RESPONSE OF MAIZE (*Zea mays* L.) VARIETIES TO MAGNESIUM AND IRON FERTILIZATION IN SUDAN SAVANNA, NIGERIA.

BY

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DECLARATION

I hereby declare that, this work is the product of my research efforts undertaken under the supervision of Prof. I.B. MOHAMMED and has not been presented anywhere for the award of a degree or certificate. All sources have been duly acknowledged.

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CERTIFICATION

This is to certify that, the research work for this dissertation and subsequent write – up where carried out by Mustapha Adamu Abubakar (SPS/13/MAG/00007) under my supervision.

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APPROVAL

This dissertation titled Response of Maize (*Zea mays* L.) Varieties to Magnesium and Iron Fertilization in the Sudan Savanna, Nigeria by Mustapha Adamu Abubakar (SPS/13/MAG/00007) has been examined and approved for the award of Master of Science Degree in Agronomy of Bayero University, Kano.

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DEDICATION

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ABSTRACT

A study was conducted in 2015 and 2016 rainy season at Bayero University Teaching and Research Farm to investigate response of maize varieties to magnesium and iron fertilization in the Nigerian Sudan savanna Zone. Treatments comprised of four varieties of maize (SAMMAZ 27, SAMMAZ 15 as open pollinated varieties and JO-F and OBA 98 as hybrid) ; four levels each of Magnesium and Iron sulphate (0, 15, 16.7 (foliar) and 25 kg/ha; 0, 0.6 (foliar), 8 and 10 kg/ha) respectively, replicated three times. The treatments were factorially combined and laid in a split – spilt plot design with varieties in the main plot, magnesium levels in the sub plot and iron levels in the sub – sub plot. The results showed that all the four varieties differed significantly with respect to most of the growth and yield characters examined in both years. Sammaz 27 out yielded all other varieties in both years. The varieties responded significantly ($p \leq 0.01$) to the applied nutrients in their growth and yield attributes. Application of both magnesium and iron concentrations indicated a positive influence on plant height, cob yield and grain yield. Similarly, foliar applications of both magnesium and iron at the rate of 16.7 kg/ha and 0.6 kg/ha of magnesium and iron respectively recorded significantly more number of leaves, days to 50% tasseling and days to 50% silking. Interaction between variety and magnesium in both years was recorded on 100 seed weight and grain yield with the higher yield obtained when Sammaz 27 received 25 kg/ha of magnesium. Higher rates of Magnesium and Iron reduced days to tasseling in 2016, increased chlorophyll content, number of leaves and plant height. Application of magnesium supported heavier seeds in the two years under investigation. Cob and grain yields were increased with application of magnesium and iron in the two years of study. It was suggested that farmers should use Sammaz 27 for higher yield of maize in the Sudan savanna of Nigeria. The Mg and Fe interaction indicated that higher yield of maize could be obtained with combined application of Magnesium 25 kg/ha and foliar Iron of 0.6 kg/ha.

CHAPTER ONE

1.0 INTRODUCTION

1.1BACKGROUND INFORMATION

Maize (*Zea mays* L.) is one of the most important cereal crops grown in Africa and ranks the third most cultivated in Nigeria (FAO, 2015). In Nigeria, the most important cereals are sorghum, millet, rice, maize and wheat (Wudiri, 1991). Of all these cereals, maize remains the most popularly grown and consumed in all ecological zones of the country. Nigeria is currently the tenth largest producer of maize in the world, and the largest producer in Africa (IITA, 2012).

The crop was initially confined to the southern part of the country, particularly the southwest, but with the development of early and extra-early maturing varieties, its cultivation has spread to the Sudan ecological zone. The cultivation of maize has spread more than that of sorghum. The grain yield potential is twice as high as compared to other cereal crops (Tollenar and Lee, 2002), possibly due to the higher yields that are obtained with improved varieties when adequate quantities of fertilizers were applied. For the 2002 – 2004 periods, world average yield of maize was estimated at 4.57 t/ha(FAO, 2005). It is one of the important crops in sub -Saharan Africa as such, an important staple for more than 1.2 billion people in sub - Saharan Africa and Latin America.

Crop nutrition research in sub Saharan Africa has largely focused on primary macronutrients (Chilimba, 2000; Stoorvogel *et al*., 1993; Voortman, 2012; Vanlauwe *et al*., 2015). In sub saharan Africa, a lot of studies showed that there are existing deficiencies in secondary nutrients and micronutrients limiting crop productivity.

Deficiencies in secondary and micronutrients during crop growth in western Kenya led to a drop in yield from 10 t/ha to 7 t/ha (Kihara, 2013).

Despite the increased area under maize production, yields have remained quite low, average yield of maize being1.4 t/ha in 2013 compared to 9.5 t/ha in the USA and the World average of5.5 t/ha(FAOSTAT, 2013). The major factors limiting the yield of maize in Nigeria include the inherently poor soils (Jibrin *et al*., 2012), frequent droughts (Kamara *et al*., 2009), lack of proper adherence to improved agronomic practices, low use of improved inputs (Badu-Apraku *et al*., 2009), and continuous use of blanked N, P and K application.

Maize is a high nutrient – requiring crop (Voortman, 2012). Its requirement for nutrients cannot be met by the native soil resources alone, except through external inputs of inorganic fertilizer application and sustainable effective management practices. This is attributed to the increasingly low fertility of the soil in the tropics. Maize like all other plants requires for its growth and development, mineral elements at the right time and correct amount. Normally, any fertilizer application should be based on a soil test. Increased use of organic and mineral fertilizers together with diversification of cropping to include legumes grown in rotation is an important tool in restoring or sustaining soil fertility of the intensifying cropping systems of the dry savannas.

However, sulphate of magnesium and iron fertilizers are some other sources of magnesium and iron that can be used to replenish the soil. Due to lack of information and high prices of these nutrients and of course low agricultural based income, only a few researchers who have access to use these salts and in most cases use very low rates with NPK fertilizers (Kihara *et al*., 2017). Magnesium is required by a large number of enzymes involved in energy transfer, particularly those utilizing ATP (Fredeen *et al.*, 1989). It is a constituent of chlorophyll molecules and is required for normal structural development of chloroplast as well as other organelles such as mitochondria. Thus it is to be expected that magnesium deficiency would have a damaging effect on photosynthesis in maize. Iron is also very essential in the growth and development of maize plants. Its deficiency leads to retardation in plant growth leading to low yield.

1.2. PROBLEM STATEMENT

Due to the intensification of agriculture in the Sudan savanna zone of Nigeria, available soil nutrients are constantly exploited by crops, leading to deficiency of essential plant nutrients. Also, most of the maize varieties grown in Nigeria are highly susceptible to downy mildew, streak, and rust diseases, susceptible to *Striga hermonthica*, drought and inappropriate selection of variety for a specific location leads to low yield of maize variety. In order to make maize farming economically feasible resistance lines were bred and made available to farmers for an increased yield of maize. Also, continuous cropping, decrease use of farmyard manure and adverse practices by farmers contribute to the continuous decline of essential plant nutrients in the soil especially micro and secondary macronutrients. Another contributory factor includes intensification and continuous cropping which result in serious nutrient depletion and imbalance. This is exacerbated by poor soil fertilizer management by farmers. Similarly, practice of adding only N, P and K by farmers without due consideration to the addition of secondary macro and micro nutrients fertilizers such as magnesium and iron have been known to influence maize yield. Soils in the savannah were found to be degraded as a result of continuous crop removal and farm management practices (El- Fourly *et al.*, 2010).

Despite the well-known role of magnesium (Mg) and iron (Fe) for various critical functions, there is surprisingly little research activity on the role of these elements nutrition in maize production and quality. However, their deficiency is increasingly becoming an important limiting factor in intensive crop production systems especially in soils fertilized only with N, P and K (Amusa *et al*., 2002). It was envisaged that, proper fertilization with magnesium and iron especially in the above type of soil could likely have positive effect on the growth and development on this crop and increase in yield becomes vital to sustain the ever increasing population.

1.3. JUSTIFICATION OF THE STUDY

In view of the increasing population of Nigeria there is needed to intensify efforts to produce more food for the humans and feed for the livestock. Among the cereals, maize has the highest yield potential and is widely cultivated and consumed across the country. Although currently, productivity is low, improved technologies are now available to support higher yields at farmers' level. Apart from the development of high yielding, drought tolerant varieties, better agronomic practices including efficient nutrient management have been developed to support higher crop productivity and return. It is increasingly recognized that maize production in some locations, of the world has increased through application of magnesium and iron (Abunyewa and Mercer 2004). This approach has therefore intensified further research efforts aimed at addressing maize response to magnesium and iron fertilization and equally determining optimum rates of magnesium and iron levels for maize production. However, not much was reported to have been done about interaction of these nutrients with varieties of maize in Sudan savannas of Nigeria. Perhaps this could be due to the dependence on ideal calcium to magnesium ratio in the soil for plant magnesium requirements or on the assumptions that the absence of magnesium and iron is not a serious cause for concern by farmers in the area.

Reduced fallow intervals, human activities that tend to limit soil fertility, incidental application of organic matter as source of magnesium and iron cannot be considered sufficient. It therefore becomes necessary to incorporate magnesium and iron in the fertilizer programme based on actual crop needs if improvement in maize yield in the savanna is to be achieved. Iron crop removal and already low soil magnesium and iron in the savanna soil, in addition to human activities tend to limit soil fertility. It is therefore necessary to include magnesium and iron in the nutrition of maize to achieve increase in maize yield in the savanna. Increase in human population, need for livestock and poultry production and other factors; make it necessary to device appropriate ways of increasing maize grain yield per unit area. At present, new varieties have been developed like SAMMAZ 27, SAMMAZ 15, JO-F, 0BA 98 so there is need to adopt proper fertilization in the nutrition of the crop. Magnesium and iron are essential nutrients for maize growth and development. However, it is vital to know the optimum rate of the magnesium and iron for increased yield of maize.

It was noted that, foliar spray fertilization improves nutrient balance within the plant (Nassrin *et al*., 2012) and is mostly effective when there are problem in the nutrient uptake by the plant roots. Low yield of maize is attributed to the exclusion of some secondary macro nutrients (Mg) and micro (Fe) nutrients in fertilizer recommendations of maize, a condition which frequently leads to nutrient imbalance. It has been concluded that more work is desirable on the use of micro and secondary macro nutrients for maximum maize production. This is in line with (Chilimba, 2000), that for successful cultivation of maize in the tropical forest and savanna zones, there is need to include micro and secondary nutrients in maize fertilizer recommendations. Numerous field trials around the world on maize have shown that, substantial yield increases can be achieved with iron and magnesium in addition to N, P and K. This study was carried out to evaluate the response of maize varieties to different levels of iron and magnesium sulphate fertilization and to determine the appropriate application rates of the two nutrients for increased yield of maize.

1.4. OBJECTIVES OF THE RESEARCH

The objectives of the study are;

- To evaluate the response of maize varieties to iron fertilization.
- To study the response of maize varieties to magnesium fertilization and
- To investigate the growth and yield of open pollinated and hybrid varieties of maize in the Sudan savanna of Nigeria.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. ROLE OF MICRONUTRIENTS IN CROP PRODUCTION

Micronutrients are elements which are essential for growth of plant, but are required in much smaller amounts than those of the primary nutrients; N, P and K. They are as important as the primary and secondary nutrients in plant nutrition. Micronutrients are boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn) and chloride (Cl). Play an active role in the plant metabolic processes starting from cell wall development to respiration, photosynthesis, chlorophyll formation, enzyme activity, nitrogen fixation and reduction. Requirement for micronutrient of maize are relatively small and the ranges between their deficiency and toxicity in the plant and soil are rather narrow. Expectations of higher maize productivity through the use of adequate fertilizer nutrients sometimes leads to limiting to some micronutrients in the soil and most times due to over mining of nutrients by crops and shortage which often show deficiency symptoms and reduction in yield. Micronutrients affects photosynthesis directly or indirectly and also, vital processes in plants such as respiration and protein synthesis (Marschner, 1995).

Micronutrients are increasingly becoming important to world agriculture as crop removal of these essential elements increases (Brady 2002). Micronutrients deficiency is due to not only the low contents of these elements in the soil but more often to their unavailability to growing plants. Micronutrient cations are most soluble and available under acid conditions. The result of experiments conducted at National Maize Research Programme, Rampur (NMRP) farmland using micronutrients on maize for both summer and winter seasons during the year 2003 and 2004 revealed that all micronutrients demonstrated a response except for sulphur. Crop yield was decreased in the absence of boron. Iron is known to aid in chlorophyll formation, though it is not an integral part of chlorophyll. Magnesium on the other hand is known to promote enzyme transformation.

2.2. IMPORTANCE OF IRON IN PLANT NUTRITION AND CONSEQUENCES OF ITS DEFICIENCIES

2.2.1 Iron Availability to Plants

Iron is essential for crop growth and food production, even though only small amounts are required. Without iron, the benefit of all other good management practices would be of little or no value. Iron is present at high quantities in soils, but its availability to plants is usually very low and therefore iron deficiency is a common problem.

Although most of the iron in the earth crust is in the form of Fe^{3+}, the Fe^{2+} form is physiologically more significant to plants. This form is relatively soluble, but is readily oxidized to Fe^{3+}, which then precipitates. The Fe^{3+} is insoluble in neutral and high pH soils, making iron unavailable to plants in alkaline and calcareous soils. Furthermore, in these types of soils, iron readily combines with phosphates, carbonates, calcium, magnesium and hydroxide ions. In such types of soil, it is recommended to use iron chelates.

2.2.2 Iron Uptake by Plants

Plants take up iron in its oxidized forms, Fe^{2+} (ferrous form) or Fe^{3+} (ferric form), using different uptake mechanisms. One of these is chelation mechanism; the plants releases compounds called siderophores which bind iron and enhance its solubility. This mechanism also involves bacteria.

Another mechanism involves the release of protons (H^+) and reductants by the plant roots to lower pH levels in root zone, resulting in increased iron solubility. In this respect, choice of nitrogen fertilizer is significant. Ammonium nitrogen increases proton release by roots, thus lowering pH and facilitating iron uptake. Nitrate nitrogen enhances the release of hydroxide ions that increase pH in the root zone and counteract efficient iron uptake.

Mineral contents in the plants depend primarily on the nature of the soil environment and biological properties of the species. Iron is an essential nutrient for plant growth and development. Iron is necessary to mediate the numerous biochemical reactions essential for growth and development of the maize plant. It functions to accept and donate electrons and plays important roles in the electron-transport chains of photosynthesis and respiration. Iron helps in the synthesis of DNA in plants. Furthermore, many metabolic pathways are activated by iron and it is a prosthetic group constituent of many enzymes. It is essential for the maintenance of chloroplast structure and function. Iron act as catalyst in the production, formation and development of chlorophyll. It also helps in the reduction of nitrate and sulphate in the soil. Amounts of iron that are available to plants might be inadequate dependent on various soil factors, example very high or low soil temperature, high humidity, poor soil aeration and compaction, high pH, HCO_3^- and $CaCO_3$ contents. Besides, the bad physical properties of the soil , iron chlorosis is related with PO_4^- and NO^-_3 anion and other heavy metals concentration such as Zn, Cu, Mn, Co, Ni, Cd (Basar, 2000).

Deficiencies of iron in maize plants are only slightly sensitive to lack of iron. Where deficiencies do occur, foliar application particularly those made at later stages of leaf growth and at early stem extension have been shown to increase maize yield. The symptoms of deficiency can be confusing with manganese deficiency but manganese deficiency is very rare in maize. The deficiency starts on younger leaves. Plants show chlorotic leaves with inter-venal strips. At severe deficiency, necrotic zones develop at leaf margins and tips. The deficiency effects are made worst by high soil pH, water logged soils, calcareous soils, high copper and manganese or zinc soils

2.3. IMPORTANCE OF MAGNESIUM IN PLANT NUTRITION AND CONSEQUENCES OF ITS DEFICIENCY

Magnesium is an essential plant nutrient. It has a wide range of key roles in many plant functions. One of the magnesium's well-known roles is in the photosynthetic process, as it is a building block of the chlorophyll, which makes leaves appear green. It activates more enzymatic systems than any other nutrients

2.3.1 Magnesium Pool in the Soil

In the soil, magnesium is present in three fractions:

Magnesium in soil solution: Magnesium in soil solution is in equilibrium with the exchangeable magnesium and is readily available for plants.

Exchangeable magnesium: This is the most important fraction for determining the magnesium that is available to plants. This fraction consists of the magnesium held by clay particles and organic matter. It is in equilibrium with magnesium in soil solution.

Non-exchangeable magnesium: consists of the magnesium that is a constituent of primary minerals in the soil. The break down process of minerals in soils is very slow; therefore, this magnesium fraction is not available to plants.

Magnesium availability and uptake: Conditions such as low soil pH, low temperatures, dry soil conditions and high levels of competing elements such as potassium and calcium, reduce the availability of magnesium. Under such conditions, magnesium deficiency is more likely.

2.3.2 Effect of Soil pH on Magnesium Availability

In low pH soils, the solubility of magnesium decreases and becomes less available. Due to the large hydrated radius of the magnesium ion, the strength of its bond to the exchange sites in soil is relatively low. Acidic soils increase the tendency of magnesium to leach, because they have less exchangeable sites (lower CEC).

In acidic soils, elements such as manganese and aluminum become more soluble and result in reduced magnesium uptake. Other positive charged ions such as potassium and ammonium may also compete with magnesium and reduce its uptake and translocation from the roots to upper plant parts. Therefore, excessive application of these nutrients might prompt magnesium deficiency. Care should be especially taken in sandy soils, as their CEC is low and can hold less magnesium.

Although magnesium has been classified as a secondary element of plant nutrition (Epstein, 1972), its role in enhancing crop growth and yield was considered important as that of N, P and K. Enormous research effort has been focused on nitrogen and phosphorus considered as most limiting nutrients of plant nutrition in the Nigerian savanna (Tarfa, 2002; Chude *et al*., 2001; Enwezor *et al*., 1989; Lombin, 1987), but much less is known of magnesium. It is therefore not surprising the paucity of information on crop magnesium responses especially in the Nigerian savanna.

Magnesium has a variety of uses within the plant biochemistry. Magnesium is involved in numerous physiological processes and its deficiency can severely reduce the yield and quality of crops. Since magnesium availability in the soil and uptake in to the plant is often limited by unfavorable soil or climatic conditions. Application of magnesium to leaves might be a reasonable alternative fertilization strategy. Magnesium activates more than 300 enzymes, example ribulose - 1, 5 bisphosphate-carboxylase/oxygenase (Rubisco), Glutamine syntheses or Glutathione synthesis and therefore participate in the assimilation of C, N and S, respectively (Marschner, 2012).

Furthermore, magnesium-binding to ATP is essential for the plasma membrane H+-ATPases activity having magnesium ATP as substrate. Consequently, phloem loading and partitioning of photo assimilates from source to sink organs depends on magnesium availability (Cakmak *et al*.,1994). Protein biosynthesis cannot take place without magnesium, since it connects the sub units of ribosome’s (Maathuis, 2009).

Being aware of its impact on plant metabolism, it seems astonishing that, magnesium has received little attention in agricultural research in the last decades although its deficiency can cause severe reduction in yield and quality of crops (Gransee and Fuhrs, 2013; Neuhaus *et al*., 2014). Magnesium as the central atom in the chlorophyll molecule is needed for photosynthesis. It is also required for cell division, protein formation, phosphorus metabolism, plant respiration and activation of several enzyme systems. Magnesium is taken up by plants as divalent cations, Mg^{2+}. It is mobile and easily translocated from older to younger tissues.

When deficiencies occur, the older leaves are affected first with a loss of color between the leaf veins, beginning at the leaf margins or tips and progressing inward. The leaves appear striped, with yellowing and browning of leaf tips and edges as symptoms progress (which may be confused with K deficiency), resulting in less photosynthesis and overall crop stunting. Magnesium deficiency leads to impairment in root growth. It may have serious impact on uptake of mineral nutrients and water especially under marginal soil conditions. Magnesium has long being noted for its essential role in chlorophyll formation and photosynthesis. However, growing evidence shows that sink organs such as roots and developing seeds are also severely affected by magnesium deficiency. Magnesium deficiency is increasingly becoming an important limiting factor in intensive crop production systems especially in soils fertilized only with N, P and K. Small amounts of magnesium can be applied to growing crops through foliar fertilization to correct or prevent developing deficiencies, but the preferred approach is to soil-apply the required amounts before planting. Genetic responses to magnesium starvation and restoration have been analyzed in the model species *Arabidopsis thaliana* (Herman, *et al*., 2010) but Cakmak and Yazici (2010) called magnesium, a forgotten element in crop production. The authors considered the deficiency of this nutrient to be a growing problem and limiting factor especially in intensive production systems.

2.4. PERFORMANCE OF MAIZE VARIETIES

Maize improvement for grain yield potential, stability of yield including plant and grain characteristics have gone through several stages in Nigeria since 1950. The breeding efforts which began with the introgression of genes for pest and disease resistance (Fajemisin, 1985; Fakorede *et al*., 1993; 2001) to the development of maize genotypes (open pollinated and hybrids) with high grain yield potential (Kim, *et al.*, 1993) as well as adaptation to different ecologies and stress factors (Kim, 1997), have resulted in the development and release of productive maize varieties for different agro ecologies in Nigeria. Introduction of high yielding open pollinated varieties and hybrids in to the Nigeria's savanna between 1985 and 1990 resulted in further yield increase ranging from 4.25 t ha^{-1} to 5.15t/h-1 representing an average of 22% yield advantage especially for the hybrids (Kim, *et al*., 1993). Maize grain yield since then has witnessed a phenomenal increase as high as 14.7t ha^{-1} in high yielding environments of the West and Central Africa representing 20 to 40% yield advantage (Kim, 1997). In a recent study which compared the performance of open pollinated maize developed for West and Central Africa between 1970 and 1999 across the West African Savannas, Kamara *et al*., (2004) also reported genetic gain in grain yield of 0.41% per $year^{-1}$.

Increase in maize production however, has not kept pace with the increasing demand. High population pressure and repeated sub division of land, coupled with limited resources available to the large proportion of the population living below the poverty index, severely constrained maize production. Average farm sizes are shrinking largely due to the traditional land inheritance practice of subdividing land (Kilson,1955; Karanja, 1991; Yamano, 2007; Shreffler and Nii Amoo, 2009). Decreasing farm sizes coupled with increasing population drives a deficit spiral in which yields decrease because farmers can afford fewer and fewer inputs (Ojiem *et al*., 1996; Macharia *et al*., 2010). A study conducted in Kenya to evaluate the performance of open pollinated maize variety and a common hybrid variety revealed that, the hybrid outperformed open pollinated variety under conventional farming practices. However, their relative performance has not been tested under small scale intensive production practice.

Grain yield of hybrid (12.8 tons ha^{-1}) was not statistically different from that of open pollinated one (10.2 tons ha^{-1}), even though the number of rows per cob and number of ears per plant of the former were significantly higher than those of the latter. However, yields of both varieties were about twice the published potential yield of improved hybrid maize (6 ton ha^{-1}) grown with conventional practices. Seed kernels of open pollinated variety weighed 1.6 times more than those of hybrid. Cost of producing open pollinated variety was significantly less than producing hybrid and twice more profitable (Omondi *et al.*, 2014).

The study therefore, concluded that, growing open pollinated variety using small-scale, intensive farming practices may be a viable option for most small-scale, resource-challenged farmers to increase economic yields (Omondi, *et al*., 2014). Maize is one of the most important high value cereal crops in many households in Nigeria (FAO, 2010).

2.5 CONSTRAINT TO MAIZE PRODUCTION IN THE NIGERIAN SAVANNA

Information in the literature show that an estimated one million hectares of land was planted to maize in the country between1989-1990 and over 50% of this was cultivated in the northern states of Nigeria. From then, production of dry grains has intensified with the benefit of improved cultivars, use of irrigation facilities especially in the drier Sudan and Sahel agro – ecologies and adoption of efficient crop husbandry practices such as timely and correct amount of fertilizer application and management. Ofor *et al*., (2009), reported that within that period, average yield per hectare in the northern savanna on peasant farms was about 0.6 ton ha^{-1} while that of commercial farms was about 2.0 metric ton ha^{-1}. With the expansion of maize belts across the varied agro-ecological zones of northern Nigeria and the quest to increase production to meet food sufficiency, the intensification has led to increase production in the last one decade. For instance, average yield on smallholder farms in 2010 stood at 2500 – 2750 kg ha^{-1} while annual production for the same period was 8.9 million metric tons of dry grains (NBS, 2010).

However, in spite of this increase in production, the potential maize grain yield in the Nigerian Savannas has remained elusive due to several constraints. These constraints include low soil fertility, pests and diseases infestation, rampant menace of competing weeds, imbalanced chemical fertilization, cross boundary climatic changes (heat waves, drought and flood, soil acidity/salinity, animal grazing, migratory birds, use of low yielding seeds cultivars and other environmental hazards (Kamara 2013 and Ofor *et al*., 2009). These myriad of constraints have impacted negatively on sustainable maize production in Nigeria and ultimately limit food security.

Low soil fertility condition of Nigerian savanna is undoubtedly the most serious constraint facing the vast majority of subsistent farmers in Nigeria. Studies have shown that, soils of the Nigerian Savanna are deficient in the major plant nutrients mainly N, P and K (Chude, *et al*., 2003). Lack of these nutrients has caused serious yield reductions due to unhealthy growth, leaf chlorosis, poor root development, plant lodging and pre – mature senescence. In response to this, chemical fertilizers are continuously applied in order to improve soil fertility and enhance good plant nutrition and yield.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. EXPERIMENTAL SITE

The experiment was carried out during 2015 and 2016 rainy season at Bayero University, Kano Teaching and Research Farm (latitude 11° 58'N and longitude 8°25'E). The experimental site was sown with sorghum in 2014 season and the soil was sandy loam. The location of the study area was Sudan Savannah zone of Nigeria.

3.1.1 Soil Analyses

Soil samples were collected from the experimental site using soil auger at the depth of 0-15 and15-30 cm. The samples were then composited dried, ground and sieved using 2 mm sieve. The sieved sample was taken to laboratory for determination of physico- chemical properties using standard procedures (Blackman, 1965). Soil pH was evaluated with a glass electrode pH meter at 1:1 soil to water ratio. Organic carbon was determined by acid dichromate wet oxidation procedure. Total nitrogen contents of the soil was analyzed by micro – Kjeldahl method. Available phosphorus using Mehlich- 3 test. Exchangeable bases (Ca, Mg, K and Na) were extracted with 1 M NH4OAC solution and buffered at pH 7.0. Calcium and magnesium in the leachate were determined with an atomic absorption spectrophotometer, while K and Na was determined using flame photometer. Available iron was extracted in 0.1 M HCl and determined by atomic absorption spectrophotometer.

3.1.2 Meteorological Data

Data on rainfall, daily temperature (minimum and maximum temperature) from (Watch Dog), solar radiation and relative humidity was obtained from the weather station of the Department of Geography Bayero University, Kano meteorological station.

3.1.3Land preparation

The land was harrowed and then ridged at 75 cm between rows. The boarder row was provided as 1m between replicates and 0.5m between plots aimed to minimize nutrient seepage.

3.1.4Treatments and Experimental Design

The experiment consisted of four varieties of maize (open pollinated – SAMMAZ 27, SAMMAZ 15 and hybrid – JO-F and OBA 98; four levels of Magnesium (0, 15, 16.7 (foliar) and 25 kg/ha and four levels of Iron (0, 0.6 (foliar), 8 and 10 kg/ha). The design employ was split - split with the variety assigned to the main and Magnesium and Iron assigned to the sub and sub – sub plots, respectively. The treatments replicated three times.

3.2. DESCRIPTION OF THE VARIETIES USED FOR THE TRIAL

3.2.1 Sammaz 15

It is a medium maturing open pollinated maize variety. It matures within 100 days of sowing and adapted to moist savanna. It is more suitable for regions with short growing periods or mere unpredictable weather like rainfall. It tolerates heavy striga infestation without suffering crop losses. It has good N use efficiency and the seeds were sourced from IITA, Kano.

3.2.2 Sammaz 27

It is an early maturing variety, best suited to Guinea and Sudan savanna. It is high yielding and striga tolerant. It matures within 80 days with yields of 3 - 4.5 t/ha. The seed was sourced from IITA, Kano.

3.2.3.Oba- 98

It is a hybrid variety with white seeds and adapted to forest and the savanna regions. In terms of prolificacy, it is an excellent variety. It reaches maturity in 105 days after sowing. It is resistant to lodging, rust, blight and streak diseases. It produces up to 6.5-8.0 t/ha and the grain is quality protein maize. It is medium maturing and was sourced from Premier Seed Company LTD.

3.2.4.JO-F

It is a hybrid variety that matures in 95 days after sowing and is a white seeded crop. The seeds were sourced from Da- all green Seed Company Limited. It has yield potential of up to 6 t/ha.

3.3CULTURAL PRACTICES

3.3.1Plot Size

Each plot size was 2m x 3m ($6m^2$) while the net plot was 2m x I .5m ($3m^2$). The total land area was $1152m^2$ with 1m and 0.5m as alley way between replicates and plots respectively. Each replicate contained 64 plots given a total of 192 plots per location.

3.3.2 Sowing

Sowing was carried out by hand. Two seeds were sown per hole at the spacing of 0.25m and 0.75m as intra and inter rows respectively. The seedlings were later thinned to one plant per stand at two weeks after sowing (2WAS).

3.3.3 Fertilizer Application

The four varieties equally received NPK fertilizer at 120: 60:60 kg/ha, using NPK 15: 15: 15 and urea (46%N). The P and K plus half dose of N were applied as basal in the form of NPK at 2 WAS while the half of N was band applied at five weeks after sowing. Iron and magnesium application was carried out as per the treatments at 15 DAS and those applied through foliar means were sprayed at 5 WAS.

3.3.4 Weeding

Hoe weeding was carried out to control weeds at 3 and 6 WAS to minimize crop-weed competition.

3.3.5 Pests and Diseases Control

An outbreak of stem borer was observed during the second season and Vetox 85 at 1.68 a.i/ha in 25 liters of water was applied to control the borer.

3.3.6 Harvesting

Harvesting was carried out at physiological maturity (signified by black layer located within the base of the kernels). This was carried out from the net plot that is, the two inner most middle rows in each plot.

3.4DATA COLLECTION

All the agronomic characters measured were sampled from net plot of each experimental unit. Five (5) plants were randomly picked and average were taken and recorded.

3.4.1 Plant Height (cm)

Plant height was measured from five (5) randomly selected and tagged plants within the net plot at 6 WAS using graduated meter rule. It was measured from the ground level to the uppermost part of the plant. The average was taken and recorded.

3.4.2. Leaf Area

Five (5) plants were randomly picked for leaf area measurement. Three (3) leaves from the tagged plant were measured and average leaf area was recorded. Leaf area was obtained using leaf area meter model YMJ-A.

3.4.3 Leaf Area Index

The leaf area index was obtained by dividing the leaf area values by ground cover by the plant leaves.

$LAI = \frac{LA}{GC}$ where LAI = Leaf area index, LA = Leaf area, GC = Ground cover

3.4.4 Leaf Chlorophyll Content

Chlorophyll content of the plant leaves from each plot was determined using SPAD meter.

3.4.5 Number of Leaves

Number of leaves per plant was determined by counting the leaves produced by the five (5) randomly selected plant stands and means values recorded. This was taken at maturity stage.

3.4.6Days to 50% Tasseling

Number of days from sowing to when 50% of the plants in each plot have tasseled was recorded. It was done through constant observation and counting of the plants in each plot when tasseling must have started.

3.4.7 Days to 50% Silking

Number of days from sowing to the period when 50% of the plants in each plot produced silk was recorded. It was also done through constant observation and counting of the plants that silked in each plot.

3.4.8 Cob Yield (kg/ha)

Cobs harvested in each net plot were weighed and the values were extrapolated to per hectare basis. This was taken after detaching of the cob sheath.

3.4.9 Number of Kernels per Cob

This was obtained by counting the number of grains per row and then multiplied by total number of rows per cob. This was taken randomly from five (5) cobs irrespective of whether the cob is filled up with kernels or not.

3.4.10 100-Seed Weight (g)

Hundred seeds were randomly picked, counted after threshing the harvest from each plot, and this was weighed and recorded. This was taken randomly from each plot.

3.4.11 Grain Yield (kg/ha)

Grains per plot were first weighed and the value was converted to per hectare basis for each plot.

3.5 DATA ANALYSIS

Data collected on the above characters were subjected to analysis of variance (ANOVA) as described by Snedecor and Cochran (1967) using JMPPRO and the treatments means found to be significantly different were separated using Student Newman's Kuels (SNK).

CHAPTER FOUR

4.0. RESULTS AND DISCUSSION

4.1. RESULTS

4.1.1 Physico-Chemical Properties of Soils in the Experimental Site in 2015 and 2016 Raining Season

The results of the soil analyses at the experimental site revealed that soil textural class in 2015 was sandy loam (0-15cm) and loam sand (15-30cm) while that of 2016 was sandy clay loam and sandy loam (Table 1). The soil at both years had pH (6.6 to 6.5) which is slightly acidic; the soil had low organic carbon ranging from 0.003 to 0.005g/kg across the years. Total nitrogen content for both years was 0.04 to 0.11% and 0.30%respectively, which were medium for 2015 and low for 2016. The available phosphorus content of was low (9.41to 14.67mgKg^{-1}).The organic matter content for the two seasons was ranging from 0.006 to 0.009g/kg. Among the exchangeable cations [Ca, Mg, Na, and K,] Ca was medium range from (0.1 to 3.8cmolkg^{-1}), sodium (Na) content of both years were (0.16 to 0.32 cmol (+) kg^{-}1) considered as medium.SO_4,was low across both years, Iron (Fe) was 9.72 to 13.96 for 2015 season and (12.54 to 16,91cmol (+) kg^{-1}) for 2016 where both considered as were medium, whereas K was medium for both years (0.31 to 0.47cmol $^{(+)}$ kg^{-1}) The CEC of the soil in both years were medium and ranged between 6.30 cmol^{+}kgha^{-1} for 2015 and 2016 were 6.09cmol^{+} kgha^{-1} for 2016 season.

4.1.2 Response of Variety, Iron and Magnesium on growth characters of Maize

Plant height (cm)

Effect of variety, iron and magnesium on plant height of maize is shown in Table 2. In 2015, variety Sammaz 27 had significantly ($p \leq 0.01$) taller plants compared to Oba

Table 1: **Physico-chemical Properties of the soil at Experimental sites during 2015 and 2016 raining season at Bayero University Research farm**.

	2015		2016	
Soil properties	**0-15 cm**	**15-30cm**	**0-15cm**	**15-30cm**
Physical properties (%)				
Sand	71	86	51	70
Clay	10	9	24	17
Silt	19	5	25	13
Textural Class	Sandy loam	Loamy sand	Sandy clay loam	Sandy loam
Chemical properties of soil				
pH (H_2O)	6.62	6.45	6.55	6.19
Organic Carbon (g/kg)	0.005	0.003	0.005	0.004
Total Nitrogen (%)	0.11	0.04	0.07	0.07
Available P ($mgKg^{-1}$)	14.76	10.22	12.37	9.41
Organic Matter (g/kg)	0.009	0.006	0.009	0.008
Exchangeable base				
Ca	3.61	2.74	3.04	2.40
Mg	2.08	1.25	1.67	0.88
Na	0.32	0.28	0.23	0.16
SO_4 (mg/Kg)	6.25	4.41	5.79	4.99
Fe (mg/Kg)	13.96	9.72	16.91	12.54
K (mg/Kg)	0.40	0.31	0.47	0.38
CEC	7.11	6.09	8.23	7.34

98, JO-F and Sammaz 15 variety on the other hand, produced statistically shorter plants.

Effect of Magnesium on plant height of maize showed that among all the treatments considered the application of 15 kg/ha Mg produced significantly ($p \leq 0.01$) shorter plants among all the other treatments that were at par with each other. The results further showed that application of Iron at 8 kg/ha produced significantly shorter plants while the other treatments were at par with each other but with taller plants.

Interaction between variety and Iron in 2015 (Table 3) showed that application of Iron at 0.6 kg/ha on Sammaz 27 had taller plants while control had the shortest plant. A similar pattern of response was observed on varieties JO-F and Oba 98.For Sammaz 15, application of 10 Fe kg/ha had significantly taller plants.

Interaction between Magnesium and Iron levels in 2015 (Table 4) showed that combined application of 16.7 Mg kg/ha and 0.6 Fe kg/ha produced taller plants followed by 25 kg/ha Mg and the control level of Iron. Shorter plants were however, observed in plots treated with 15 kg/ha of Mg and 8 kg/ha of Fe.

Interaction between variety and Magnesium on plant height in 2015 showed that, all the four varieties tested responded differently to varying levels of Magnesium. Variety Sammaz 27 had taller plants with application of 16.7 and 25 kg/ha of Mg. Variety JO-F on the other hand, had shorter plants at the control and at 15 kg/ha Mg.

Number of leaves per plant

Effect of Variety, Magnesium and Iron levels on number of leaves of maize is presented in Table 2. The result showed significant ($p \leq 0.01$) differences among the varieties where variety JO-F consistently had more leaves in the two year study than the other varieties tested. Variety Sammaz 27 on the other hand, had the least number of leaves throughout the study period.

Effect of different levels of Magnesium showed that except in 2015, no significant difference was observed among the different levels investigated in 2016. In 2015 rainy season, application of 15 kg/ha Mg was observed to produced significantly ($p \leq 0.01$) higher number of leaves even though at par with the application of 16.7 and 25 kg/ha Mg.

Table 2showed the response of maize to varying levels of Iron on number of leaves. Significant ($p \leq 0.01$) difference was only observed in 2015 rainy season where the control had higher number of leaves although at par with application of 0.6 and 8 kg/ha of Fe. Application of 10 kg/ha on the other hand, had the least number of leaves among the other levels considered.

Chlorophyll content

The effect of Variety, Magnesium and Iron on chlorophyll content in 2015 and 2016 is presented in Table 2. In 2015 rainy season, variety Oba 98 recorded significantly (≤ 0.01) higher chlorophyll content compared with JO-F, Sammaz 15 and Sammaz 27. Sammaz 15 variety however, had the least chlorophyll content among all the varieties tested. The effect of different Mg levels on chlorophyll content was significant only in 2015 with application of 16.7 and 25 kg/ha Mg producing higher chlorophyll content compared with the control and 15 kg/ha Mg that recorded lower values.

Effect of different Iron levels on chlorophyll content of maize was significant only in 2015 rainy season with all the rates examined having similar effect except that of control which recorded significantly ($p \leq 0.01$) lower values.

Interaction between the different varieties and Iron levels on chlorophyll content indicated that variety Oba 98 had higher chlorophyll content with application of 8 and 10 kg/ha Fe. Variety Sammaz 15 on the other hand produced the least chlorophyll content under the control and 0.6 kg/ha.

Table 7 showed the interaction between Magnesium and Iron levels on chlorophyll content. Control application of Iron and Magnesium had the least chlorophyll content even though at par with those of 15 and 16.7 kg/ha of Mg. Application of 0.6 kg/ha Fe under 0 Mg, 8 kg/ha Fe under 15, 16.7 and 25 kg/ha Mg and at 10 kg/ha Fe under 25 kg/ha Mg however produced higher chlorophyll content.

Leaf area

Effect of Variety, Magnesium and Iron levels on Leaf Area is presented in (Table 8).The result showed significant ($p \leq 0.01$) difference among the varieties where varieties Oba 98 and JO-F have more leaf area in 2015 while the least leaf area values were recorded by these varieties together with variety Sammaz 27 in 2016. However, variety Sammaz 15 recorded significantly ($p \leq 0.01$) more leaf area compared to other varieties tested in 2016.

Effect of different levels of Mg showed that except in 2016, no significant difference was observed among the different levels investigated in 2015. In 2016 rainy season, application of 15 and 25 kg/ha Mg was observed to produced significantly ($p \leq 0.01$) higher leaf area even though at par with application of 16.7 kg/ha Mg Table 8.

Table 2 Effect of Varieties, Iron and Magnesium Levels on Plant Height, Number of Leaves and SPAD in 2015 and 2016 Rainy Season at BUK

	Plant Height (cm)		Number of Leaves		Chlorophyll Content (SPAD)	
Treatments	2015	2016	2015	2016	2015	2016
Variety (V)						
JO-F	85.0c	119.4b	13.9a	13.9a	70.4b	46.55a
Oba 98	89.7b	133.0a	12.9b	12.5b	81.4a	46.60a
SAMMAZ 15	84.8c	130.6a	12.8b	12.4bc	63.9c	57.70a
SAMMAZ 27	98.3a	131.7a	11.8c	12.0c	71.4b	56.91a
P – value	<0.0001**	0.0115**	<0.0001**	<0.0001**	<0.01**	0.090NS
SE ±	1.26	3.93	0.13	0.24	0.94	2.45
Mg (kg/ha)						
0	89.6a	129.6	12.7b	12.4	70.8bc	46.4
15	86.2b	129.1	13.0a	12.9	70.4c	50.9
16.7	92.1a	129.6	12.8ab	12.7	73.0a	50.2
25	90.0a	126.4	12.9ab	12.8	72.8ab	50.0
P – value	0.0011**	0.88NS	<0.01**	0.3371NS	0.03*	0.091NS
SE ±	1.26	3.93	0.13	0.24	0.94	2.45
Fe (kg/ha)						
0 (control)	91.0a	127.3ab	13.0a	12.7	67.6b	50.4
0.6	91.0a	134.4a	12.9ab	12.8	71.8a	48.5
8	85.9b	128.0ab	12.8ab	13.0	73.9a	51.1
10	89.9a	125.2b	12.7b	12.5	73.6a	47.3
P – value	0.014**	0.01**	<0.01**	0.4921NS	<0.01**	0.548NS
SE ±	1.26	3.93	0.13	0.24	0.94	2.45
Interactions						
V*Fe	**	NS	NS	NS	**	NS
Fe*Mg	**	NS	NS	NS	**	NS
V*Mg	**	NS	NS	NS	NS	NS
V*Fe*Mg	NS	NS	NS	NS	NS	NS

Means within the same column carrying the same letter are not significantly different at **= significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level

Table 3: Interaction between Varieties and Iron Levels on Plant Height (cm) in 2015 Rainy Season at BUK

			Fe (kg/ha)	
Varieties	0	0.6	8	10
SAMMAZ 27	98.8ab	103.0a	94.3bcd	97.2bc
SAMMAZ 15	84.7f-i	79.0h	84.1ghi	91.4de
JO-F	86.3e-g	90.2def	80.0hi	83.6ghi
OBA 98	94.1bcd	92.0cde	85.3fgh	87.4efg
SE±			2.18	

Means within the same column carrying the same letter are not significantly different at **= significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level

Table 4: Interaction between Magnesium and Iron levels on Plant Height (cm) in 2015 Rainy Season at BUK

			Fe (kg/ha)	
Mg (kg/ha)	0	0.6	8	10
0	88.8cde	91bcde	86.1ef	92.6a-d
15	88.1def	94.1abc	80.1g	82.4fg
16.7	90.8b-e	91.3b-e	88.8cde	97.4a
25	96.3ab	87.7def	88.7cde	87.3def
SE±			2.18	

Means within the same column carrying the same letter are not significantly different at significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level

Table 5: Interaction between Varieties and Magnesium levels on Plant Height (cm) in 2015 Rainy Season at BUK

		Mg (kg/ha)		
Variety	0	15	16.7	25
SAMMAZ 27	95.6bc	94.7bc	104.1a	98.9ab
SAMMAZ 15	90.0cd	78.2g	85.1def	85.9def
JO-F	87.4def	81.7fg	83.6efg	87.4def
OBA 98	85.4def	90.0cd	95.5bc	87.8de
SE±		2.18		

Means within the same column carrying the same letter are not significantly different at **= significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level

Table 6: Interaction between Varieties and Iron levels on Chlorophyll Content (SPAD) in 2015Rainy Season at BUK

			Fe (kg/ha)	
Variety	0	0.6	8	10
SAMMAZ 27	68.2g	72.6def	72efg	72.9de
SAMMAZ 15	54.7i	63.6h	69.2efg	68.0g
JO-F	71.1efg	71.6efg	68.3fg	70.4
OBA 98	76.6cd	79.6bc	86.2a	83.2ab
SE±			1.64	

Means within the same column carrying the same letter are not significantly different at **= significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level

Table 7: Interaction between Magnesium and Iron Levels on Chlorophyll Content2015Rainy Season at BUK

			Fe (kg/ha)	
Mg(kg/ha)	0	0.6	8	10
0 (control)	64.9f	76.2a	68.9def	73.1a-d
15	67.5ef	68.1ef	75.6a	70.4a-e
16.7	68.5ef	73.5abc	76.2a	74.0ab
25	69.7a-e	69.6cde	74.9a	77.0a
SE±			1.64	

Means within the same column carrying the same letter are not significantly different at **= significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level

Table 8.Effect of Varieties, Iron and Magnesium Levels on Leaf Area and Leaf Area Index (LAI) in 2015 and 2016 Rainy Season at BUK

	Leaf Area (cm^2)		Leaf Area Index	
Treatments	2015	2016	2015	2016
Variety (V)				
JO-F	673.2a	351.7b	0.36a	0.19b
Oba 98	703.3a	363.5b	0.38a	0.19b
SAMMAZ 15	565.2b	394.4a	0.30b	0.21a
SAMMAZ 27	601.6b	358.2b	0.32b	0.19b
P-value	<0.00101**	<0.0001**	<0.0001**	<0.0001**
SE ±	22.6	6.99	0.01	0.004
Mg (kg/ha)				
0	640	351.7b	0.34	0.18b
15	602.4	375.7a	0.32	0.20a
25	655.7	377.1a	0.35	0.20a
16.7	645.4	363.6ab	0.34	0.19ab
p-value	0.1956 NS	0.0061**	0.1956NS	0.0061**
SE±	22.6	6.99	0.01	0.004
Fe (kg/ha)				
0 (control)	644.2	359.7	0.34	0.19
0.6	629.4	365.3	0.34	0.19
8	628.5	379.4	0.34	0.20
10	641.3	363.3	0.34	0.19
p-value	0.9018 NS	0.0816NS	0.9018NS	0.0816NS
SE±	22.6	6.99	0.01	0.004
Interactions				
V*Fe	**	**	**	**
Fe*Mg	NS	**	NS	**
V*Mg	**	**	**	**
V*Fe*Mg	NS	NS	NS	NS

Means within the same column carrying the same letter are not significantly different at

**= significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level

Table 8 shows the response of maize to different levels of iron on leaf area. No significant difference was observed in both years of the study.

Leaf area index (LAI)

Effect of Variety, Magnesium and Iron levels on LAI is presented in (Table 8). The result showed that variety Oba 98 and JO-F produced significantly ($p \leq 0.01$) higher LAI in 2015 but they recorded the lowest LAI values in 2016. However, variety Sammaz 15 recorded significantly ($p \leq 0.01$) higher LAI in 2016 compared to other varieties tested.

Effect of different levels of Mg showed that, no significant difference was observed among the different levels investigated in 2015. However in 2016, application of 15 and 25 kg/ha Mg was observed to produced significantly ($p \leq 0.01$) higher LAI even though, at par with application of16.7 kg/ha Mg. The response of maize to varying levels of Fe on LAI was not significant in both years.

The interaction between variety and magnesium levels on leaf area in 2015 is presented in Table 9. The result revealed that irrespective of the different levels of magnesium applied, variety Oba 98 consistently had higher leaf area values compared to other varieties tested. Application of 0 kg/ha to Sammaz 27 and 15, 16.7 and 25 kg/ha to Sammaz 15, produced the lowest leaf area.

Interaction between variety and iron levels on leaf area indicated that Oba 98 produced larger leaf area under application of 10 kg/ha of Fe. Application of 8 and 10 kg/ha of Fe on Sammaz 15 produced the smallest leaf area in 2015 (Table 10).

Table 11 shows the interaction between variety and magnesium levels on leaf area index in 2015. The result indicated that, Oba 98 consistently had higher LAI irrespective of the level of Mg applied. However, Sammaz 27 and Sammaz 15 recorded the least LAI with application of 0 and 15 kg/ha of Mg respectively.

Table 12 shows the interaction between varieties and iron levels on LAI in 2015. At the different levels of iron, significant ($p \leq 0.01$) differences were observed among the different levels tested. Application of 10 kg/ha Fe had higher LAI value on variety Oba 98 and lowest LAI values was obtained with application of 10 kg/ha of Fe on Sammaz 15 and 27.

Interaction between variety and magnesium levels on leaf area was significant in 2016. Application of 25 kg/ha of Mg to Sammaz 15 produced higher leaf area compared to other varieties receiving similar or different treatment combinations. Variety JO-F produced lower leaf area with 0 kg/ha of Mg (Table 13).

Interaction between varieties and iron levels on leaf area in 2016 (Table 14) indicated that application of iron at different level consistently produced significantly ($p \leq 0.01$) higher leaf area even though, similar to value obtained with Oba 98 under 8 kg/ha of iron. Variety JO-F recorded the least leaf area with application of 10 kg/ha of Fe.

Interaction between iron and magnesium on leaf area in 2016, revealed that application of 8 kg/ha Fe with 0 kg/ha Mg, 0 kg/ha Fe with 15 kg/ha Mg, 8 kg/ha Fe with 25 kg/ha Mg produced significantly ($p \leq 0.01$) higher leaf area of maize compared to other treatments combinations.

Table 9: Interaction between Varieties and Magnesium levels on leaf area (cm^2)in 2015 Rainy Season at BUK

		Mg (kg/ha)		
Varieties	0	15	16.7	25
SAMMAZ 27	480f	591.2cde	662.6	672.9abcd
SAMMAZ 15	647.5bcd	489ef	544.7ef	579.5def
JO-F	682.9abc	648.8abcd	688.1abc	673.1abcd
OBA 98	749.5a	680.6abcd	686abc	697.2ab
SE±		39.13		

Table 10: Interaction between Varieties and Iron on leaf area (cm^2) in 2015 Rainy Season at BUK

		Fe (kg/ha)		
Varieties	0	0.6	8	10
SAMMAZ 27	652.7bcd	609.8b-f	600.8b-f	543.3ef
SAMMAZ 15	598.9b-f	559.3d-f	586.1c-f	516.4f
JO-F	654.2bcd	673.7bc	692.2b	672.9bc
OBA 98	671.1bc	674.6bc	634.9b-e	832.6a
SE±		39.1		

Table 11: Interaction between Varieties and Magnesium levels on LAI in 2015 Rainy Season at BUK

		Mg (kg/ha)		
Varieties	0	15	16.7	25
SAMMAZ 27	0.26c	0.32a-c	0.35a-c	0.36ab
SAMMAZ 15	0.35a-c	0.26c	0.30bc	0.31a-c
JO-F	0.36ab	0.35a-c	0.37ab	0.36ab
OBA 98	0.39a	0.36ab	0.37ab	0.37ab
SE±		0.02		

Means within the same column carrying the same letter are not significantly different at **= significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level

Table 12: Interaction between Varieties and Iron levels on LAI in 2015 Rainy Season at BUK

Varieties	0	Fe (kg/ha) 0.6	8	10
SAMMAZ 27	0.35bcd	0.33b-f	0.32b-f	0.29ef
SAMMAZ 15	0.32b-f	0.30d-f	0.31c-f	0.28f
JO-F	0.35bcd	0.36bc	0.37b	0.36bc
OBA 98	0.36bc	0.36bc	0.34b-e	0.44a
SE±		0.02		

Table 13: Interaction between Varieties and Magnesium levels onleaf area (cm^2) in 2016 Rainy Season at BUK

Varieties	0	Mg (kg/ha) 15	16.7	25
SAMMAZ 27	353.1cde	370cd	379.4bc	330.4ef
SAMMAZ 15	366.3cd	406.2b	352.4cde	452.5a
JO-F	312.6f	352.3cde	377bc	365cd
OBA 98	374.8bcd	374.4bcd	344def	360.7cde
SE±		12.11		

Table 14: Interaction between Varieties and Iron levels on leaf area (cm^2) in 2016 Rainy Season at BUK

Varieties	0	Fe (kg/ha) 0.6	8	10
SAMMAZ 27	352.5cde	351.9cde	365.4bcd	362.9b-e
SAMMAZ 1SAMMAZ 15	389.4ab	406.5a	379.9abc	401.8a
JO-F	351.3cde	362b-e	361.5b-e	332.1
OBA 98	345.6de	341de	411a	356.2cde
SE±		12.11		

Means within the same column carrying the same letter are not significantly different at **= significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level

Lower leaf area values were recorded when 10 kg/ha Fe with 0 kg/ha Mg and 0 kg/ha Fe and 0 kg/ha Mg was applied on maize (Table 15).

Interaction between varieties and magnesium levels on LAI in 2016. Variety Sammaz 15 had significantly ($p \leq 0.01$) higher LAI under application of 25 kg/ha Mg. Variety JO-F on the other hand produced the least LAI with 0 kg/ha Mg (Table16).

Interaction between varieties and iron levels in 2016 on LAI. The result revealed that variety Sammaz 15 had significantly ($p \leq 0.01$) produced higher LAI with application of 0.6 and 10 kg/ha of Fe. However, with application of 8 kg/ha Fe Oba 98 produced higher LAI value similar with Sammaz 15. Variety JO-F produced the least LAI under application of 10 kg/ha Fe (Table 17).

Interaction between magnesium and iron on LAI was significant in 2016 (Table18). The result indicated that application of 0 kg/ha Mg and 0 kg/ha Fe had the least LAI even though at par with those obtained when 15 kg/ha Mg with 8 kg/ha Fe, 0 kg/ha Mg with 0.6 kg/ha Fe and 16.7kg/ha Mg with 0.6 kg/ha Fe were applied.

However, application of 0 kg/ha Mg under 8 kg/ha Fe and 15 kg/ha Mg under 0 kg/ha Fe however, produced higher LAI even though, at par with 25 kg/ha Mg under 8, 0 and 10 kg/ha of Fe.

4.1.3 Response of Variety, Iron and Magnesium on Reproductive Characters

Days to 50% tasseling

Table 19 shows the effect of Variety, Magnesium and Iron on days to 50% tasseling in 2015 and 2016 rainy season. Significant ($p<0.001$) differences were observed among the varieties in both 2015 and 2016 rainy seasons. Variety JO-F excelled in attaining tasseling later than the rest of the treatments except Sammaz 15. Variety Sammaz 27 on the other hand reached tasseling earlier than the other treatments tested in 2015. However, in 2016 Sammaz 15 reached tasseling much later and significantly ($p\leq0.01$) then the other treatments used with Sammaz 27 reaching tasseling earlier.

The effect of Magnesium on days to 50% tasseling of maize was not significant in 2015 while there was significant difference during 2016 raining season with the control (zero application) recording more number of days to reach 50% tasseling while minimum number of days were recorded with application of 16.7 and 25 kg/ha of Mg.

Interaction between variety and Iron on days to 50% tasselling (Table 20) showed that irrespective of iron levels used there was more days to tasseling with Sammaz 15 while fewer days to tasseling was recorded in Sammaz 27 with application of iron from control up to 10 kg/ha.

Days to 50% silking

Effect of variety, magnesium and Iron on days to 50% silking is presented in Table 19. Significant differences were observed among the varieties in both years of the study. In 2015, JO-F had more days to commence silking but statistically similar with Sammaz 15 which had more days to silking in both years of investigation. Sammaz 27 had recorded minimum number of days to 50% silking in both years of the study. Application of magnesium had no effect during 2015 raining season while in 2016 raining season, the control had more days to silking even though at par with 15 and 25 kg/ha.

Table 15: Interaction between Iron and Magnesium levels on leaf area (cm^2) in 2016 Rainy Season at BUK

Iron (kg/ha)	Mg (kg/ha) 0	15	16.7	25
Control	330.9e	392.5a	341de	374.3abc
0.6	353.4c-e	383abc	358.7b-e	366.2a-d
8	394.8a	358.9b-e	373.6abc	390.5ab
10	327.6e	368.5a-d	379.4abc	377.5abc
SE±		12.11		

Table 16: Interaction between Varieties and Magnesium levels on leaf area index in 2016 Rainy Season at BUK

Varieties	Mg (kg/ha) 0	15	16.7	25
SAMMAZ 27	0.188cde	0.19cd	0.20bc	0.176ef
SAMMAZ 15	0.19cd	0.22b	0.188cde	0.24a
JO-F	0.167f	0.188cde	0.20bc	0.19cd
OBA 98	0.19bcd	0.19bcd	0.183def	0.192cde
SE±		0.006		

Table 17: Interaction between Varieties and Iron levels on leaf area index in 2016 Rainy Season at BUK

Varieties	Fe (kg/ha) 0	0.6	8	10
SAMMAZ 27	0.188cde	0.188cde	0.195bcd	0.193b-e
SAMMAZ 15	0.208ab	0.217a	0.203abc	0.214a
JO-F	0.187cde	0.193b-e	0.193b-e	0.177e
OBA 98	0.184de	0.182de	0.219a	0.189cde
SE±		0.006		

Means within the same column carrying the same letter are not significantly different at **= significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level

Table 18: Interaction between Magnesium and Iron levels on leaf area index in 2016 Rainy Season at BUK

		Fe (kg/ha)		
Mg(kg/ha)	0	0.6	8	10
Control	0.176e	0.189cde	0.211a	0.175e
15	0.209a	0.204abc	0.191b-e	0.197a-d
16.7	0.182de	0.191b-e	0.20abc	0.202abc
25	0.20abc	0.195a-d	0.208ab	0.201abc
SE±		0.006		

Means within the same column carrying the same letter are not significantly different at **= significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level

Table 20: Interaction between Varieties and Iron levels on Days to 50% Tasseling in 2016 Rainy Season at BUK

			Fe (kg/ha)	
Varieties	0	0.6	8	10
SAMMAZ 27	47.2h	48.5g	48.4g	49.1fg
SAMMAZ 15	52.7ab	53.1a	52.7ab	52.7ab
JO-F	52.3abc	51.7bcd	52.3abc	51.5cd
OBA 98	51.6cd	51.6cd	50.1ef	50.9de
SE±			0.418	

Means within the same column carrying the same letter are not significantly different at **= significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level

Table 21: Interaction between Varieties and Iron Levels on Days to 50% Silking in 2016Rainy Season at BUK

		Fe (kg/ha)		
Variety	0	8	10	0.6
SAMMAZ 27	50.5g	51.5fg	53.2e	51.8f
SAMMAZ 15	56.5a	56.1ab	56.1ab	56.1ab
JO-F	55.7abc	55.2abcd	55bcd	55.1bcd
OBA 98	54.6cd	54.2de	54de	54.7cd
SE±	0.499	0.499	0.499	0.499

Means within the same column carrying the same letter are not significantly different at **= significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level

Table 19 Effect of Varieties, Iron and Magnesium Levels on days to 50% Tasseling and Silking in 2015 and 2016 Rainy Season at BUK

	50% Tasseling		50% Silking	
Treatments	2015	2016	2015	2016
Variety (V)				
JO-F	54.7a	52.0b	58.4a	55.3b
Oba 98	53.1b	51.0c	56.3b	54.4c
SAMMAZ 15	53.6ab	52..8a	57.1ab	56.2a
SAMMAZ 27	48.0c	48.3d	51.1c	51.8d
P-value	<0.00101**	<0.0001**	<0.0001**	<0.0001**
SE ±	0.524	0.241	0.571	0.288
Mg (kg/ha)				
0	52,8	51.37a	56.0	54.8a
15	52.3	51.29ab	55.9	54.5ab
25	51.9	50.67c	55.2	54.06b
16.7	52.4	50,8bc	55.8	54.3ab
p-value	0.511NS	0.0261**	0.6343NS	0.01568*
SE±	0.524	0.241	0.571	0.288
Fe (kg/ha)				
0 (control)	52.3	50.96	55.83	54.31
0.6	52.5	51.23	55.83	54.44
8	52.5	50.82	55.75	54.27
10	52.1	51.04	55.46	54.60
p-value	0.926NS	0.06553NS	0.9324NS	0.07499NS
SE±	0.524	0.241	0.571	0.288
Interactions				
V*Fe	NS	**	NS	**
Fe*Mg	NS	NS	NS	NS
V*Mg	NS	NS	NS	NS
V*Fe*Mg	NS	NS	NS	NS

Means within the same column carrying the same letter are not significantly different at **= significant at 0.001% probability level. NS=Not significant, *= significant at 0.05% probability level

Application of 16.7 kg/ha Mg on the other hand had statistically (≤ 0.01) fewer days to 50% silking.

Interactions between variety and Iron in 2016 raining season (Table 21) showed that higher number of days to silking was observed with Sammaz 15 throughout the application rates of iron used. Sammaz 27 on the other hand reached silking earlier under all the iron rates applied.

100 seed weight (g)

Effect of variety, magnesium and iron on 100-seed weight in 2015 and 2016 raining seasons is shown in Table 22. There was significant difference among the varieties with Sammaz 27 producing significantly ($p \leq 0.01$) heavier seeds in the two years under study, followed by JO-F in 2015. However, Oba 98 had lighter seeds in both years among the varieties tested. At the different levels of Magnesium application of 25 kg/ha Mg produced seeds with higher weight, but only in 2015. The control plots on the other hand had the least 100 seed weight. No significant difference was observed in 2016. At the different levels of iron significant ($p \leq 0.01$) difference was observed among the different levels tested. Application of 10, 8 kg/ha and the control in 2015 and 8 and 10 kg/ha Fe in 2016 had significantly ($p \leq 0.01$) higher seed weights than the other rates.

Interactions between variety and Iron in 2015 (Table 23) indicated that application of 0.6 kg/ha and the control produced heavier seeds in Sammaz 27 while consistently, Oba 98 had lighter seeds under all the different iron levels used.

The interaction between Iron and Magnesium (Table 24) showed that application of Mg at 25 kg/ha with no application Fe (control) had heavier seeds among all the treatment combination. However, zero application of Mg with 0.6 kg/ha Fe produced the least 100 seeds weight.

Interaction between varieties and magnesium revealed that application of 16.7 and 25 kg/ha Mg to Sammaz 27 produced heavier seed weight while Oba 98 with zero application of Mg produced the least values in terms of 100 seed weight.

Number of kernels per cob

Response of maize varieties to different levels magnesium and Iron is presented in Table 22. Significant effect was observed in both the cropping seasons. In 2015, JO-F and Sammaz 15 recorded significantly ($p \leq 0.01$) higher number of kernels per cob while Sammaz 27 and Oba 98 recorded the lowest number of kernels per cob. In 2016, the results showed that Sammaz 15 had significantly ($p \leq 0.01$) higher number of kernels followed by Sammaz 27 and Oba 98 varieties while JO-F recorded the lowest number of kernels per cob. No significant difference was observed on number of kernels per cob of maize with application of iron, magnesium and their interactions in both years of the study Table 22.

Cob yield (kg/ha)

Effect of maize varieties, magnesium and Iron levels on cob yield in 2015 and 2016 rainy seasons is presented in Table 26.Significant differences were observed among the varieties where Sammaz 27 in both years of the study, recorded significantly ($p \leq 0.01$) higher cob yield including Sammaz 15 in 2015. Variety JO-F however, produced the least yield in both years of the investigation. At the different Mg levels, significant difference was only observed in 2016 rainy seasons where all the treatment had significantly ($p \leq 0.01$) higher cob yield except the control.

Table 22. Effect of Varieties, Iron and Magnesium Levels on 100 Seed Weight and Number of Kernels in 2015 and 2016 Rainy Season at BUK

	100 Seed Weight (g)		Number of Kernels	
Treatments	2015	2016	2015	2016
Variety (V)				
JO-F	15.7bc	17.5b	481.5a	381.0b
Oba 98	15.6c	15.9c	450.6b	393.1ab
SAMMAZ 15	16.2b	17.5b	474.6a	415.6a
SAMMAZ 27	18.2a	20.7a	438.9b	385.9ab
P – value	<0.0001**	<0.0001**	0.0007**	0.1722NS
SE ±	0.2299	0.523	9.977	14.424
Mg (kg/ha)				
0	15.5c	17.9	472.2	375.2
15	16.4b	17.2	453.3	397.0
25	17.4a	18.3	464.1	402.9
16.7	16.4b	18.1	456.1	400.5
P – value	<0.0001**	0.3126NS	0.3551NS	0.3266NS
SE±	0.2299	0.523	9.977	14.424
Fe (kg/ha)				
0 (control)	16.6ab	17.0c	456.3	402.1
0.6	16.1b	17.5bc	462.2	390.0
8	16.2ab	18.7a	468.6	393.0
10	16.7a	18.4ab	458.4	390.4
P – value	0.01**	0.0164*	0.7230NS	0.8759NS
SE±	0.2299	0.523	9.977	14.424
Interactions				
V*Fe	**	NS	NS	NS
Fe*Mg	**	NS	NS	NS
V*Mg	**	NS	NS	NS
V*Fe*Mg	NS	NS	NS	NS

Means within the same column carrying the same letter are not significantly different at **= significant at 0.001% probability level. NS=Not significant, *= significant at 0.05% probability level

Table 23: Interaction between Varieties and Iron Levels on 100 Seed Weight (g) in 2015 Rainy Season at BUK

		Fe (kg/ha)		
Varieties	0	0.6	8	10
SAMMAZ 27	18.7ab	19.2a	16.9cd	17.8bc
SAMMAZ 15	17cd	15.7e	16.1de	15.9de
JO-F	15.3e	13.8f	16.3de	17.6c
OBA 98	15.4e	15.6e	15.7e	15.6e
SE±		0.398		

Means within the same column carrying the same letter are not significantly different at **= significant at 0.001% probability level. NS=Not significant, *= significant at 0.05% probability level

Table 24: Interaction between Magnesium and Iron levels on 100 Seed Weight (g) in 2015Rainy Season at BUK

		Fe (kg/ha)		
Mg (kg/ha)	0	0.6	8	10
0	16.2def	14.3g	15.7ef	15.9ef
15	15.5f	16.49cdef	16.4cdef	17.1bcd
16.7	15.9ef	17.5b	15.7ef	16.5bcde
25	18.8a	16.2def	17.2bcd	17.3bc
SE±		0.398		

Table 25: Interaction between Varieties and Magnesium levels on 100 Seed Weight (g) in 2015 Rainy Season at BUK

		Mg (kg/ha)		
Varieties	0	15	16.7	25
SAMMAZ 27	17.0bcd	17.7b	19.0a	19.2a
SAMMAZ 15	15.0gh	17.0bcd	15.4efg	17.3bc
JO-F	16.2def	15.6efg	14.8gh	16.4cde
OBA 98	14.0h	15.2fg	16.3cde	16.7bcd
SE±		0.398		

Means within the same column carrying the same letter are not significantly different at **= significant at 0.001% probability level. NS=Not significant, *= significant at 0.05% probability level

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At the different iron levels, significant difference was observed in the two seasons under the study. Application of 0.6 and 8 kg/ha of Fe resulted in higher cob yield in 2015 and 2016 cropping seasons. On the other hand, Application of 10 kg/ha Fe recorded the lowest cob yield even though similar with the control.

Interaction between variety and Iron (Table 27), existed in both years of the investigation. In 2015, application of 0.6 kg/ha of Fe recorded the highest cob yield in Sammaz 27 followed by control in the same variety. Control application of Fe on the other hand, had the lower cob yield in variety JO-F and Oba 98.

Table 28 shows that the interaction between magnesium and iron in 2015 raining season. The Table indicated that application of 25 kg/ha of Mg with 0.6 kg/ha of Fe followed by 15 kg/ha of Mg with 8 and 10 kg/ha of Fe produced higher cob yield than the other treatment combinations used. The least cob yield was however, obtained from the application of 25 kg/ha of Mg and 8 kg/ha of Fe, followed by 25 and 0 kg/ha of Mg and 0 kg/ha of Fe and also 25 and 0 kg/ha of Mg with 10 kg/ha of Fe.

Interaction between variety and iron on cob yield is presented in Table 29 the table indicates that variety Sammaz 27 with the application of 0.6 and 8 kg/ha produced higher cob yield followed by 10 kg/ha Fe. JO-F on the other hand, had the least cob yield with 0 and 10 kg/ha Fe. In 2016 rainy season, interaction between magnesium and Iron on cob yield was observed (Table 30). Application of 25 kg/ha of Mg with 0.6 kg/ha of Fe and 16.7 and 25 kg/ha of Mg with 8 kg/ha of Fe produced higher cob yield than the rest of the treatment combinations. The least cob yield was however, obtained with 0 kg/ha of Mg and 0.6 kg/ha of Fe.

Table 26 Effect of Maize Varieties, Iron and Magnesium levels on Cob Yield (kg/ha) and Grain Yield (kg/ha) in 2015 and 2016 Rainy Season at BUK

	Cob Yield (kg/ha)		Grain Yield (kg/ha)	
Treatments	2015	2016	2015	2016
Variety (V)				
JO-F	5263.2b	2969.5c	4010.2c	2227.4c
Oba 98	5546.6ab	3362.4b	4280.7b	2633.1b
SAMMAZ 15	5704.9a	3672.6b	4323.6ab	2708.2b
SAMMAZ 27	5717.9a	5201.3a	4550.9a	4253.5a
P – value	0.0288*	<0.0001**	0.0008**	<0.0001**
SE ±	146.879	138.614	111.835	118.822
Mg (kg/ha)				
0	5473.3	3475.6b	4197.2	2713.9b
15	5749.9	3816.6a	4443.7	2943.0ab
16.7	5535.1	3976.0a	4270.2	3109.4a
25	5474.3	3937.6a	4254.4	3055.9a
P – value	0.316NS	0.009**	0.250NS	0.024*
SE±	146.879	138.614	111.835	118.822
Fe (kg/ha)				
0 (control)	5353.9b	3611.1bc	4110.2b	2782.9c
0.6	5828.3a	3910.3ab	4500.4a	3066.5ab
8	5569.3ab	4116.4a	4312.1ab	3154.3a
10	5481.1b	3568.0c	4242.7b	2818.6bc
P – value	0.043*	0.002**	0.026*	0.016*
SE±	146.879	138.614	111.835	118.822
Interactions				
V*Fe	**	**	**	*
Fe*Mg	**	**	**	**
V*Mg	NS	**	NS	**
V*Fe*Mg	NS	NS	NS	NS

Means within the same column carrying the same letter are not significantly different at **= significant at 0.001% probability level. NS=Not significant, *= significant at 0.05% probability level.

Table 27: Interaction between Varieties and Iron levels on Cob Yield (kg/ha) in 2015 Rainy Season at BUK

		Variety		
Fe (Kg/ha)	SAMMAZ 27	SAMMAZ 15	JO-F	Oba 98
Control	6187.67ab	5740.3a-d	4737.2f	4750.5f
0.6	6395.67a	5321.2def	5943.09a-d	5653.2b-e
8	5015.2ef	5848.3a-d	5384c-f	6029.76a-c
10	5272.9def	5909.9a-d	4988.7ef	5752.9a-d
SE±			254.40	

Table 28: Interaction between Magnesium and Iron levels on Cob Yield in 2015 Rainy Season at BUK

			Fe (kg/ha)	
Mg (kg/ha)	0	0.6	8	10
0	5134.4ef	5723.0b-e	5925.4bc	5110.3ef
15	5253.5def	5415.3c-f	6232.7ab	6098.3b
16.7	5874.9bcd	5371.9c-f	5292.8c-f	5600.8bcd
25	5152.8ef	6802.9a	4826.3f	5115.2ef
SE±			193.70	

Table 29: Interaction between Varieties and Iron levels on Cob Yield in 2016 Rainy Season at BUK

			Fe (kg/ha)	
Variety	0	0.6	8	10
SAMMAZ 27	4560bc	5772.8a	5315.7a	5156.7ab
SAMMAZ 15	3487.8d	3352.6d	4359.8c	3490d
JO-F	2967.5de	3268.3d	3260.1d	2382.3e
OBA 98	3429.3d	3247.4d	3529.9d	3243.1d
SE±			240.09	

Means within the same column carrying the same letter are not significantly different at *

Table 31, indicates the interaction between variety and magnesium on cob yield. Variety Sammaz 27 produced higher cob yield when combined with 16.7 and 25 kg/ha Mg. Variety JO-F on the other hand, produced the least cob yield with 0 and 15 kg/ha of Mg.

Grain yield (kg/ha)

Effect of variety, magnesium and iron on grain yield in 2015 and 2016 raining seasons is shown in Table 26. Significant difference was observed among the varieties where Sammaz 27 produced significantly ($p \leq 0.01$) higher grain yield in both years of the investigation. Variety Sammaz 15 was second in grain yield and superior over JO-F and Oba 98. The least grain yield was however, obtained with JO-F in both years. The table also, shows that application of magnesium did not show significant effect on the grain yield in 2015 trial. However, in 2016, there was significant effect where except the control, all the treatments had significantly higher grain yield but were statistically similar. The different iron levels also, showed significant effect on grain yield of maize in both years of the study. Application of 0.6 and 8 kg/ha Fe significantly ($p \leq 0.01$) had higher grain yield than the rest of the treatments applied. However, the control and 10 kg/ha Fe produced the least grain yield.

Interaction between variety and iron (Table 32) showed that application of 0.6 kg/ha Fe produced higher grain yield in Sammaz 27 though statistically similar with the control. Variety JO-F and Oba 98 however, were the least in grain yield production under control of Fe. Variety Oba 98 with the application of 8 kg/ha of Fe also had higher yield statistically similar to Sammaz 27.

Table 30: Interaction between Magnesium and Iron levels on Cob Yield in 2016 Rainy Season at BUK

			Fe (kg/ha)	
Mg (kg/ha)	0	0.6	8	10
0	3962.3abc	2883.8e	3865abc	3191de
15	3598.7cd	4135.3abc	3791bcd	3741.5bcd
16.7	3674.1cd	4143.5abc	4446.1a	3640.1cd
25	3209.5de	4478.5a	4363.3ab	3699.2cd
SE±			240.09	

Table .31: Interaction between Varieties and Magnesium levels on Cob Yield in 2016 Rainy Season at BUK

		Mg (kg/ha)		
Variety	0	15	16.7	25
SAMMAZ 27	4800.4bc	4983.5b	5315ab	5706.3a
SAMMAZ 15	3068.5fgh	3793de	4223.8cd	3604.4def
JO-F	2908gh	2531.2h	3227.6efg	3211.4efg
OBA 98	3125.5fgh	3958.3d	3137.5fgh	3228.4efg
SE±			240.09	

Means within the same column carrying the same letter are not significantly different at **= significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level.

Table 32: Interaction between varieties and iron levels on Grain Yield (kg/ha) in 2015 rainy season

			Fe (Kg/ha)	
Variety	0	0.6	8	10
SAMMAZ 27	4925.4ab	5137.9a	3954.9d-g	4185.4cde
SAMMAZ 15	4289cde	3997.7d-g	4455bcd	4552.6bc
JO-F	3553.6g	4517.7bc	4182.7c-f	3786.9efg
OBA98	3672.8fg	4348.3cd	4655.9abc	4445.9bcd
SE±			193.70	

Means within the same column carrying the same letter are not significantly different at **= significant at 0.01% probability level. NS=Not significant, *= significant at 0.05% probability level.

Table 33 indicates interaction between magnesium and iron on grain yield of maize in 2015. Application of magnesium at 25 kg/ha with 0.6 kg/ha of iron had higher grain yield even though at par with 15 kg/ha of Mg and 8 kg/ha of Fe. However, application of 25 kg/h of Mg with 8 kg/ha of Fe produced the lower yield of maize.

Interaction between variety and iron in 2016 (Table 34) was significant, where application of 0.6, 8, and 10 kg/ha of Fe on Sammaz 27 had higher yield while application of 10 kg/ha Fe on JO-F produced the lower yield.

Interaction between magnesium and iron (Table 35) in 2016 showed that application of 25 kg/ha of Mg with 0.6 kg/ha of Fe recorded the higher grain yield but were statistically similar with the application of 15 and 16.7 kg/ha of Mg at the same Fe level. The control plots treated with 0.6 and10 kg/ha of Fe however, recorded the lower grain yields. Interaction between magnesium and variety on grain yield (Table 36) in 2016 indicates that, application of 25 kg/ha of Mg on Sammaz 27 produced higher grain yield and was statistically the same with that of 15 and 16.7 kg/ha of Mg. The least grain yield was produced from application of 0 and 15 kg/ha of Mg with JO-F maize variety.

Table 33: Interaction between Magnesium and Iron levels on Grain Yield (kg/ha) in 2015 Rainy Season at BUK

			Fe (Kg/ha)	
Mg (Kg/ha)	0	0.6	8	10
0	3951.7de	4386.5bcd	4546.9bc	3903.5de
15	3961.8de	4189.8cde	4844.4ab	4778.7ab
16.7	4490.6bc	4158.7cde	4079.4cde	4352.2bcd
25	4036.8cde	5266.6a	3777.8e	3936.7de
SE±			193.70	

Table 34: Interaction between Varieties and Iron levels on Grain Yield (kg/ha) in 2016 Rainy Season at BUK

			Fe (Kg/ha)	
Varieties	0	0.6	8	10
SAMMAZ 27	3636.8b	4775.8a	4304.7a	4296.5a
SAMMAZ 15	2603.2cde	2475.2de	3130.2bc	2624.3cde
JO-F	2209.7ef	2441.6de	2416.2de	1842.2f
OBA 98	2681.7cde	2573.5de	2765.9cd	2511.4de
SE±		205.81		

Table 35: Interaction between Magnesium and Iron levels on Grain Yield (kg/ha) in 2016 Rainy Season at BUK

			Fe (kg/ha)	
Mg (kg/ha)	0	0.6	8	10
0	3030.8a-e	2214.8g	3124.9a-d	2485.1fg
15	2707.7d-g	3297.2abc	2809.7c-f	2957.4a-f
16.7	2834.4c-f	3254.4abc	3443.9ab	2904.8bc-f
25	2558.5efg	3499.7a	3238.6a-d	2927.1b-f
SE±		205.81		

Table 36: Interaction between Magnesium levels and Varieties on Grain Yield (kg/ha) 2016 Rainy Seasonat BUK

		Variety		
Mg (kg/ha)	Sammaz 27	Sammaz 15	JO-F	Oba 98
0	3876b	2389.2ef	2180.2fg	2410.2ef
15	4110.9ab	2780.1cde	1756.2g	3125c
16.7	4401.1ab	3022cd	2493d-f	2522d-f
25	4625.9a	2642c-f	2480.2d-f	2476ef
SE±				

4.2 DISCUSSIONS

4.2.1 Performance of Maize Varieties

The results obtained indicated that there were significant ($P \leq 0.01$) differences among the different varieties in respect of growth and yield characters such as plant height, number of leaves, chlorophyll content, leaf area and leaf area index, 100 seeds weight, number of kernels, cob and grain yield. The higher leaf area and LAI of Oba 98, JO-F and Sammaz 15 varieties is slightly in agreement with findings of Fakorede and Mock (1979) who reported that improved hybrid have higher leaf area and LAI values compared to other varieties. Such revelation could be associated with the differences in the genetic make- up of the varieties as agreed by an earlier report of Malik, (2010). In a similar investigation, Odeleye and Odeleye (2001) reported that maize varieties differ in their growth characters, yield and its components.

In another studies however, Ahmed and Sadek (1992) reported that maize cultivars differ in their growth characters, yield and its components. Sharifai *et al., (*2008) also, reported the superiority of certain varieties in terms of plant height, total dry matter, relative growth rate and grain yield as a result of more responsiveness to fertilizer sources and genetic make-up. Across the two years of study, the open pollinated and early maturing variety Sammaz 27 out yielded the other varieties including the hybrids with higher grain yield and superiority in most yield components.

The higher yield of variety Sammaz 27 over other varieties could be due to variations in genetic structure; which is associated with variety with respect to high yield, adaptation to environmental stresses and diseases resistance, mineral concentrations and potentials to transport photosynthetic materials within the plants; its ability to conduct and partitioning photosynthetic materials through its stomata towards economic yield. This is similar to the findings of Costa and Campos (1990); Gardner, *et al*., (1990) and Zaki *et al.,* (1999) which attributed yield differences in maize cultivars to stomata conductance value and to differences between genotypes in partitioning of photosynthetic materials towards economic yield. Udoh, (2005) also attributed that the high yield of some improved or open pollinated maize varieties to differences in genetic make - up, diseases resistance and adaptation to environmental condition. This is in line with the findings of Clark *et al*., (1997). Similarly, Omondi *et al*. (2014), reported that grain of open pollinated maize weighed 1.6 times more than those of hybrid.

Among the varieties tested Sammaz 15 produced higher number of kernels per cob; possibly it had more number of kernels that were formed in the ears which are more effective in partitioning of photosynthate to the sink. This is slightly in contrast with the findings of Begna *et al*., (1997) who reported that higher grain yield among maize cultivars was due to greater number of kernels that are formed in the ears which are more effective sink for carbohydrate synthesized in the leaves. However, this is in contrast with the observations made by Malik (2010), and Manasseh *et al*. (2016), that hybrids generally produced more grains than open pollinated maize varieties. Open pollinated varieties have been developed for high yielding and resistant / tolerant to biotic and abiotic stresses and as such, could out - performed some of the hybrid materials. Between the two hybrids, Oba 98 had higher grain yield compared with JO-F, in spite of their similarity in growth habit and yield characteristics. It is likely that Oba 98 given its long maturity period had extended period for dry matter production and grain filling. The fact that 2015 trial produced more growth and yield components as compared with 2016 trial was due to rainfall received during the growing period

4.2.2 Effect of Magnesium

The results obtained revealed that there was yield increase with increase in magnesium rates including the foliar application. Application of magnesium at 25 kg/ha resulted in increased 100 seeds weight, cob and grain yield of maize in all the two years of the study. The yield of maize varieties has increase due to synergetic interaction between varieties tested with levels of magnesium.. This is almost in line with the work of Frey *et al*., (1992), who reported a higher yield increase of 44 % as a result of 25 kg/ha application of magnesium to maize in northern Ghana. Also, Bello *et al*., (2018) reported that there is consistent yield increase in both hybrid and open pollinated maize varieties with application of secondary macro nutrients compared to control. Similar result was reported by (Grzebisz, 2013) who observed significant yield increase with 20 kg/ha magnesium. This is in agreement with the findings of Abunyewa and Mercer – Quarshie (2004) who noted magnesium as a structural component of chlorophyll and therefore it is important in the process of photosynthesis and dry matter production. When magnesium is in short supply plant growth will be reduced and potentially yield will be limited. It was evident that addition of magnesium was accompanied by higher chlorophyll content, cob and grain yield of maize. This might have supported the superior yield attributes and higher yields recorded.

4.2.3 Effect of Iron

The addition of iron resulted in a consistent gain in 100 seeds weight, leaf area index, chlorophyll content, cob and grain yield at the rate of 8 kg/ha compared to control.

This agrees with the findings of Nassrin *et al.(*2012) who reported that application of micronutrients resulted in luxuriant growth with excessive leaf area and yield of maize. Similar results were observed by Bello *et al*., (2018). Also, Kanwal, (2010) reported that there is an increase in maize yield with the application of micronutrient. The decline in yield of maize in the absence of this micronutrient is due to nutrient imbalance. This is also in agreement with the findings of Adhikary, *et al*.(2010) and El – Gizawy and Hythum, (2012) who reported that higher grain yield was recorded with the maize supplied with micronutrient combined with recommended dose of NPK. However, in another study, Abbas *et al.* (2009) reported that application of Fe along with the recommended level of NPK had no significant effect compared with recommended NPK alone. It is likely that the levels used in the past studies were low to account for significant response suggesting that the soils of the experimental sites were low in Fe and therefore, higher levels are needed to improve maize production.

Foliar application of iron at the rate of 0.6 kg/ha significantly increased cob and grain yield of maize, these increased was observed in the similar research conducted by Salem and El – Gizawy(2012) who reported that foliar spray of micronutrient gave the higher maize grain yield in both seasons of the study. Potarzyckiand Grzebisz (2009), reported an increase in maize grain yield by nearly 18% with application of 1.0 – 1.5 kg/ha foliar application of iron. It has been concluded that foliar application of iron are useful for improving the nutrient status, physiological performance of maize plant. These findings are in harmony to those obtained through foliar application of micronutrient (El – fourly *et al*., 1997; El – fourly *et al*., 2011).Many studies have highlighted the significance of Fe in maize nutrition even though as a micronutrient, the element is needed in trace amount (Vanlauwe *et al.,* 2015), depending on the inherent Fe content of the soil.

4.2.4 Interaction of Treatments

Effect of Iron and Magnesium Interactions

There is a significant ($p \leq 0.01$) difference on plant height, chlorophyll content, leaf area, LAI, 100 seed weight, and cob and grain yield of maize with application of 10 kg/ha of Fe and 16.7 kg/ha of Mg produced taller plants, more chlorophyll contents. Application of 0.6 kg/ha Fe and 25 kg/ha Mg produced higher cob and grain yield of maize. This implies that there is a synergy between the two nutrients tested in the two year trial. This finding is in harmony with what was obtained by Bello *et al,* (2018), who reported that the addition of secondary macro and micronutrient resulted in a consistent gain in grain yield of 0.2 – 1.08 t/ha compared to NPK treatment in maize production. In a similar research however, Abunyewa and Mercer, (2004) reported a percent increase in maize grain yield ranging between 9 – 152% over the control.

Effect of iron and variety interactions

There is significant ($p \leq 0.01$) increase in growth and yield characters of maize varieties interacting with iron at different rates. It has been observed in the experiment that all the four varieties behave differently with the rates of iron fertilizer applied. This is line with the findings of Odeleye and Odeleye (2001), who reported that maize varieties differ in their growth characters, yield and its components. Open pollinated variety (Sammaz 27) out – performed other varieties in terms of 100 seeds weight, cob and grain yield. This is in agreement with the findings of Clark *et al*., (1997), who reported that higher yield among the maize varieties may be as a result of variation in genetic structure, mineral concentrations and potentials to transport photosynthetic materials within plant. Havlin *et al.*(2003) also reported that plants responded to low iron rate when phosphorus in the soil is low. Salem, *et al*.,(2016), reported that foliar application of nutrient proved to be a better way to increase the nutrients contents in maize grain. This indicated that foliar applications particularly those made at later stages of leaf growth and at early stem extension have been shown to increase maize yield.

Effect of magnesium and variety interactions

There is a significant interaction between varieties tested with levels of magnesium. Generally, interaction varies from nutrient to nutrient, crop species to species, and sometimes among cultivars of the same species. Here the interaction is between different varieties of maize with different levels of magnesium. The result revealed that there is an increased in leaf area, leaf area index, plant height, 100 seeds weight, cob and grain weight. All the four varieties responded differently to varying rates of magnesium. This is as a result of differences in the genetic make - up of the varieties tested. Application of 25 kg/ha magnesium produced higher yield in Sammaz 27 while other varieties produced yield that differed with Sammaz 27 with magnesium application. In a similar research Rasheed *et al*.,(2004), reported that application of 15 kg/ha Mg obtained maize grain yield increase of 1.1 t/ha. In another experiment Potarzycki, (2009), revealed that there is a yield increase with application of magnesium of up to 9.89 t/ha greater than yield of maize supplied with N.P.K alone (9.49 t/ha). Abunyewa and Mercer – Quarshie (2004), gained yield increament of 108 %. Frey, *et al*., (1992), reported a grain yield increase of 124 % over the control when 25 kg/ha of magnesium and 10 kg/ha of Fe were applied.

The significant interaction of variety, Fe and Mg could be due to the differential response of the varieties to the two micro nutrients given them varied genetic composition. Some of the maize varieties had higher demand or exhibits superior performance at higher nutrient levels than other. It is possible that, the varied varietal response could be informed by the soil condition apart from the genetic make - up (Jones and Wild, 1975). The interaction between Mg and Fe on some growth components could be due to the complementary roles of the two nutrients as they support each other in promoting physiology and growth in plants. However in some of the results like that of cob yield higher doses of Mg plus lower levels of Fe gave heavier cobs suggesting this combination as appropriate.

CHAPTER FIVE

5.0. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. SUMMARY

A field experiment was conducted in 2015 and 2016 rainy seasons at the Bayero University Teaching and Research Farm, Kano ($11^0$58'N and $8^0$25'E) to study the response of maize varieties to different levels of magnesium and iron sulphate in the savanna. The objectives of the study include: the evaluation of growth and yield of some hybrid and open pollinated maize varieties in the Sudan savanna of Nigeria and the assessment of the response of varieties to magnesium and iron fertilization on growth and yield of the crop in the study area.

The treatments consisted of four maize varieties (two open pollinated varieties - SAMMAZ 27 and SAMMAZ 15, and two hybrid varieties (JO-F and Oba 98), four levels of magnesium (0, 15, 16.7 and 25kg/ha) and four levels of iron (0, 0.6, 8, and 10 kg/ha). The treatments were laid out in split – split plot design, replicated three times. The maize varieties were assigned to the main plot, levels of magnesium to the sub plot and iron in sub – sub plot.

The results showed that, the varieties differed significantly on both growth and yield characters. Also there were differential varietal response to the different levels of magnesium and iron. However, application of 10 kg/ha Iron was observed to significantly increase plant height, leaf area index, 100 seed weight in 2015 trial. Invariably, application of 0.6 kg/ha Iron substantially increased leaf chlorophyll contents, cob yield and grain yield of the tested maize varieties. Similarly, was inferred that the application of 16.7 kg/ha Magnesium reduced growing days to 50% tasseling with higher leaf chlorophyll content across the varieties. Application of 16.7 and 25 kg/ha of magnesium also produced higher cob yield in 2016 with plant height in 2015 rainy season. Variety Sammaz 27produced taller plants, higher cob and grain yield when Iron was applied at (0.6 kg/ha). Higher number of leaves was recorded with variety JO-F. Sammaz 15 was found to be superior in terms of tasseling and leaf area index when compared with the other varieties. Combined application of Magnesium and Iron significantly ($p<0.001$) increased most of the growth and yield characters in both years of the investigation. Application of 10 kg/ha Iron and 16.7 kg/ha Magnesium enhanced plant height and leaf area index of maize. However, application of 0.6 kg/ha Iron and 25 kg/ha Magnesium had higher 100 seed weight (g), cob and grain yield of the crop. Application of 16.7 and 25 kg/ha magnesium on the other hand, produced heavier seeds, taller plant, cob and grain yield in both trials.

5.2 CONCLUSION

The results of the experiment showed that Sammaz 27 seemed more promising in grain yield among the four varieties tested. Higher grain yield of maize was recorded with application of Magnesium at 25 and 16.7 kg/ha. However, application of 0.6 kg/ha Iron produced higher grain yield among the different levels studied. Also, combined application of 25 kg/ha Magnesium and 0.6 kg/ha Iron produced higher grain yield. Growing variety Sammaz 27 with the application of 25 kg/ha Mg gave the higher grain yield of maize. Planting of Sammaz 27 with the application of 0.6 kg/ha Fe also gave higher grain yield.

5.3 RECOMMENDATIONS

Based on the results obtained from the experiment, farmers in the study area could be advised to:

1). Grow variety Sammaz 27 for higher productivity in the Sudan savanna of Nigeria.

2.) Apply Magnesium at the rate 25 kg/ha for higher yields or alternatively, the Magnesium fertilization could be foliar applied at 16.7 kg/ha.

3). Apply Fe at 10 kg/ha in the soil or 0.6 kg/ha foliar applied.

4) Apply Magnesium and Iron at 25 kg/ha and 0.6 kg/ha for higher grain yield of maize.

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