentration of the plant tissues and by implication increased the micronutrients in the grain.

5.13 Principal Component Analysis (PCA) of the Soil Chemical Properties

Seven principal components were greater than one (>1) and the fifteen retained chemical properties clustered together and cumulatively explained 71.68% of the variation within the soil fertility treatments. Principal components one (PC1) or cluster 1 demonstrates the influence of soil pH on Cu, B, Na, Mg and P availability and these can be interpreted as soil reaction.

Boron adsorption is known to increase with soil pH while P fixation is high at low pH especially in soils with preponderance of Fe and Al oxides. The negative loading for extractable boron and exchangeable magnesium may be due to low level of them in the soil and high phosphorous is antagonistic to boron in low pH soils. The dominance of phosphorus in this cluster confirms the moderate to slightly acid conditions of the study soil pH (6.6) and since micronutrients solubility and availability decreased as soil pH increases hence decreased in availability of copper and boron in the soil. This suggests that micronutrients availability was not influenced by soil pH as seen in the correlation tables. Copper availability is governed by the total amount in soil (Lucas and Knezek, 1972) and influenced by soil pH in that availability decreases strongly with increasing pH although less than in other micronutrient.

Clusters 2 and 3 can be interpreted as soil exchange site furnishing the soil solution with exchangeable K, Ca and Mg as a function of soil acidity. This showed the reaction of the soil and the pH of the soil is low to moderately acidic which is suitable for agricultural purposes. This can also be viewed as a measure of the calcium content of the soil and generally additions of calcium may result in a lower concentration of potassium and magnesium. Calcium and magnesium are the dominant exchangeable bases and they are important as activator of many enzyme systems such as one involved in the synthesis of nucleic acids. Calcium is an important nutrient in quality protein maize because higher calcium and higher niacin availability leads to higher tryptophan

(Graham *et al.,* 1980). Potassium as a nutrient is essential in the synthesis of ammonium acids and proteins from ammonium ions. Adequate supply of potassium was also essential for efficient photosynthesis and maintains stability in plants (Rejado, 1979).

The PC 4 although has an additional 9.23% of the total variance. This cluster is purely organic colloid responsible for furnishing the soil with micronutrients (Brady and Weil, 2004). Some of the micronutrients tend to be held as complex combinations in organic (humus) colloids. Correlations between organic matter and contents of copper, molybdenum and zinc had been noted (Brady and Weil, 2004). The availability of boron and molybdenum in this cluster though held in organic colloids must be due to their release through decomposition and hence improved the fertility of the soil. Boron and molybdenum are important micronutrients in that boron facilitates the translocation of sugars, ensures proper seed set, increase yield and modifies the nutritional quality of crops while molybdenum is essential for nitrogen metabolism and in the production of corn (Gupta, 1993). The organic carbon content showed a positive loading means that although the soil of the savanna is low in organic matter, the organic carbon content of the soil used was suitable for the maize grown.

PC 5, 6 and 7 had an additional 7.70%, 6.94% and 6.74% respectively of the total variance and had a positive loading for organic carbon, exchangeable sodium, extractable zinc, copper, molybdenum and soil nitrogen respectively. The loading for zinc was high while copper was low and this may be due to its solubility in soils and the uptake of Cu by plants which fall rapidly as the soil pH increases. Zinc is important for protein synthesis related to pollen tube formation (Ender *et al*., 1983), responses of plants to stress, and carbohydrate dynamics (Shrotri *et al*., 1983). It has been found to be a constituent of dehydrogenate, proteinase, peptidase and aldolase, adequate zinc is absolutely necessary for the synthesis of alanine, glycine, proline, threonine, serine, valine, etc and it has a specific role in the synthesis of tyrosine, tryptophan and

phenylalanine (Brady, 1984). The major nutrient for crude protein production is nitrogen and organic carbon contents of the soil. The low nitrogen contribution, only 6.74% interpreted that the protein content of the maize will also be low which will lead to low prolamin and hence good quality of the maize produced. The soil nutrient factors determining the protein quality are mainly P, K, Ca, Mg, Zn, B, Cu and Mo .

5.14 Principal Components Analysis of the Tissue Properties

The principal components analysis of the tissue properties showed the principal component one (PC1) which explains 25% of the variance was dominated by phosphorus, zinc, calcium and copper with a negative loading for total nitrogen. PC2 was dominated by boron but had a negative loading for molybdenum. The third and fourth PC shows a positive loading for magnesium, iron and potassium concentrations in the leaves of the maize crop.

However, from the above, the zinc in the tissue of the maize will be strongly related in that zinc has been found to be a constituent of dehydrogenate, proteinase, peptidase and aldolase; adequate zinc is absolutely necessary for the synthesis of alanine, tryptophan, phenyalanine, proline, valine etc., zinc is also required for protein synthesis (Mengah and Kirby, 2011). Copper is also an important micronutrient, it is involved in both photosynthesis and respiration and capable of acting as electron carriers in the enzymes systems that brings about oxidation – reduction reactions in plants (Brady and Weil, 2004). Copper is directly concerned in the formation of y-amino-n-butyric acid in the plant nodules and as this acid is a particular constituent of nodule protein, the effect of copper appears to be a unique requirement. The moderately acidic condition of the soil also favoured the availability of copper and zinc.

The positive loading for phosphorous may be influenced by the soil reaction because high level of phosphorous reduces zinc and to a lesser degree calcium uptake. This corroborates the

finding in the study where the soil available P was not significant. The correlation Table 4.33 showed a positive correlation between the soil micronutrients (Cu, Zn, and B) and the tissue Cu, Zn and B contents of the plant tissue. These correlations are positive and represented weak associations between micronutrients and their levels in the tissue.

It can be interpreted that increased levels of these micronutrients increased their accumulation in the maize tissue and maybe the maize grain. This was similar to Imakumbili *et* al., (2010) who found a similar association between soil and grain zinc, iron and copper. In the first loading of the parameters, there were positive correlation between the phosphorous, calcium, copper and zinc level in the maize tissue in this order: TZn > TP > TCu > TCa with a negative loading for TN. The principal components two (PC 2) had an additional 14.87% of the total variance and was dominated by boron with a negative loading for molybdenum. The second loading showed a positive loading for boron and negative loading for molybdenum. Its availability may be due to the low content of organic matter of the soil studied and the B content may have contributed to the protein contents of the maize since boron commonly limits yield and its demand for cereals is low. The negative loading for molybdenum may be due to high copper and low phosphate levels of the soil used in the experiment. The third and fourth PC shows a positive loading for magnesium, iron and potassium concentrations in the leaves of the maize crop. In the soil used for the experiment calcium and magnesium were dominant exchangeable bases while the uptake of potassium was significant. Iron is needed for chlorophyll synthesis and in the synthesis of proteins and nucleic acids. It is also a component of enzyme nitrogenase.

The positive loading for nitrogen in the tissue showed that increase in the N fertilization of the soil decreases the nitrogen in the tissue and subsequently a decrease of N content of the

grain as reported earlier that increase in N fertilization decreases the quality of the maize (Deosthale and Visweswar, 1972).

5.15 Principal Components Analysis of Grain Nutrients

Principal component one (PC1) increased with increasing crude protein, nitrogen, lysine and tryptophan contents of the grain. This was in agreement with the correlation analysis that showed a positive association between the crude protein, nitrogen, lysine and tryptophan contents of the grain showed that the factor loadings of crude protein and total nitrogen of the grain contributed to the grain protein content of the maize which eventually dictated the quality of the maize. This suggests that the crude protein and the nitrogen vary together in that if one increases the other will increase also. This can be viewed as a measure of the quality of the crude protein and the PC correlates most strongly with the crude protein content of the maize. .

The second loading showed that increase in lysine content of the grain also increased the tryptophan content of the QPM (lysine > tryptophan) and that these two amino acids are very important in the quality of the maize grain. The quality of the maize can be viewed as a measure of these amino acids which must have resulted in the micronutrients added with the nitrogen fertilizer to the soil.

The second loading showed that the quantity of lysine was greater than tryptophan (lysine > tryptophan) and that these two amino acids were very important in the quality of the maize grain. Nitrogen in the grain was not correlated with the lysine but was negatively correlated with tryptophan. It had been reported that the level of nitrogen fertilizer influences the quantity and quality of protein maize (Deosthale and Visweswar, 1972). Sawhney and Mark (1969) also reported that higher protein in response to fertilizer N was mainly the result of the increased accumulation of prolamin, a poor quality protein in the grain.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

This study was conducted to evaluate the effect of nitrogen and micronutrients on the yield and protein quality of maize in a northern Guinea savannah Alfisol of Nigeria. Maize consumed in Nigeria has a nutritional constraint in that it is low in two essential amino acids, lysine and tryptophan, and so are of poor quality for weaning babies and animal nutrition. Micronutrient additions to the major macronutrients are becoming necessary to enhance the fertility of the soil.

Breeders have developed genetically stable materials, environmental factors seem to have great influence on the protein content of the crop, since environmental and management factors interact strongly, and may influence the variability of the chemical composition of the maize grain. With these developed varieties in place, this work was conceived to define the soil and crop factors that influence protein contents and quality in these maize varieties with the following objectives (i) to determine the suitable levels of nitrogen and micronutrients on the yield of maize (QPM and normal) varieties in the northern Guinea savanna (ii) to establish the effect of nitrogen and micronutrients on the lysine and tryptophan content of maize and (iii) to determine the soil nutrient factors influencing nutritional quality of QPM varieties introduced to the northern Guinea savanna in comparison with the normal maize.

To achieve these objectives, greenhouse and field trials were conducted to determine the levels of nitrogen and micronutrients needed for the maintenance of the maize varieties and to assess the performance of the QPM in comparison with the conventional maize varieties.

The soils used for the study were Alfisols, slightly acidic in reaction with low to moderate organic carbon content (0.4-0.58%), low total nitrogen (0.06-0.07%) and available P content

(6.8-7.58mgkg-^{1}). The treatments consisted of four rates of nitrogen fertilizer as Urea (0, 50, 100 and 150kgNha^{-1}) and micronutrient cocktail formulation containing Cu, Zn, Fe, B and Mo. The following conclusions were based on the results obtained in this study:

i. The greenhouse study revealed that micronutrients application enhanced the performance of the QPM than the normal maize. SUSUMA variety (QPM) was superior in performance to SAMMAZ 14 (QPM) in that it produced taller plants (65.50cm), more number of leaves (12.75) and higher dry matter yield of 6.67g/pot at low application of nitrogen (50kgNha^{-1}).

ii. The mean response of maize DMY to nitrogen levels gave a general response to N levels up to 100kgNh^{a-1} with adequate amounts of micronutrient. Greenhouse study revealed that micronutrients application enhanced the performance of the QPM than the normal maize.

iii. The results from the field showed that all the maize varieties significantly responded to the nitrogen applied and that the QPM (SAMMAZ 14 and SUSUMA) varieties were superior in their response to nitrogen at 100kgNha^{-1} while the normal maize (SAMMAZ 11 and SAMMAZ 12) responded significantly to nitrogen up to the highest rate applied (150kgha^{-1}) in this order of response SUSUMA> SAMMAZ 14 > SAMMAZ 11 > SAMMAZ 12. The trials showed that maize growth and yield parameters responded to the applications of inorganic fertilizers and micronutrients. This indicated that the response of maize to nitrogen fertilizer was superior with micronutrients but the normal maize did not respond to micronutrient except SAMMAZ 11 although the response was not at significant level.

iv. The contrast analysis that compared the performance showed that the QPM varieties significantly outperformed the normal varieties by 17.93%. It also showed that there was a significant difference in the potentials of QPM_A and QPM_B varieties. The added micronutrients enhanced yield of SAMMAZ 14 and SUSUMA (QPM) while SAMMAZ 11 SAMMAZ 12 were not enhanced by added micronutrients.

v. The Stover yield also increased as the nitrogen rate increased. The Stover yield trend was in this order: SAMMAZ 11 > SUSUMA > SAMMAZ 14 > SAMMAZ 12. This did not follow any particular trend with respect to the nature of the varieties as it was for the grain yield.

vi. Applications of nitrogen and micronutrients increased plant heights and 1000- grain weight in all the varieties with the QPM varieties being superior.

vii. The pH of the soil was moderate to slightly acid and decreased with nitrogen and added micronutrients, while organic carbon was low.

viii. The available phosphorus and nitrogen contents of the soil increased with micronutrient additions though the exchangeable basic cations were not influenced significantly by the addition of micronutrients.

ix. The addition of micronutrients increased Cu, Zn, Fe and B concentrations in the leaves of the QPM varieties in that they were more efficient in micronutrients utilization while the normal maize response was with no micronutrients application. Mo concentration did not increase with added micronutrients in all cases.

x. The interaction between nitrogen fertilizer and micronutrients gave a crude protein content of 9.1%, lysine content of 14.3% and tryptophan content of 16.7% by the QPM varieties over the normal maize varieties. The crude protein recorded was

higher in this study than that recorded in literature. The crude protein was high compared to 9.01% recorded by Osei *et al.* (1999) and Prasanna *et al.* (2001) for QPM. Aduku (2005) reported a value of 8.0% crude protein for normal maize and QPM**.**

xi. SUSUMA, the better of the QPM had just lysine content of 3.19% and 5.08% tryptophan better than SAMMAZ 11 a conventional maize variety which implies that giving the normal maize variety the same environment and same management factors can help the normal maize to pick up more essential amino acids.

xii. The correlation analysis showed that all the agronomic parameters influenced grain yield positively. The grain yield increased as soil pH, total nitrogen, calcium, zinc, copper and boron contents of the soil increased. However, N and crude protein contents decreased with increase in grain yield indicating some elements of dilution of nutrients taken up as yield increased.

xiii. Grain N and crude protein contents increased as totals soil N, pH, and organic carbon contents of the soil increased while lysine and tryptophan contents of the maize increased with N and K contents of the soil and was negative and significantly correlated with B and exchangeable acidity of the soil.

xiv. The principal component analysis supported that as grain yield increases, the nitrogen and the crude protein contents of the maize decreased. Lysine positively influenced the tryptophan contents of the maize. The principal component analysis showed that potassium, phosphorus, magnesium, iron, boron and copper contents of the leaf contributed positively to the maize tissue and subsequently the grain quality.

xv. The factors most responsible for enhanced grain quality in the QPM varieties from the correlation analysis and PCA were nitrogen, potassium, calcium and zinc contents of the soil.

6.2 Conclusion

The following conclusion can be drawn from the study:

- That the soils were slightly deficient in micronutrients as yield levels of maize were increased consistently by margins of 18 – 26% with the application of micronutrient cocktail. .
- The QPM varieties attained maximum performance at 100kg N/ha relative to 150kg N for normal maize, and so were more N efficient and superior to normal maize in yield by 21.43% over the normal maize. .
- That the critical nutrient element which influenced protein quality the mist in maize were N, K, Zn and Ca, which suggests the need to fortify commercial compound fertilizers with Zn for high levels of lysine and tryptophan content in maize grain.

6.3 Recommendations

- Quality protein maize should be adopted by farmers in the northern Guinea savanna zone of Nigeria since the same environment used for the normal maize is conducive for the cultivation of the quality protein maize.
- The micronutrients should be applied separately for easy assessment of their role in quality production.
- The chemical reactions of the amino acid should be studied especially their functional groups. This may help to determine what actually triggers the level of increase in the lysine and tryptophan contents of the maize.
- SUSUMA (QPM) variety is recommended to farmers because it was more economical in the use of nitrogen fertilizer since it gave the highest response to both N fertilizer and micronutrients.

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APPENDICES

Appendix 1: Rainfall, Temperature, Sunshine and Relative Humidity during the experimental period 2008-2009.

THE MEAN MONTHLY SAMARU WEATHER 2008

Month	Humidity %	Temp (^{O}C) Max	Temp (^{O}C) Min	Sunshine Hours	Wind speed Km/d(average)	Open Pan Evaporation Mm/day	Rainfall Mm
1	19.74	28.97	13.60	0	191.19	8.20	0
2	12.31	31.76	15.69	0	142.05	7.52	0
3	19.55	38.61	19.90	0	141.61	6.29	0
4	36.53	37.27	21.67	0	150.71	6.36	72.6
5	63.03	34.94	21.90	0	204.76	6.15	95.2
6	72.33	32.97	20.87	6.85	201.33	6.52	111.7
7	79.19	30.52	20.06	5.44	169.42	8.33	229.8
8	81.97	29.71	19.45	4.58	122.79	6.29	359.0
9	77.13	31.47	25.47	6.49	103.84	6.36	217.8
10	58.45	33.23	18.23	8.16	78.87	6.15	89.0
11	20.83	33.83	12.80	9.30	103.56	6.52	0
12	20.94	32.09	14.58	8.86	128.38	8.33	0

SAMARU WEATHER MONTLY MEAN 2009

Month	Humidity %	Temp Max	Temp Min	Sunshine Hours	Wind speed Km/d(average)	Open Pan Evaporation Mm/day	Rainfall Mm
1	14.84	33.81	14.13	8.57	108.23	10.14	0
2	9.43	36.29	16.86	8.30	133.25	8.89	0
3	10.03	38.00	19.65	6.79	150.39	7.99	0
4	48.67	38.43	23.16	8.24	196.21	7.14	20.3
5	60.87	35.48	22.23	8.22	159.79	7.98	85.1
6	71.23	33.20	21.00	8.07	182.14	6.06	89.5
7	73.39	31.29	20.00	7.37	159.44	6.43	285.0
8	80.61	29.97	20.42	5.69	119.34	6.76	439.7
9	75.50	31.87	20.03	6.74	100.22	6.06	206.7
10	71.03	32.77	20.26	6.63	106.37	6.43	151.7
11	37.47	32.37	14.80	8.12	118.89	6.76	0
12	16.52	33.45	13.26	9.14	117.19	8.26	0

Appendix 2: Amino Acid and Crude protein Concentrations in Maize Grain from Plants Grown with no added Micronutrients and with addition of micronutrients (2008)

TREATMENTS (% dry weight)
SAMMAZ 14

Amino Acid	N_OM_o	N_OM_1	N_1M_O	N_1M_1	N_2M_O	N_2M_1	N_3M_O	N_3M_1
Lysine	0.44	0.26	0.87	0.74	0.80	0.56	0.87	0.74
Histidine	0.42	0.29	0.78	0.66	0.74	0.51	0.78	0.66
Arginine	0.29	0.20	0.61	0.54	0.57	0.41	0.61	0.54
Threonine	0.41	0.27	0.78	0.66	0.74	0.52	0.78	0.66
Valine	0.35	0.23	0.68	0.58	0.64	0.46	0.68	0.58
Methionine	1.33	0.81	2.35	2.42	2.35	1.89	2.35	2.42
Isoleucine	0.43	0.28	0.82	0.69	0.77	0.55	0.82	0.69
Leucine	0.12	0.08	0.24	0.20	0.22	0.16	0.24	0.20
Thyrosine	0.36	0.23	0.72	0.61	0.66	0.46	0.72	0.61
Phenyalanine	0.28	0.18	0.54	0.46	0.52	0.34	0.54	0.46
Tryptophan	2.69	1.49	5.81	4.77	5.18	3.45	5.81	4.77

Appendix 3:

TREATMENTS (% dry weight)
SUSOMA

Amino Acid	N_OM_o	N_OM_1	N_1M_O	N_1M_1	N_2M_O	N_2M_1	N_3M_O	N_3M_1
Lysine	0.71	0.73	0.36	0.42	0.37	0.95	0.77	1.17
Histidine	0.67	0.69	0.35	0.39	0.36	0.85	0.69	1.15
Arginine	0.52	0.54	0.26	0.29	0.27	0.66	0.54	0.81
Threonine	0.66	0.67	0.35	0.39	0.36	0.85	0.70	1.01
Valine	0.58	0.59	0.31	0.34	0.31	0.74	0.61	0.95
Methionine	2.27	2.42	1.04	1.29	1.30	2.66	2.24	3.40
Isoleucine	0.71	0.54	0.37	0.42	0.39	0.89	0.71	1.10
Leucine	0.21	0.21	1.00	0.12	0.11	0.25	0.21	0.32
Thyrosine	0.60	0.61	0.31	0.35	0.32	0.79	0.60	1.35
Phenyalanine	0.46	0.47	0.24	0.26	0.24	0.60	0.49	0.78
Tryptophan	4.35	4.67	2.11	2.56	2.19	6.41	4.93	8.42

Appendix 4:

TREATMENTS (% dry weight) SAMMAZ 12								
Amino Acid	N_OM_o	N_OM_1	N_1M_O	N_1M_1	N_2M_O	N_2M_1	N_3M_O	N_3M_1
Lysine	1.11	1.01	0.92	1.09	0.99	2.27	1.28	0.77
Histidine	1.02	0.89	0.82	0.94	0.88	2.42	1.28	0.69
Arginine	0.75	0.68	0.64	0.71	0.68	1.63	0.91	0.54
Threonine	0.98	0.89	0.82	0.92	0.87	2.28	1.11	0.69
Valine	0.85	0.77	0.72	0.81	0.77	1.74	1.01	0.61
Methionine	3.30	2.81	2.59	3.00	2.73	3.41	3.74	2.18
Isoleucine	1.03	0.92	0.87	0.98	0.92	2.18	1.23	2.21
Leucine	0.29	0.25	0.25	0.27	0.26	0.61	0.35	0.20
Thyrosine	1.31	0.84	0.76	0.83	0.79	2.39	1.48	0.60
Phenyalanine	0.74	0.63	0.58	0.67	0.64	1.64	0.86	0.48
Tryptophan	7.74	7.11	6.24	3.32	6.75	22.73	9.25	4.93

Appendix 5:

TREATMENTS (%dry weight) SAMMAZ 11								
Amino Acid	N_OM_o	N_OM_1	N_1M_O	N_1M_1	N_2M_O	N_2M_1	N_3M_O	N_3M_1
Lysine	0.87	0.97	1.08	0.48	0.82	0.92	0.71	1.14
Histidine	0.78	0.87	0.97	0.50	0.75	0.87	0.65	1.05
Arginine	0.61	0.67	0.73	0.39	0.58	0.54	0.52	0.76
Threonine	0.78	0.86	0.95	0.50	0.74	0.97	0.66	1.00
Valine	0.68	0.77	0.83	0.43	0.65	0.95	0.56	0.86
Methionine	2.35	2.70	3.09	1.76	2.26	3.60	2.24	3.29
Isoleucine	0.82	0.91	1.00	0.54	0.79	0.95	0.70	1.03
Leucine	0.24	0.26	0.29	0.15	0.23	0.43	0.20	0.30
Thyrosine	0.72	0.79	0.90	0.43	0.70	0.85	0.60	1.33
Phenyalanine	0.54	0.62	0.73	0.34	0.52	0.83	0.45	0.77
Tryptophan	5.81	6.68	7.63	2.67	5.34	6.89	4.40	8.08

Appendix 6:

TREATMENTS (%dry weight) SAMMAZ 14								
Amino Acid	N_0M_0	N_0M_1	N_1M_0	N_1M_1	N_2M_0	N_2M_1	N_3M_0	N_3M_1
Lysine	1.14	1.09	1.09	0.81	1.36	0.29	0.99	1.14
Histidine	1.11	0.97	1.00	0.77	1.32	0.29	0.87	1.07
Arginine	0.79	0.74	0.74	0.56	0.93	0.23	0.67	0.78
Threonine	0.99	0.94	0.95	0.75	1.17	0.29	0.86	0.99
Valine	0.89	0.84	0.83	0.66	1.06	0.25	0.75	0.89
Methionine	3.36	3.07	3.18	2.26	3.94	0.93	2.69	3.36
Isoleucine	1.07	1.00	1.00	0.78	1.26	0.32	0.91	1.07
Leucine	0.30	0.29	0.29	0.23	0.37	0.08	0.26	0.29
Tyrosine	1.33	0.89	1.28	0.69	1.62	0.26	0.79	1.33
Phenylalanine	0.77	0.77	0.73	0.52	0.91	0.19	0.63	0.77
Tryptophan	8.08	7.63	7.63	5.22	10.59	1.64	6.85	8.08

Appendix 7:

TREATMENTS (%dry weight) SUSOMA								
Amino Acid	N_0M_0	N_0M_1	N_1M_0	N_1M_1	N_2M_0	N_2M_1	N_3M_0	N_3M_1
Lysine	0.35	0.60	0.26	0.46	0.31	0.32	0.38	0.39
Histidine	034	0.55	0.26	0.45	0.30	0.31	0.36	0.38
Arginine	0.26	0.43	0.19	0.34	0.24	0.31	0.27	0.28
Threonine	0.34	0.56	0.26	0.44	0.31	0.31	0.36	0.38
Valine	0.30	0.50	0.22	0.39	0.26	0.27	0.33	0.33
Methionine	1.06	1.91	0.79	1.55	0.96	0.97	1.41	1.33
Isoleucine	0.37	0.59	0.27	0.48	0.33	0.34	0.39	0.41
Leucine	0.10	0.16	0.72	0.13	0.09	0.09	0.11	0.11
Tyrosine	0.30	0.49	0.23	0.39	0.27	0.27	0.31	0.32
Phenylalanine	0.23	0.37	0.17	0.30	0.21	0.21	0.25	0.26
Tryptophan	2.02	3.75	1.44	2.75	1.72	1.74	2.20	2.31

Appendix 8:

TREATMENTS (%dry weight)
SAMMAZ 12

Amino Acid	N_0M_0	N_0M_1	N_1M_0	N_1M_1	N_2M_0	N_2M_1	N_3M_0	N_3M_1
Lysine	0.49	0.61	0.56	0.42	0.62	1.09	0.73	0.82
Histidine	0.47	0.57	0.51	0.40	0.56	1.00	0.66	0.74
Arginine	0.36	0.44	0.40	0.31	0.43	0.73	0.52	0.58
Threonine	0.46	0.55	0.51	0.40	0.57	0.95	0.65	0.74
Valine	0.41	0..49	0.46	0.35	0.51	0.34	0.56	0.63
Methionine	1.63	1.91	1.75	1.39	1.98	3.09	2.20	2.45
Isoleucine	0.51	0.59	0.56	0.44	0.60	1.00	0.70	0.77
Leucine	0.14	0.17	0.15	0.12	0.16	0.29	0.20	0.22
Tyrosine	0.41	0.49	0.45	0.35	0.49	1.29	0.60	0.70
Phenylalanine	0.32	0.38	0.35	0.27	0.37	0.75	0.45	0.52
Tryptophan	2.89	3.73	3.43	2.47	4.00	7.63	4.49	5.24

Appendix 9:

TREATMENTS (%dry weight)
SAMMAZ 11

Amino Acid	N_0M_0	N_0M_1	N_1M_0	N_1M_1	N_2M_0	N_2M_1	N_3M_0	N_3M_1
Lysine	0.63	0.62	0.64	0.76	0.95	0.86	0.55	0.58
Histidine	0.59	0.56	0.59	0.68	0.84	0.77	0.51	0.54
Arginine	0.45	0.43	0.46	0.53	0.66	0.61	0.40	0.41
Threonine	0.58	0.57	0.59	0.67	0.85	0.77	0.52	0.55
Valine	0.51	0.49	0.52	0.57	0.74	0.66	0.47	0.48
Methionine	1.98	1.90	2.11	2.19	2.66	2.49	1.80	1.91
Isoleucine	0.61	0.60	0.61	0.72	0.89	0.81	0.56	0.57
Leucine	0.17	0.17	0.18	0.20	0.25	0.23	0.16	0.16
Tyrosine	0.49	0.49	0.49	0.61	0.78	0.73	0.46	0.45
Phenylalanine	0.39	0.38	0.39	0.46	0.60	0.55	0.35	0.36
Tryptophan	3.88	3.87	3.92	4.93	6.41	5.61	3.31	3.63