DIFFERENTIAL SUSCEPTIBILITY OF THREE MAIZE (*Zea mays* L.) CULTIVARS TO ZINC DEFICIENCY IN THE NORTHERN GUINEA SAVANNA ZONE OF NIGERIA

BY

BOLANLE TITILAYO OLOWOOKERE (Mrs)

B.Sc (Hons) Chemistry
University of Ibadan

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Department of Soil Science
Faculty of Agriculture
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Zaria

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DECLARATION

I hereby declare that this thesis has been written by me and that it is the record of my own research work. It has not been presented before in any previous application for a higher degree.

Bolanle Titilayo Olowookere
(M.Sc. Candidate)

The above declaration is affirmed.

Dr. V.O. Chude
(Major Supervisor)

CERTIFICATION

This thesis entitled "DIFFERENTIAL SUSCEPTIBILITY OF MAIZE (*Zea mays* L.) CULTIVARS TO ZINC DEFICIENCY IN THE NORTHERN GUINEA SAVANNA ZONE OF NIGERIA" by BOLANLE TITILAYO OLOWOOKERE meets the regulations governing award of the degree of Master of Science of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

DR. V.O. CHUDE
Chairman, Supervisory Committee — 28/2/97 Date

Dr. E.N.O. IWUAFOR
Member, Supervisory Committee — 15/7/97 Date

DR. E.O. UYOVBISERE
Member, Supervisory Committee — 31/7/97 Date

DR. V.O. CHUDE
Acting Head, Dept. of Soil Science — 28/2/97 Date

PROFESSOR J.O. OLAYEMI
Dean, Postgraduate School — 27/10/97 Date

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DEDICATION

I dedicate this work to the Almighty God who has broken the gate of brass and cut the bars of iron in sunder in my life.

and

To my dear husband

Mr. Orimoloye Olowookere

who has been a source of inspiration throughout the course of study.

ABSTRACT

Field trials were conducted at Samaru over a period of two years 1991/93 to study the differential susceptibility of three maize cultivars (Ag-Kaduna, mega hybrid and T2BSR-Y) to zinc deficiency. The zinc application rates were 0, 1.0, 2-5, 5-0 and 7-5kg $Znha^{-1}$. There were response in cob length diameter, 1,000 grain weight and grain yield of maize with increase in zinc rates- A zinc rate of l-0kg $Znha^{-1}$ appeared to be good for optimum yield of maize-

Ag-Kaduna appears to be less susceptible to zinc deficiency than the other two varieties- When the nutrient concentrations were compared with zinc rates there appeared a markedly decrease in the concentration of Iron (Fe) and Phosphorus (P) as zinc rate increased- This shows that the absorption of Fe and P in the varieties appear to be the cause of differential susceptibility to zinc deficiency.

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CHAPTER ONE

1.0 INTRODUCTION

Zinc deficiency is gradually becoming widespread in the seasonally dry Nigerian savanna, as agriculture becomes increasingly more intensive on soils with low organic matter and low cation exchange capacity (Chude and Abdullahi, 1994).

Lombin (1983) evaluated the zinc status of Nigerian savanna soils and reported a range of 0.69-4.41mgkg^{-1} 0.1N Hcl extractable zinc and 0.35-3.90mgKg^{-1} 0.05N Hcl + 0.025 N H_2SO_4 extractable zinc. Studies conducted by Pam (1990) on savanna also showed that 0.01NHCl Zn ranged from 1.0-9.5mg Kg^{-1}.

Osiname (1972) also observed low zinc levels in some soils of the Western Nigerian Savanna. Osiname et al (1973a) attributed these low levels to low total zinc content of the soils. Ponnamperuma (1976) stated that most mineral stress problems including zinc deficiency can be alleviated by chemical amendments and water control which are beyond the means of most developing countries. He therefore suggested that breeding for tolerance to soil stress may be a simpler and less expensive method of overcoming the stresses. This will reduce our dependence on fertilizer for optimum crop yield.

Shukla et al (1973) reported that varieties within a crop often differ in their yielding capacity, nutrient requirement and efficiency in nutrient uptake. Millikan (1961) showed that in certain cases, these differences among varieties of a plant species have been found to be greater than those existing between related genera. This approach of tailoring the crop to suit the soil has received very limited attention in Nigeria.

In a greenhouse study, Chude and Abdullahi (1994) (in press) reported that various maize cultivars differed in their susceptibility to zinc deficiency. A similar study under field condition is desirable from a more practical point of view. Therefore, the objectives of this present study were to:

a) Screen three different maize cultivars and evaluate their different susceptibilities to zinc deficiency.

b) Evaluate the response of the different cultivars to zinc fertilization under field condition.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Forms of zinc in soils

Krauskopf (1972) pointed out that zinc occurs most frequently in the lithosphere as the mineral ZnS (sphalerite) and forms a silicate mineral (sauconite) in which it is an essential constituent but the pure mineral is rare. Zinc also occurs in ferro-magnesium minerals, biotite, magnetite and hornblende. It is held in sedimentary rocks partly as adsorbed Zn^{2+} on fine grained material and partly in the structure of the clay minerals probably substituting for Mg^{2+} (Elgabaly 1950). ZnO (Zincite), $Zn\,CO_3$ (Smithsonite are too soluble to persist in soils. Under reducing condition, where H_2S is produced ZnS (sphalerite) can form but under normal oxidising conditions S^{2-} is too low for this mineral to be stable (Krauskopf, 1972).

Zinc is not only present in soils as minerals, but it can also be adsorbed to solid surfaces or held by exchange sites. Zinc predominantly occurs in soil as a divalent cation and as such may be adsorbed on the adsorption complexes of clays and organic matter. Zinc is preferentially adsorbed at low concentration level below pH 7.7 as shown by (Lindsay, 1972) as Zn^{2+} and at higher pH values as neutral zinc hydroxide $Zn(OH)_2$.

Zinc adsorption limits the concent
soil solution and also it is a source
when the zinc supply in soil solution h
Predicting zinc behaviour in soil is c
occurrence of a great number of co
$Zn(OH)^{+}$, $Zn(OH)_3$, $HZnO_2$, these chelat
soil interactions in soils. Analysis of
showed that 30-60% of the zinc presen
with Fe_2O_3 minerals and 20 to 45% wi
Bingham et al (1964) suggested that the
in excess of the exchange capacity of so
precipitation of $Zn(OH)_2$, but the pos
precipitation was not critically examir

2.2 Soil zinc content

According to Thorne (1957), the tc
of soils is not necessarily related
Goldschmidt (1954) reported the average
the lithosphere to be approximately 80mg
considered a trace element in soil.

Hibbard (1940) found that zinc in
was much more concentrated near the su
and the concentration was greatest in
accumulated organic matter from leaf
plants residues for long periods.

Thorne et al (1942) reported the z
number of Utah soils varied from 30-2

zinc was greatest in the surface horizons and decreased with depth. Cotteine et al (1981) found the mean total zinc content of selected South Western Nigerian soils to be 26-189mg Kg^{-1}. The means of EDTA extractable zinc decreased sharply with depth in the profile.

Fagbami et al (1985) found the total zinc in the basement complex soils of south western Nigeria to range from 6.0-100.mgKg^{-1}, while Banjoko 1979 reported a range of 0.5-9.6mgKg^{-1} available zinc in the surface soils of the forest zone of south western Nigeria. Chude et al (1985) reported values of between 12 and 92mgKg^{-1} total Zinc in some Western Nigerian soils. According to them soils derived from igneous and metamorphic rocks contained more total zinc than soils derived from sedimentary rocks.

Beavington and Varley (1979) obtained a mean value of 66mgKg^{-1} total Zn on clay soils of Lake Chad Basin in Nigeria. Udo and Fagbami, (1979) obtained zinc content of 80mgKg^{-1} (Vom) and 67mgKg^{-1} in Dogon Gaba in Northern Nigerian savanna with surface soils containing more zinc than the subsurface. Osiname et al (1973b) found that available zinc was lower in the Savanna (1-2mgKg^{-1}) than in the rain forest zone (2-5mgKg^{-1}).

Lombin (1983) evaluated the micronutrient fertility in 55 representative soils of the seasonally dry Nigerian savanna soils. He reported that both 0.1NHCl extractable

and double acid extractable zinc were in general low ranging from 0.54-4.14mgKg^{-1} and 0.35-3.90mgKg^{-1} respectively.

2.3 Crop Response to zinc

Crops respond to micronutrient fertilizers in addition to their response to major nutrients for normal growth. The required concentration of zinc in soil solution is very small not more than 0.1mgKg^{-1} (Thorne, 1957). The micronutrient responses of rainfed cereal crops under dry land agriculture has not yet been widely reported in the savanna zone, although clear deficiencies of Zn have been established in derived savanna zone (Osiname et al, 1973a) and also irrigated agriculture in Sudan and Sahel savanna zone. This shows that micronutrient fertility of savanna soils can no longer be taken for granted.

In a multilocational fertilizer trail, Iwuafor et al (1991) reported that maize responded to zinc fertilizer up to 1kgZnha^{-1} at Kano and Gusau, while at Samaru and Malumfashi, the response to zinc was evident up to 2kgZnha^{-1} with increase of about 30% on their yield in average. Kang (1973) reported deficiency of zinc as common minor element problems of upland rainfed rice. Sobulo (1982) reported that application of 5Kgha^{-1} of Zn and Fe increased rice yield by 17% at Ilesha. Osiname et al (1973a) also obtained large grain yields which

increased with application of zinc at low rates on sandy soils in savanna zone. The importance of zinc in this zone had been earlier established by (Agboola et al 1976), who reported an increase in maize yield by about 33% with zinc application, which was similar to a yield increase of about 35% reported in Guinea or derived savanna (Osiname et al, 1973a).

Zinc deficiency problems were observed in Cacao in Western Nigeria (Egbe and Omotoso, 1972). Kayode (1985) also reported in a two year study in the rain forest and savanna zones of Nigeria that zinc significantly increased maize yield in the new and old savanna soils, whereas significant increased maize yield in the new and old savanna soils was recorded only in an old field of the forest zone.

Pam (1990) reported response to zinc application by maize at the 3 locations he studied, although response to zinc application was only in the greenhouse at Samaru.

2.4 Factors affecting soil zinc availability

Available zinc refers to that fraction of the total zinc accessible to plant roots. In Northern Nigerian, zinc status is low indicating that acidic granitic and quartzitic igneous rocks are the likely source. Osiname (1972), Udo and Fagbami (1979). Lombin (1983) reported that the availability in the seasonally dry Nigerian savanna appeared to be a function of organic matter, soil

pH and leaching intensity. Earlier, Thorne (1957) had indicated that zinc availability were controlled by such factors as:

a) soil pH

b) Organic matter content

c) Adsorption

d) Precipitation by phosphates

e) Leaching intensity.

2.4.1 Soil pH

Zinc deficiency usually occur in soils of pH 6.0 and above. However, Alben and Boggs (1936) found evidence of zinc deficiency on soils more acid than pH 5.5 but he explained this on the basis of a very low total zinc content. Deficient soils between pH 7.4 and 8.5 contained adequate total zinc but it's availability was low. Camp (1945) and Wear (1956) reported decline in availability of zinc as pH of the soil rises, the critical value being between the pH range of 5.5-6.5. It was found that soil zinc extractable with normal Nacl increased with decreasing soil pH.

Epstein and Stout (1951) analyzed supernatant solutions from a series of bentonite culture of uniform total zinc content and found an increasing amount of soluble zinc with increasing H^+ concentration.

Shaw and Dean (1952) observed zinc deficiency in soils in the range of pH 6.0-8.0, zinc forms an hydroxide with the

ability to act as a base or weak acid depending on the pH of the liquid environment. $HZnO_2^-$ acid zincate is prevalent in lower concentrations of alkali, while $ZnO_2^=$ predominates as the concentration of the alkali increases. There is also an increased solubility of zinc with NaOH additions as the pH exceeded 6.5. This is an evidence of the formation of soluble zincate ions, but there is an absence of increased zinc solubility in the alkaline range with $Ca(OH)_2$ due to low solubility of calcium zincate.

Calcium being the prevalent cation in soil solution for plant growth, the above information indicate that zincate formation is probably not an important factor in increasing zinc availability in non-alkali soils within the alkalinity range favourable for plant growth. This is in contrast to Viets et al (1957) that found a decrease in zinc uptake by plants by about half when the soil pH was increased from 5-7. They attributed the decrease to the formation of insoluble hydroxides, carbonates and zincates which are usually precipitated out of solution. Therefore the predominant occurrence of Zn deficiencies in the pH range of 6-8 is favoured by conditions of minimum zinc solubility.

Zinc is retained in the soil in relation to other cations in the order $H^+ > Zn^{2+} > Ca^{2+} > Mg^{2+} > K^t$. At low pH, H^+ will displace Zn^{2+} from exchange sites of

some colloids into soil solution. At high pH, the concentration of H^+ is low, zinc will therefore remain tightly bound on the exchange sites and become unavailable to the plants. Sillampaa (1972) could not established any relationship between soil pH and zinc uptake by plants. However, Banjoko (1979); Udo and Fagbami (1979); Chude and Obigbesan (1982) observed a strong correlation between soil pH and zinc availability.

2.4.2 Organic Matter

Organic matter can interact with zinc in two ways thus:-

a) Soluble zinc can be mineralized from organic matter and made available to plants.

b) zinc can be band into organic constituents that are immobile.

Chelation and complexing of zinc by organic matter may reduce its availability and zinc retained by organic matter is designated as chelated or complexed. Chelated zinc refers to that form of zinc extractable with copper acetate. While complexed zinc is that which is not extractable by either Cu or NH_4 acetate but which is released by oxidation of the organic matter with H_2O_2 (hydrogen peroxide).

Amounts of biologically and chemically extracted zinc were highly correlated with organic matter. (Lombin, 1983; Martens, 1968; Osiname et al, 1973a; Chude

and Obigbesan 1982).

Role of micronutrient in the fertility of Nigeria savanna soils is critical in these soils thus making organic matter to serve as the main reservoir of plant available zinc. (Lombin, 1983). A strong correlation had been found between soil organic matter contents and percentage of clay in the West Africa savanna soils as demonstrated by (Jones, 1973). Flores et al (1979) reported significant negative correlation while Udo and Fagbami (1979) reported non-significant correlation.

2.4.3 Precipitation by Phosphates

Zinc deficiency usually occur in soils containing abnormally high contents of soluble or total phosphate while in some instances phosphate fertilizers have induced zinc deficiencies. Loneragan et al, 1982; Farah and Soliman 1986 reported that high phosphate fertilization has a depressing effect on the uptake of zinc by plants since applied P can reduce the diffusion of zinc from the fertilizer band into the bulk solution. It was opined that P- induced zinc deficiency could be a simultaneous deficiency of both. Therefore, applying phosphate to correct for only phosphorus deficiency allows the zinc deficiency to be manifested Millikan (1947) and Loneragan (1951) reported that phosphate may decrease the availability of Zinc.

The mechanism of interaction between P and Zn is

still an unsettled issue. There are however four possible causes:-

(i) Interaction between P and Zn in the soil

(ii) The slower rate of translocation of zinc from the roots to the tops.

iii) A simple dilution effect on zinc concentration in the tops owing to the growth response to phosphorus.

(iv) A metabolic disorder within plant cells related to an imbalance between phosphorus and zinc (Olsen, 1972).

Keefer and Singh (1978) reported that an increase in the phosphate level in soils in some way changes the physiological ability of the plant to absorb zinc.

Burleson and Page (1967) were of the view that phosphorus and zinc react together within the root in a manner that reduces their mobility or solubility within the plant.

Stukenholtz et al (1966) reported that a high phosphorus concentration in the tissue inhibited translocation of zinc from the roots to tops.Sharma et al (1968) working on maize reported that added zinc increased the zinc concentration in roots more than in tops in the presence of P suggesting that the translocation of Zn to the tops was inhibited by phosphorus.

2.4.4 Adsorption

Zinc has been found adsorbed in small amounts on colloids in most soils. Adsorption reactions can reduce zinc solubility to deficiency levels. Such adsorption reactions can occur on many types of surfaces including (1) clay minerals (2) Organic matter (3) Lime mineral. There is a strong indication that strongest adsorption of zinc on crystal lattices is associated with surfaces that contain Mg^{2+}.

Elgably and Jenny (1943) investigate the adsorption and fixation of zinc on montmorntonite clays zinc adsorption from $Zncl_2$ solution involves the ions Zn^{2+}, $(Zncl)^{+}$ and $(ZnOH)^{+}$. But that by Nacl and $Cacl_2$ is restricted to divalent zinc ions. Elgabaly (1950) noted that Zn adsorbed by vermiculites and some low expansion clay as Kaolinite is not all exchangeable. DeMumbrum and Jackson (1956) reported that montmorrillonite sorted about 10% more Zn and Cu than of cations which form strong bases.

2.4.5 Leaching Intensity

Lombin (1983) reported that there is significant zinc responses of maize in several location within the Nigeria savanna zone (Lat $7^{0}3^{0}$' to $14^{0}0$'N). Most of the responses were reported on the sandy leached inceptisols and ultisols or oxisols of the Southern Guinea and derived savanna. Lombin (1980) reported in another finding that the degree of leaching and the organic

matter content were two important soil characteristics affecting EDTA - extractable zinc levels.

2.5 Functions of Zinc

Zinc is essential for plant growth and development in the following ways.

a) It is a constituent of various essential plant metalloenzyme e.g. carbonic anhydrase, dehydrogenase, proteinase, peptidase and aldolase (Brady, 1984).

b) It influences the synthesis of chlorophyll. (Mengel and Kirkby, 1980).

c) It promotes starch formation, seed maturation and production (Brady, 1984).

d) It is involved in nitrogen metabolism.

e) It is required in the synthesis of tryptophane, a precursor of the auxin indole acetic acid (Mengel & Kirby, 1980).

f) It increases the content of vitamin C in some plants particularly red peppers and tomatoes. (Schutte, 1959).

g) It influences plant water relationship (Schutte, 1959).

2.6 Zinc deficiency symptoms

Zinc deficiency symptoms are found where the soil surface has been removed (Viets, 1951). DeRemer and Smith (1964) showed that incorporation of sugar beets

residue can cause zinc deficiency during the early stages of decomposition. In Ghana, zinc deficiency occurred on cocoa when planted on newly cleared land where the brush was burnt in place. Osiname et al (1973) associated this phenomenon with high soil pH.

In Nigeria, zinc deficiency problem were observed on cocoa in Western Nigeria. (Egbe and Omotosho, 1972) Osiname et al (1973) identified and reported zinc deficiencies in cereal crops particularly maize and rice. Agboola and Corey (1970) indicated that the probability of zinc deficiency in the sandy soils of the savanna zone of Western Nigeria is probably due to low total Zinc. Lombin (1983) predicted that zinc deficiency will in the near future be imminent in Nigeria Southern Guinea savanna oxisols and ultisols.

Zinc deficiencies are also found on soils with restricted root zones which may be caused by hardpans, high water tables or other factors. Lucas and Knezek (1972) reported that compacted areas caused by tractors wheels also cause zinc deficiency in certain soils. Zinc deficiency produces changes in leaf morphology and in leaf histology depending on the crop showing deficiencies symptom, the disorder is called different names which include:

i) White bud in maize and sorghum

ii) Little leaf or rosette in cotton and fruit trees

(Foth 1984).

iii) Mottle leaf or frenching in citrus and

iv) Sickle leaf in cocoa.

Zinc deficiency in legumes include stunted growth, developing of brown spots with yellowing of the leaf tissue between the veins of lower leaves and these dead tissues drop out of the chlorotic areas (Nelson and Barber, 1964).

Ambler and Brown (1969) in Sanillac and Saginaw navy beans gave the visual zinc deficiency symptoms as necrotic and discoloured leaves. zinc deficiency results in decreased seed production in peas and beans. (Schutte 1959).

Zinc deficiency symptoms in vegetable crops show in new leaves as being abnormally small and mottled with yellow or uniformly chlorotic. (Purvis and Carolus, 1964). In cotton it is seen as pronounced interveinal chlorosis and bronzing of leaves which become brittle with upturned margins, arrested stalk elongation, delayed growth,delayed fruiting, which thereby leads to reduction in yield (Berger, 1969 and Donald, 1964). Shukla et al (1973) in sorghum varieties found that the fourth and fifth emerging leaf while still completely unfolded developed chlorosis towards the base. It then spreads to the middle of lamina and became papery white with leathery texture while the leaves tip remain green. The

affected leaves finally turned flaccid which led to the drying of the leaf blade thereby stunting the growth.

Maize exhibits interveinal chlorosis under zinc deficient conditions as chlorotic bands which arise from the base of the leaf blade. In severe cases, the young leaves are bleached and this is known as white bud disease of maize (Kanehiro, 1973). Stunting is another obvious deficiency symptom associated with zinc in maize this lends credence to the observation that zinc is important in the synthesis of the plant growth hormone, indole acetic acid. (Kanehiro, 1973).

2.7 Correction of Zinc deficiencies

The widespread occurrence of zinc deficiencies could make it a serious nutritional problem. But zinc deficiencies are relatively easy to correct. (Thorne, 1957).

Correction can be done by means of

a) Soil treatments

b) Trunk injections

c) Foliage spray and

d) Management practices.

2.7.1 Soil treatments

Band applied $ZnSO_4$ $7H_2O$ frequently shows slightly greater availability than similar applications of granular ZnO or $ZnCO_3$ in high pH soils.

ZnS has not been successfully used as Zn- fertilizer

because they dissolve too slowly. Zn-Chelates according to Lindsay (1972) are generally more available than inorganic sources per unit of zinc. Zn-EDTA is the most frequently used although other zinc-chelates are available, higher zinc uptake and yield were obtained from plots receiving ZnEDTA than those receiving $ZnSO_4$. It was concluded that chelated sources were much more effective at low rates than was $ZnSO_4$.

Ganiron *et al* (1968) in contrast in his field studies with maize did not show an advantage for Zn-EDTA over $ZnSO_4$ when applied as a land treatment at seedling. According to Lindsay (1972) if chelated fertilizer are mixed or placed in acid soils, the advantage over inorganic sources is much less.

2.7.2 Foliage Sprays

Chapman (1966) recommended foliar zinc sprays of 0.9-4.5kg of $ZnSO_4$ $7H_2O$ per 378l of water applied in early summer and repeated as necessary hydrated lime is often included to neutralise acidity and avoid leaf and fruit damage. Foliar spray are commonly used on pineapple (*Ananas comosus*) citrus, deciduous fruits and nut trees. 920 l/ha of 0.5% $ZnSO_4$ $7H_2O$ applied at 3 leaf and again at 5 leaves stage of growth. (Lingle and Holmberg, 1957).

Dormant sprays are applied in late winter or early spring and typical spray range from 4.5-23kg of $ZnSO_4$ per

378L of water.

2.7.3 Injections

Zinc salts are placed in holes bored at intervals around the trunks to correct zinc deficiency and a good recovery of trees have been recovered through this approach. Driving zinc coated nails into trunks of trees is another means of correcting zinc deficiency in trees. An injection treatment usually lasts two or three years before zinc deficiency symptoms are again evident. It is not therefore widely used because it requires a lot of labour.

2.7.4 Management Practises

Certain management practices have been identified to be effective in correcting zinc deficiency.

Thorne (1957) in an extensive review showed that growing alfalfa has helped in alleviating zinc deficiency symptoms in fruit trees or grapes. Hoagland et al (1937) planted apricot and corn seedlings between alfalfa planted a year before in zinc deficient soil, and no deficiency symptoms were developed on the corn and apricot.

The importance of alfalfa on available Zn in soils result from the deep feeding roots contacting deep soils and bringing zinc to the surface.

2.8 Differential susceptibility of plant species and cultivars to zinc deficiency

Species are known to be physiologically homogenous

populations so the need to study the differential behaviour of varieties and inbred lines are necessary. In a study of 25 annual crop and pasture varieties, representing 21 species, Gladstones and Loneragan (1967) concluded in their findings that species differ characteristically in their feeding power for zinc. Also in a green house experiment to study the relationship between differential susceptibility to zinc deficiency and nutrient composition of 13 cultivars of corn, Safaya and Gupta (1979) reported no correlation between the differential susceptibility of plant species in terms of dry matter yield and nutrient composition as well as the degree of their response to zinc. Out of the 13 cultivars, 11 exhibited higher shoot P uptake under zinc deficient treatment compared to the zinc sufficient ones.

Millikan (1963) in his many studies reported the severity of zinc deficiency sympton in the plant showed no correlation with plant zinc concentrations. On the contrary zinc deficient plants often exhibit a higher P concentration in their shoot tissues which cannot be entirely ascribed to reduced plant growth and hence a simple phenomenon of accredition.

Brown and Tiffin (1962) grew 14 plant species or varieties on a calcareous Zn- deficient soil, seven developed zinc deficiency, two developed fe deficiency and five did not develop any micronutrient deficiency.

Safaya (1976) reported that zinc deficient corn plants absorbed P much faster than those supplied with zinc. Amber and Brown (1969) found that Fe and P aggravated zinc deficiency caused differential susceptibility to zinc deficiency in sanilac navy bean. Sanilac developed severe zinc deficiency symptoms and contained twice as much P (1.7%) in its tops as Saginaw.

Warnock (1970) showed that zinc deficient corn plants accumulated a large excess Fe concentration was associated with zinc deficiency in the plant and not with the level of Fe in the soil solution. From the above, differential susceptibility or tolerance of plant species and cultivars to zinc deficiency has rarely been found to correlate with the zinc content.

2.8.1 Causes of varietal differences to Zinc deficiency

Diversity among germ [redacted]plasms in the ability to acquire plant nutrients from the enivronment has been investigated (Godwin and Blair, 1991). The genotype of maize (Zea mays L) plays a large role in the quantitative and qualitative accumulation of nutrients. Hiesey and Wilner (1965) reported that genetic variability is common among individuals in a local plant population. In the study carried out by Agarwala et al (1971). They also indicated a possibility of genetic control as being responsible for differential susceptibility of some wheat varieties to zinc stress.

Shukla and Raj (1974) suggested that the genetic make up of a variety affects its capability to exploit soil nutrients. Genetic variability is common among individuals in a local plant population as recorded by (Hiesey and Wilner, 1965).

Shukla et al (1973) reported varietal differences with regard to crops and varieties within a crop often differ in their yielding capacity, nutrient requirement and efficiency in nutrient uptake.

Ellis, (1965) and Judy et al (1964) observed that sanilac variety of navy bean is more susceptible to zinc deficiency than the Saginaw variety. They observed that Sanilac yielded less and contained less zinc than Saginaw where zinc was not applied to the soil. However, where zinc was applied the yield of Sanilac equaled that of Saginaw.

Genotypic differences in the uptake of several nutrients in corn have been reported by many scientists. Bell et al. (1958) showed that corn varieties differ in their capacity to utilize ferric iron. Brown and Tiffin, (1960) suggested that susceptibility to chlorosis in plants may be related to the metabolic process involved in the separation of Fe from the Fe-chelate and that roots P and chelating agent may all be competitors for Fe at the roots. Brown and Bell (1969) established that variation in genetic are responsible for a differential

uptake of Fe by two corn genotypes, Ys, and Pa 54 in which Fe stress enhanced Fe uptake more in Pa 54 than Ys_1.

From the above exploiting genetic diversity of plants for enhanced productivity in low fertility soils is a desirable one to meet food demands.

2.8.2 Plant nutrient efficiency

The term nutrient efficiency was been used widely as a measure of the capacity of a plant to acquire and utilize nutrients for production of crops or forages. According to (Clark, 1990), this definition may be misleading and vary greatly in the quest for increased productivity and identification of mechanisms for enhanced nutrient acquisition and utilization.

The definition of nutrient efficiency can be divided into:

a) One emphasizing productivity and

b) those emphasizing the internal nutrient requirement of plant, with regard to yield parameters. Nutrient efficiency has been defined as the ability to produce a high plant yield in a soil or other media that would otherwise limit the production of a standard line (Buso and Bliss, 1988).

Other definition referred to as agronomic efficiency include plant production of shoots or harvestable product per unit of nutrient applied. (Blair and Cordero, 1978).

Nutrient efficiency emphasizing utilization is generally defined as total plant biomass produced per unit nutrient absorbed which is equivalent to the reciprocal of nutrient concentration in the entire plant. This is called the nutrient efficiency ratio used to describe the internal nutrient requirement in many agronomic species (Coltmann et al, 1985) for example to calculate zinc efficiency ratio:-

$$\text{Zn efficiency ratio} = \frac{\text{Total plant dry mass}}{\text{Total Zn accumulation.}}$$

Some researchers used the amount of harvestable product instead of total plant biomass.

But Siddiq and Glass, (1981) suggested that a more appropriate measure of nutrient efficiency is the product of yield times the reciprocal of nutrient concentration given as utilization efficiency.

$$\text{Zn utilization efficiency} = \frac{\text{total plant dry mass}}{\text{tissue (Zn)}}$$

Uptake efficiency can also be used which is defined as nutrient uptake per unit root length, surface area or weight. For example:

$$\text{Zn uptake} = \frac{\text{total Zn accumulation}}{\text{fine root dry mass}}$$

Identification of species with differing nutrient efficiencies by any of the definition includes general investigation of potential, morphological, physiological and biochemical mechanisms involved. It is difficult to separate cause from effect when evaluating potential

mechanisms of efficient nutrient uptake and utilization. For example, a cultivar with a large root system is likely to accumulate a greater amount of P and achieve greater yields than a cultivar with a small root system.

Germplasms differ in yields under nutrient efficient or inefficient if they are normal in appearance and have similar yields when an optimal amount of the nutrient is available.

2.9 Zinc interactions with other Nutrients

Nutrition of plants with micronutrient depend on several factors other than the ability of the soil to supply these elements. These factors include the rate of nutrient absorption, distribution of nutrient to functional sites and nutrient mobility within the plant (Olsen, 1972). Interaction may be defined as (i) an influence, a mutual or reciprocal action, of one element upon another in relation to plant growth, and (ii) the differential response to one element in combination with varying levels of a second element applied simultaneously. Interaction occur between the micronutrient as well as some macronutrients and these modify the nutrition of plants.

Zinc interactions with other elements such as P, Fe, N has been reported by many workers. Viets et al (1957) found that pH exerted a greater and more consistent effect on zinc concentration and uptake by plants than

the total amount of plant growth.

2.9.1 Zn - N:-

In many parts of the world, zinc fertilization has replaced N-fertilization in the attention of soil scientist particularly in light textured soils having low organic matter and high pH. Kumar et al, (1985) reported that there was response of zinc in the absence of nitrogen when studying the interaction of nitrogen and zinc in pearl millet. They observed that plants without nitrogen exhibit stunted growth and a pale yellow colour that even when zinc was supplied without nitrogen it further disturbs the balance indicating that the application of nitrogen is essential.

Ozanne, (1955) reported severe deficiency of zinc in subterranean clover with increased in N supply, regardless of the source.

Sobulo, (1982) in investigating response of upland rice to N,P,K, Fe and N in Western Nigeria reported that zinc increased yield of rice by increasing N content in the leaf, concluding that zinc increased efficiency of applied N in paddy yield production.

2.9.2 Zinc-Phosphorus

This interaction is designated as a P-induced Zn deficiency, and the disorder is commonly associated with high levels of available P or with application of P to the soil Olsen (1972) reported that the actual causal

relationship and mechanism are still unknown.

Olsen listed four possible causes under consideration.

2.9.2.1 P-Zn interaction in the soil

Early study indicated that Zn_2 (PO_4) was a good source of Zn for sorghum (Boawn et al, 1957). Some other studies indicated that the cause of P-induced deficiency in the soil was suspected to be the formation of an insoluble Zn_3 $(PO_4)_2$ which reduced the concentration of Zn in the soil solution to deficiency levels. Caroll and Loneragan 1969) strongly indicated that precipitation of Zn_3 (PO_4) is not involved in P - induced zinc deficiency in plants Stuckenholtz et al (1966) observed no change in 0.1NHCl - soluble zinc in an alkaline soil as rate of P increased from 10 to 1000ppm. Brown et al. (1970) found that rate of P did not greatly affect extractable zinc, but tendered to increase the zinc rather than decrease it. These reports on Zinc solubility in soils treated with different levels of P strongly supports the evidence from solubility Zn_3 $(PO_4)_2$ that precipitation in the soil is likely to be the cause of a P - induced deficiency in plants.

2.9.2.2 Effect of Zn- P on translocation

Many workers have reported the applied P induced or accentuated Zn deficiency symptoms in plants. (Thorne, 1957; Millikan, 1963). High phosphate applications

increased the severity of zinc deficiency symptoms in flax (Millikan 1964, 1961). In some cases, applied P reduced the concentration of Zn in the above ground portion of the plant and lowered the total uptake of zinc (Loneragan 1951; Stuchenholtz et al 1966). Burleson et al (1961) suggested the possibility of P - Zn antagonism within the root to explain the cause of P - induced Zn.

In some reports, applied P decreased the zinc concentration, but total uptake of Zinc was the same or decreased (Millikan, 1963). The cause of this P-induced zinc has been suggested to be due to interference by P with the uptake, translocation or utilization of zinc (Thorne, 1957; Adriano at al, 1971; Boawn and Brown 1968).

2.9.2.3 Dilution effect

When the rate of plant growth exceeds the rate of uptake of a particular nutrient, the concentration of that nutrient in the tissue decreases or is diluted in the plant tissue (Olsen, 1972).

Loneragan (1951) reported that decreased zinc concentration in flax due to applied P caused Zn deficiency symptoms while Watanabe et al (1965) reported that a change in yield more than two fold had no significant effect on the total zinc uptake. Adriano et al (1971) reported that when P was maintained at high level growth was retarded by zinc deficiency, similarly

application of Zn when P was present at a high level led to increase in growth. Applied zinc increased yield only when P was applied. A response in yield was found for applied P, so a dilution effect upon zinc largely accounted for the interaction (Olsen, 1972).

This interaction occurs generally when the soil is deficient in P and slightly deficient in available zinc (Olsen 1972). Olsen suggested that the growth rate increases because of applied P, but the uptake rate of zinc does not increase fast enough to maintain a sufficient concentration of zinc in the tops. In some cases pf P - induced Zn the applied P-reduced the zinc concentration in the tops of the plant when the yield response to P is slight or nil. As a result supplied P reduces the total uptake of zinc by the crop. (Stuckenholtz et al, 1966).

2.9.2.4 Distribution of Zinc between roots and tops

For zinc, the plant part closest to the source of supply obtain its requirement first before significant translocation to the tops occur (Olsen, 1972). Caroll and Loneragan (1968) found that plants contained 35% of the total Zn uptake in the roots when growth was limited by zinc deficiency compared to 18% under optimum supply of zinc. This shows a greater reduction in the yield of tops compared with roots under deficiency conditions. Sharma et al (1968) reported that in the presence of P,

added zinc increased zinc concentration in corn roots more than in corn tops. Stukenholtz et al (1966) obtained reduced zinc concentration in the tops of corn plants and not in the roots. Burleson and Page (1967) while studying P and zinc interactions in flax observed high zinc concentration in roots and also increased zinc conc. in roots with increasing rates of P.

2.9.2.5 Physiological effects

There has not been any specific metabolic or functional mechanisms suggesting that P interferes with the utilization of zinc by the plant (Viets, 1966; Boawn and Brown, 1968). Sharma et al (1968) observed that the lowest increment of applied P at 25ppm caused a largest reduction of zinc concentration in the tops of wheat, sweet corn and tomato while there was little or no reduction in zinc concentration of the roots as rate of P increased above the first increment. Their findings indicate that the main effect of applied P was a physiological inhibition in the translocation of zinc from roots to tops (Olsen, 1972).

Millikan (1963) showed that the depression in yield at high P levels when the supply of zinc was insufficient was not due to a decrease in zinc concentration in the plant, but such plants gave a high value for the P/Zn ratio, suggesting that zinc is essential to P utilisation by the plant.

Although most workers agree that high phosphate applications increase the severity of zinc deficiency in plants, there are differing view regarding the relationship of this effect to the zinc and P contents of plants (Millikan, 1963).

2.9.3 Zn-Magnesium

An increase in pH by liming reduced the availability of zinc to plants. The use of liming material containing $MgCo_3$ however, resulted in a lower severity of zinc deficiency (Seatz, 1960). This indicated that the interaction of Mg with Zn occurred to a greater degree within the plant than within the soil (Olsen, 1972). Olsen also cited another postulation which suggested that since both Mg and zinc have nearly the same ionic radii the Mg ion may interact with relatively insoluble zinc compound in the soil to release it in a plant available form.

2.9.4 Zn-K

Application of high rates of potassium alleviated adverse effects of P on Zn uptake by Corn (Stukenholtz et al (1966). High exchangeable K in soil likewise lessened the antagonistic effect of P on Zn uptake (Olsen et al 1965). Large K applications increased zinc concentrations in plants even when P was deleted.

2.9.5 Zn-Iron

Olsen (1972) reported that the metabolic functioning of Fe in plants is somewhat connected with zinc supply. Brown and Tiffin, (1962) reported that zinc caused Fe Chlorosis in corn and millet but in no other plants. Added P accentuated both Fe and zinc deficiencies (Lingle et al, 1963) found that zinc depressed the uptake of Fe and affected the translocation of Fe to the tops.

Ambler and Brown, (1969) found that with increasing rates of zinc in zinc deficient soils, the zinc susceptible sanilac navy bean contained more Fe and P but less zinc than the less susceptible variety, saginaw navy bean. Varieties under zinc stress differentially exhibit Zn-deficiency symptoms by their control of Fe and P. Warnock, (1970) observed high concentration of Fe in the leaf and stems of Zn-deficient corn.

Jackson et al (1967) reported that when the P needs of sweet corn were met zinc deficiency became dominant and the plants contained very high levels of Fe. If zinc is then added, this will lead to increase in growth and a marked reduction in Fe concentration in the plants.

Haldar and Mandal (1981) reported Fe concentration in shoots and roots of rice decreased progressively with the increase in the level of P or zinc application. The depressing effect of zinc was more prominent in respect of shoot concentration. But in respect of concentration

in the root the effect of both P and zinc was similar in magnitude.

2.9.5 Cu - Zn

Millikan (1953) reported a decrease in zinc concentration in plants as a result of zinc deficiency in alfalfa and subterranean clover. Cu deficiency caused a slightly lower concentration of Cu in these plants compared with normal plants and the zinc concentration was unaffected by zinc deficiency.

Olsen, (1972) suggested that a careful control is required in the rate of zinc application in areas of Zn and Cu deficiency.

Gilbey et al (1970) observed that if zinc was applied in greater amounts than recommended it leads to zinc induced Cu deficiency in wheat and barley.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location and description of site

The experiment was conducted at the Research Farm of the Institute for Agricultural Research, Ahmadu Bello University Samaru, Zaria in Kaduna State.
Samaru is located at latitude $11^{o}11'N$ and $7^{o}83'E$ longitude in the Northern Guinea savanna vegetation zone with a mean annual rainfall of about 1,090mm concentrated in five months (May - October) of the year and a daily temperature of $24^{o}C$. (Kowal and Knabe, 1972).

The meteorological station in Samaru recorded a mean annual rainfall of 1020.90mm and 1061.70mm for the year 1992 and 1993 respectively, while a mean annual temperature of $24.5^{o}C$ was recorded for the year 1993.

Maize (zea mays L.) can grow and yield well in areas with a minimum of 900mm rainfall and a temperature range between $25^{o}C$ and $35^{o}C$ (Kowal and Kassam 1978), the climate of Samaru is suitable for the production of maize.

3.2 Soil sampling and preparation

The field from which the sampling was done was under continuous cultivation, therefore there is heterogenuity among the different parts of the field. The samples were collected before any fertilizer application. The field

was divided into different sampling units and 2-3 augured samples were taken from each unit. Two depth 0-15cm and 15-30cm were taken from each replicate. The samples were taken randomly from each replicate, mixed thoroughly and put in a polytene bag, labelled and then taken to the laboratory for processing. The composite samples were air-dried by spreading them uniformly on a polytene bag in the soil room. The air dried sample was then sieve using a 2mm-mesh sieve. The fine samples were later taken to the laboratory for soil analysis procedure.

3.3 Soil analysis procedure

3.3.1 pH determination

Soil pH was determined in a 1:1 soil water and 1:2 soil and 0.01m $Cacl_2$ suspensions with a glass electrode pH meter as described by (Schofield and Taylor 1955).

3.3.2 Total nitrogen in soil

Total soil nitrogen was determined using the Macrokjeldahl method.

3.3.3 Organic carbon

Organic carbon was determined by the wet dichromate oxidation method of Walkley and Black (1934) modified by Piper, (1942). The percentage organic matter content can be calculated from the above by multiplying the result by a factor of 1.72.

3.3.4 Determination of exchangeable bases

These were leached with neutral IN NH_4OAC (pH 7.0)

saturation method described by Chapman (1965) and determined by atomic absorption spectrometer and flame photometer for Na and K.

3.3.5 Effective cation exchange capacity

Effective cation exchange capacity was measured by summation of the amounts of exchangeable cations including exchangeable Al and H. Exchangeable acidity was determined by extracting soil with IN KCl and titrating with 0.5N NaOH using phenolphthalein indicator (Juo, 1979).

3.3.6 Particle size distribution

Particle size distribution was estimated by the hydrometer method of (Bouyoucos, 1951).

3.3.7 Available phosphorus

Available P was determined by Bray 1 method (0.025N H Cl + 0.03 N NH_4F). The concentration of P in the extract was determined colorimetrically in a spectrophotometer.

3.3.8 Determination of micronutrient

The micronutrients (Zn, Cu, Mn and Fe) were determined by the Atomic Absorption Spectrometer after extraction from the soil and the plant tissue with IN EDTA and centrifuging the resulting suspension.

3.4 Experimental design and fertilizer application

Three different cultivars of maize were used in the experiment, two were hybrids and one an open pollinated

cultivar. The hybrids were mega hybrid and Ag-Kaduna while the open pollinated one was the TZBSR-Y_1.

The experimental design used was the randomized complete block design and the treatments were replicated three times. The plot sizes were 5x5.25m^2 or 26.25m^2 or 0.0026ha^{-1}. The experiment took place between the month of June - September 1992 and 1993 respectively.

Three seeds of the maize varieties were planted at 75cm inter row and 25cm within row spacing. The herbicide primagram was applied immediately after sowing at a rate of 4 l/ha. The plots received a basal application of 150kg/ha N, as N_2O 60kg/ha P as $P_2O_5$and 60kg/ha K as K_2O for the hybrids while 120kg/ha N as N_2O 60kg/ha P as P_2O_5 and 60kg/ha K as K_2O were applied to the open pollinated maize in the form of compound fertilizer NPK 15:15:15 two weeks after planting. This was done after thinning the plants to one per hill. The zinc fertilizer or treatments were applied at the same time. Five levels of zinc were used namely (0,1.0, 2.5,5.0 and 7.5 kg Zn/ha as $ZnSO_4$ $7H_2O$.

The hybrid received 90kg/ha N as N_2O and the open pollinated received 60kg/ha N as N_2O in form of urea which was applied as top dressing 4 weeks after planting. All fertilizers were applied by band application.

3.5 Observation and measurements

The experiments were observed daily to monitor

deficiency symptoms. Plant height was taken at 35 days after planting.

3.6 Leaf sampling

The index leaves were sampled at 50% silking. These samples were rinsed in distilled water, enveloped and dried in an oven at 65^{0}C for 48 hours. The dried samples were weighed and ground in a stainless steel mill with 0.5mm sieve. These samples were stored in plastic containers for subsequent laboratory analysis.

3.7 Plant analysis

The elements in the plant tissues were determined by wet ashing, phosphorus was determined in the digest colorimetrically with the spectrophotometer, while the flame photometer was adopted for K and Na. The atomic absorption spectrophotometer was used for the determination of Cu, Fe, Mn, Zn, Ca and Mg.

3.8 Harvest

The maize cobs were harvested when they were fully matured and dried at approximately 12% moisture. The net plot consisting of three middle ridges were harvested. The cobs were further sun-dried for some days after which the length and the diameters were measured. Threshing was done, grains weighed and thousand grain weight determined.

3.9 Statistical analysis

The analysis of variance was employed to look at all

the parameters. Then simple correlation and regression analysis were run to look at the yield parameters of 3 maize cultivars on zinc deficiency.

The 'F' test was employed and the Duncans multiple range test was used to identify significant mean differences in all cases where the F - test was found significant.

3.9.1 Calculation of susceptibility index

The susceptibility index (SI) which was the percentage reduction in the grain yield was calculated thus:

$$SI = \text{yield in } \frac{(7.5kgzn) - (0kgzn)}{7.5 \text{ kg zn}} \times 100$$

OR

Where the dry matter yield is taken it is:-

$$Dmy = \frac{+zn-(-zn)}{+zn} \times 100$$

The relative increase or relative decrease was calculated thus:

$$RI \text{ or } RD = \frac{-zn}{+zn} \times 100$$

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 Physical and chemical properties of the soil

4.1.1 Soil texture

The particle size distribution of the soil is given in Table 1 with sand fraction being 530gkg^{-1} for surface soil and 528gKg^{-1}. The silt fraction is 352gKg^{-1} for surface soil and 350gKg^{-1}. The clay fraction is 120gKg^{-1} for surface soil and 123gKg^{-1} for sub soil with a mean of 121.5gKg^{-1}. The means of the particle size fractions indicate that the soil is sandy loam.

4.1.2 Soil pH

The pH of the soils in water ranged from near neutral (6.8) to slightly acid (5.1) for the surface soil and subsoil respectively with a mean of 6.2. The pH range in salt solution ($CaCl_2 2H_2O$) ranged from 4.7 in the surface soil to 5.4 in the sub soil with a mean of 5.1 as shown in Table 1.

The soil samples have higher pH in water than $CaCl_2$ solution, this implies that the soil samples have a net negative charge in the exchangeable complex which can attract positively charged ions such as Calcium ions, hence the lower pH and $CaCl_2$ solution (Balasubramanian et al 1984).

Table 1: Results of the physico-chemical analysis of the soil.

	Depth (Cm)	
Soil Characteristic	0-15	15-30
pH		
1:1 water	6.80	5.60
1.1 0.01MCaCl$_2$	4.70	5.40
Organic Carbon (gkg^{-1})	5.20	5.00
Total N (gkg^{-1}	0.50	0.38
Available P (mgkg^{-1})	12.60	10.80
Exchange acidity (cmolkg^{-1})	0.25	0.20
Cation exchange capacity (cmolkg^{-1})	1.52	1.20
Exchangeable cations (cmolkg^{-1})		
Calcium	6.50	5.21
Magnesium	1.30	1.25
Potassium	0.26	0.21
Sodium	0.18	0.10
Micronutrient (mgKg^{-1})		
Iron	52.00	45.50
Manganese	12.50	10.52
Copper	0.25	0.30
Zinc	3.75	3.50
Particle size analysis (gKg^{-1})		
Sandy	530.00	528.00
Silt	352.00	350.00
Clay	120.00	123.00
Textural Class	Sandy	Loam.

The pH of most agricultural soils in the tropics has been reported to range from 5.0 to 6.8 (Froth and Turk, 1972). Since the pH values obtained in this study are within the range reported for this area which is between 6.0 to 6.5 (Jones 1972), the soil may therefore not require liming and soil reaction is not likely to pose any serious impediment to nutrient uptake.

4.1.3 Organic carbon contents of the soil

The organic carbon contents of the soil ranged from 5.20gKg^{-1} for the surface soil to 5.0gKg^{-1} for the subsoil with a mean of 5.1gkg^{-1} as shown in Table 1. These values are slightly higher than the critical value of organic carbon content of 4.41gKg^{-1} for surface soil and 3.65gKg^{-1} for sub soil reported by (Balasubramanian et al, 1984) for some soils of the Nigerian savanna. Although the values obtained in this study appear high, there is need to maintain an adequate level of organic carbon in the soil through annual incorporation of crop residue into the soil.

4.1.4 Soil total nitrogen

The soil total nitrogen content were 0.50gKg^{-1} for the surface soil and 0.38gKg^{-1} for the subsoil with a mean of 0.44gKg^{-1} as shown in Table 1. The low total nitrogen content of the savanna soils is generally low due to the high rate of organic matter decomposition in savanna region (Adebayo and Akaeze, 1976). The total

nitrogen content obtained in this report falls within the critical range of 0.49gKg^{-1} for surface soil and 0.38gKg^{-1} for subsoil as earlier reported (Balasubramanian et al, 1984).

4.1.5 Exchangeable bases (Ca, Mg, K and Na).

Exchangeable calcium content is 6.50Cmolkg^{-1} at the surface soil and 5.21Cmolkg^{-1} at the subsoil; the mean being 5.85Cmolkg^{-1}. This mean is higher than the critical value of 3.12Cmolkg^{-1} required by crops reported by (Balasubramanian et al, 1984). This also indicate that there is availability of calcium in the soil for plant uptake.

The exchangeable sodium is 0.18Cmolkg^{-1} for surface soil and 0.10Cmolkg^{-1} for subsoil with the mean being 0.14Cmolkg^{-1}, this is in accordance with the range of (0.08 to 0.20)Cmolkg^{-1} predicted by (Balasubramanian et al 1984). The exchangeable magnesium content is 1.30Cmolkg^{-1} for surface soil and 1.5Cmolkg^{-1} for subsoil with a mean of 1.27Cmolkg^{-1}. This is higher than the critical value of 0.20 to 0.42Cmolkg^{-1} reported by (Anon, 1978). This imply that there is high amount of magnesium for plant uptake in soil solution, so magnesium may not be added to the soil through fertilization.

The exchangeable K for the surface soil is 0.26Cmolkg^{-1} and 0.21Cmolkg^{-1} for subsoil with a mean of 0.24Cmolkg^{-1}. This mean is in the rang of 0.1 to

0.5Cmolkg^{-1} predicted by (Balasubramanian et al 1984) needed for growth.

4.1.6 Exchange acidity

The exchange acidity is 0.25Cmolkg^{-1} for surface soil and 0.20Cmolkg^{-1} for subsoil with a mean of 0.23Cmolkg^{-1}. This is in accordance to Jibrin (1991) that there is no problem of reserve acidity in the soil since the exchange acidity is higher than the critical values ranging from 0.01 to 0.10 Cmolkg^{-1} required for plant growth.

4.1.7 Effective cation exchange capacity (ECEC).

The cation exchange capacity (CEC) of the soil is 5.12Cmolkg^{-1} in the surface soil and 5.30Cmolkg^{-1} in the subsoil with a mean of 5.21Cmolkg^{-1}. The cation exchange capacity is lower than that obtained by (Lombin and Singh, 1986). The cation exchange capacity of the savanna is generally low as reported by (Jones and Wild, 1976). This may be related to the low status of organic matter and clay which is Kaolinitic (Lombin, 1983). The low CEC also may be as a result of low pH values. Since CEC has been reported to be a continuous function of pH (Tisdale et al, 1985).

4.1.8 Available phosphorus

Available P varies from 12.60gkg^{-1} to 13.80gkg^{-1} for the surface and subsoil respectively with a mean of 12.70gkg^{-1}. This is low when compared with values

reported by (Jones and Wild, 1976); and (Kowal and Kassam, 1978). Plants grown on soils with low plants grown on soils with low available P develop symptoms characteristic of phosphorus deficiency. The high P content in the surface soil may be due to its association with the content of organic carbon as well as arising through nutrient recycling.

4.1.9 Available zinc

The values of 0.1NHCl extractable zinc varied from 3.75mgkg^{-1} for surface soil to 3.50mgkg^{-1} for subsoil with the mean of 3.63mgkg^{-1}. The value is similar to those obtained by other workers among whom are (Martens; 1968) (Osiname et al 1973a); (Udo and Fagbami 1979); (Cotteine et al 1981); (Orabi et al 1981); (Lombin, 1983) and (Fagbammi et al, 1985).

This result do not however agree with the observation made earlier by (Osiname, 1972) that available zinc was generally low in the savanna (1 to 2ppm) than in the forest zone (2 to 5ppm). The relatively higher value obtained in this study may be as a result of low intensity of leeching in the seasonally dry savanna. (Lombin, 1983). Chude et al (1985) reported that soil of igneous rock origin had higher amounts of extractable zinc than soils derived from sedimentary rocks.

4.2 Effects of zinc application on morphological appearance of plants.

Zinc deficiency was observed on some plants in the year 1992/93 and 1993/94 cropping season; some plants at the zero level of zinc exhibited interveinal chlorosis starting from the base of the leaf blade but this visual symptom disappeared later. However, in the second year of cropping the interveinal chlorosis also manifested on the zero plots and persisted on some plants to maturity.

The interveinal chlorosis observed indicates that zinc is involved in chlorophyll synthesis (Mengel and Kirby 1980) (Stoyanor and Mokhamed, 1980). Moreover, it suggests that there is a high possibility of increased zinc disorder with continuous cultivation in the area studied.

4.3 Yield and yield components

4.3.1 Effect of zinc application on Cob length, and cob diameter and plant height of three maize cultivars at Samaru

The effect of varieties averaged over treatments as shown in Table 2 showed that there was no varietal significance between mega hybrid and Ag-Kaduna for the year 1991/92 and 1992/93 cropping seasons with respect to cob length. The cob diameter for the varieties TZBSR-Y and mega hybrid did not show any varietal significance but the two differed from the Ag-Kaduna.

There was no statistical difference in the height of all the varieties in 1991/92 but in 1992/93, variety Ag-

Kaduna differed significantly from the open-pollinated (TZBSR-Y) as shown in Table 2 irrespective of treatment. Maize cob length and diameter of all the varieties increased significantly with increase in zinc rates for the years 1991/92 and 1992/93 cropping season as shown in Table 3. This finding corroborates with the findings of Osiname et al (1973b) who observed an increase in cob length with increase in zinc rates, suggesting that zinc rates influenced the reproductive organs of the plant to a large extent. However, Fuerhing and Soofi, (1964) reported a contrary finding.

Table 3 also showed the effect of different levels of zinc averaged over varieties on plant height. There was visual growth response to zinc but the mean are not statistically different from each other. This is in accordance with Pam, (1990) in his own study, who did not observe any response to zinc in terms of plant height of maize at Samaru. Although, Osiname et al, (1972) in South Western Nigeria observed visual growth responses in maize at four of his six trials and reported 1kg $Znha^{-1}$ to be optimum zinc rate. This implies that for this trial, the available zinc in the soil is sufficient for the growth of maize.

Table 2: Varieties differences averaged over treatment in respect of cob diameter, cob length and plant height of maize cultivars at Samaru.

Variety	Cob length(cm)		Cob diameter (cm)		Plant height(cm)	
	91/92	92/93	91/92	92/93	91/92	92/93
TZBSR-Y_1	13.80b	11.17b	2.59b	2.54b	31.67a	30.93b
mega Hybrid	14.08a	13.41a	2.49b	2.50b	32.70	31.80ab
Ag-Kaduna	15.08a	13.58a	2.73a	2.79a	33.40	34.43a
LSD (0.05)	0.749	0.834	0.150	0.158	1.570	1.357
SE±	0.26	0.258	0.052	0.054	0.542	0.468

Table 3: Effect of different levels of zinc averaged over varieties on cob length, and cob diameter and plant height.

Treatment $KgZnha^{-1}$	Cob length(cm)		Cob diameter(cm)		Plant height(cm)	
	91/92	92/93	91/92	92/93	91/92	92/93
0	13.87b	13.81b	2.57ab	2.71	30.78ab	29.89c
1.0	14.27b	13.46b	2.54b	2.61	32.28ab	31.44bc
2.5	14.37b	14.03b	2.51b	2.51	32.78ab	31.89ab
5.0	14.70ab	14.17ab	2.59	2.66	33.11a	32.17ab
7.5	15.14a	14.81a	2.74a	2.61	34.17a	33.22a
LSD (0.05)	0.966	1.075	0.203		2.027	1.751
SE ±	0.330	0.371	0.066	0.070	0.70	

Values within columns followed by the same letters are not statistically different at 5% level according to DMRT.

4.3.2 Interaction effect between the varieties and zinc rates.

There was no significant interaction between the varieties and the zinc rates of the cob length as shown in Table 4 and of the Cob diameter as shown in Table 5. Although, there are indications that increasing zinc rates resulted in corresponding increase in yield components of the varieties.

Table 6 also showed there was no interaction effect between the varieties and zinc level on plant height.

4.4 Cob yield, shelling percentage and stover yield as influenced by variety and zinc level at Samaru

The data on Cob yield, shelling percentage and stover yield as influenced by variety is presented in Table 7. There was a significant difference in the Cob yield between Ag-Kaduna and TZBSR-Y, but 72BSR-Y did not differ from the mega hybrid. In terms of yield irrespective of treatments, Ag-Kaduna yielded more across the two years. Effect of zinc application on shelling percentage presented in Table 7 show that there was a varietal significance between variety TZBSR-Y and Mega hybrid while the Ag-Kaduna and Mega Hybrid did not differ significantly from each other in 1991/92 year.

Table 4: Interaction effect of variety x Zn level on Cob length of maize.

Treatments Kg Znha^{-1}	Variety	Cob Length (cm) 1991/92 m	1992/93
0		13.34	13.75
1.0		13.92	13.92a
2.5	TZBSR-Y_1	14.05	12.83b
5.0		14.10	13.92a
7.5		13.58	13.50ab
0		14.00b	14.33b
1.0		14.28b	14.92ab
2.5	Mega Hybrid	15.35	15.20ab
5.0		15.17ab	15.83ab
7.5		16.58a	16.75a
0		14.27	13.33ab
1.0		14.92	13.25ab
2.5		14.70	12.33ab
5.0	Ag-Kaduna	13.83	12.75b
7.5		15.25	14.75a
LSD(0.05)			1.863
SE±		0.578	0.643

Table 5: Effect of zinc level and variety interaction on Cob diameter of maize.

Treatments Kg Znha^{-1}	Variety	Cob Length (cm) 1991/92	1992/93
0		2.600	2.663
1.0		2.521	2.547
2.5	TZBSR-Y_1	2.532	2.387
5.0		2.470	2.370
7.5		2.580	2.723
0		2.483	2.57
1.0		2.473	2.513
2.5	Mega Hybrid	2.393	2.430
5.0		2.573	2.630
7.5		2.567	2.357
0			
1.0		2.613b	2.877
2.5	Ag-Kaduna	2.617b	2.737
5.0		2.613b	2.673
7.5		2.727ab	2.977
7.5		3.076a	2.733
LSD (0.05)		0.336	0.122
SE±		0.116	0.122
Vx Zn		NS	NS

Table 6: Interaction effect of variety X zinc level on Plant height of maize at Samaru.

Treatments Kg Znha^{-1}	Variety	Cob Length (cm) 1991/92	1992/93
0		29.00c	29.00
1.0		31.00bc	30.33
2.5	TZBSR-Y_1	30.67bc	30.33
5.0		32.67ab	31.67
7.5		35.00a	33.33
0		31.33	29.35
1.0		33.50	31.67
2.5	Mega Hybrid	34.17	32.16
5.0		33.33	32.67
7.5		34.67	33.60
0		32.00	31.32
1.0		33.67	33.67
2.5	Ag-Kaduna	32.00	32.33
5.0		33.33	32.17
7.5		32.83	32.67
LSD (0.05)		3.51	3.04
SE±		1.212	

Table 7: Effect of varieties averaged over treatments on Cob yield, shelling percentage and stover yield of three maize cultivars.

Variety	Cob yield Kg ha^{-1}		Shelling percentage		Stover yield Kg ha^{-1}
	1991/ 1992	1992/ 1993	1991/ 1992	1992/ 1993	
TZBS-Y[1]	3702b	4426b	82.71a	84.11	48.50a
mega Hybrid	4169ab	5149ab	81.15b	83.36	47.50
Ag-Kaduna	4596	5671a	82.33ab	83.64	50.30
SE±	226.37	256.78			
LSD (0.05)	655.56		1.262	2.93	8.68

In 1992/93 cropping season there was no statistical difference between the three varieties. Effect of zinc treatment on stover yield of maize as influenced by variety is also presented in Table 7. The stover yield was only taken in the year 1992, in 1993 the cattle destroyed the straws immediately after harvest. There was no statistical difference between the stover yield in terms of variety and treatment.

The Ag-Kaduna produced more straw than the other varieties.

4.5 Cob yield, shelling percentage and stover yield of maize as influenced by treatment irrespective of variety.

The cob yield increased as treatment increased up to 2.5kg $Znha^{-1}$ after which there was a corresponding decreased in the rate as shown in Table 8. The effect of zinc application averaged over varieties as shown in Table 8 also show that the means are not statistically different from each other. There was an increase in the yield of Stover as zinc rate increase (Table 8). The increase in the yield of stover as zinc rate increased is in accordance with the findings of Fuehring and Soofi; (1964). They postulated that zinc application increases vegetative growth but not the reproductive organs. From the above, it indicates that zinc rate influenced the yield of vegetative phase of plant growth.

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There was no significant interaction between the zinc rates and variety in terms of cob yield as shown in Table 9.

Table 10 showed that the interaction effect of variety and zinc level on shelling percentage was not significant.

Table 8: Effect of different levels of zinc averaged over varieties on cob yield, shelling percentage and stover yield of maize cultivars.

Treatment Kg Zn ha^{-1}	Cob yield Kg ha^{-1}		Shelling percentage		Stover yield Kg ha^{-1}
	1991/ 1992	1992/ 1993	1991/ 1992	1992/ 1993	
0	3657a	4809a	81.23	82.23	42.90
1.0	3783a	4740a	80.44	83.47	47.30
2.5	4130ab	4955ab	81.97	83.94	48.90
5.0	4091ab	4043ab	81.49	83.83	51.00
7.5	4089a	5852b	81.85	84.45	53.90
LSD (0.05)	846.43	960.10	1.628	3.78	11.22

Values within columns followed by the same letter(s) or no letter(s) are not statistically different at 5% level DMRT.

Table 9: Effect of variety x zinc level interaction on cob yield of maize cultivars.

Treatments Kg $Znha^{-1}$	Variety	Cob Length (cm) 1991/92	($Kgha^{-1}$) 1992/93
0		2829ab	4818
1.0		3884ab	3861
2.5	TZBSR-Y_1	4030ab	4061
5.0		3449ab	4844
7.5		4318a	4545
0		3862	6053
1.0	Mega Hybrid	3672	5406
2.5		4342	5312
5.0		3936	5142
7.5		5030	6441
0		4281	6686
1.0		4834	5160
2.5	Ag-Kaduna	5102	4846
5.0		3963	4878
7.5		4800	4174
SE±		506.22	574.26
LSD (0.05)		146.59	166.29
Vx Zn		NS	NS

Table 10: Effect of variety x zinc level interaction on Shelling percentage of maize cultivars.

Treatments Kg $Znha^{-1}$	Variety	Shelling Percentage (%) 1991/92	1992/93
0		80.90	82.77
1.0		79.94	87.10
2.5	TZBSR-Y_1	80.45	83.93
5.0		81.10	84.93
7.5		81.15	81.94
0		81.79	83.33
1.0	Mega Hybrid	81.30	80.53
2.5		83.02	83.38
5.0		82.35	81.90
7.5		82.31	87.64
0		81.01	82.40
1.0		80.06	82.79
2.5	Ag-Kaduna	82.44	84.51
5.0		81.02	84.76
7.5		82.10	83.77
SE±		0.973	2.26
LSD (0.05) Vx Zn		NS	NS

Table 11: Effect of variety x zinc level interaction on stover Yield of maize.

Treatments Kg Znha^{-1}	Variety	Stover yield (Kgha^{-1}) 1991/92
0		45.40
1.0		50.20
2.5	TZBSR-Y[1]	43.10
5.0		49.00
7.5		54.90
0		43.50
1.0	Mega Hybrid	56.50
2.5		35.20
5.0		51.00
7.5		51.40
0		52.90
1.0		54.90
2.5	Ag-Kaduna	50.60
5.0		46.60
7.5		46.60
LSD (0.05)		19.44
SE±		0.116

Table 12: Effect of varieties averaged over treatments on 1000 grain weight of 3 maize cultivars at Samaru.

Variety	1000 grain weight of maize (gha^{-1}) 1991/92	1992/93
TZBSR-Y_1	206.10a	198.2
mega Hybrid	205.70a	193.7
Ag-Kaduna	217.50a	210.4
LSD (0.05)	16.98	24.58
SE±	5.86	

Table 13: Effect of different levels of Zinc averaged over varieties on 1000 grain weight of 3 maize cultivars.

Treatment $KgZnha^{-1}$	1000 grain weight of maize (gha^{-1}) 1991/92	1992/93
0	193.40c	187.40a
1.0	196.00bc	197.00a
2.5	210.00bc	200.70a
5.0	221.00ab	207.02a
7.5	228.40a	211.60a
LSD (0.05)	21.91	31.72
SE±	7.56	10.95

Values within columns followed by the same letters or no letters are not statistically different at 5% level according to Duncan's multiple range test.

Table 14: Effect of variety x zinc level interaction on 1000 grain weight of maize.

Treatments (gha^{-1}) Kg $Znha^{-1}$	Variety	1000 grain weight 1991/92	1992/93
0		187.2	208.18
1.0		217.5	191.80
2.5	TZBSR-Y_1	206.2	182.80
5.0		194.9	200.40
7.5		224.9	207.40
0		203.1	186.50
1.0		200.9	188.70
2.5	Mega Hybrid	212.6	189.00
5.0		188.1	198.40
7.5		223.7	205.80
0		197.5b	205.40
1.0		212.0ab	242.50
2.5	Ag-Kaduna	244.1	190.40
5.0		197.3b	192.30
7.5		236.5a	221.50
LSD (0.05)		37.96	18.97
SE±		13.11	
Vx Zn		NS	NS

4.7 Effect of zinc application on the grain yield of three maize cultivars at Samaru.

The cumulative effect of zinc application on grain yield is presented in Table 15. Considering the three varieties TZBSR-Y, mega hybrid and Ag-Kaduna, it was observed that among the three varieties, Ag-Kaduna has more values in terms of yield than the other two varieties for the year 1991/92 and 1992/93. The increase in the yield value may have been brought about by high values of plant height and 1000 grain weight.

Data on Table 16 shows the effect of different levels of zinc on grain yield. Yield in 1992 increased as the zinc level increased up to 2.5kgZnha^{-1} after which the yield did not respond to any further increase in treatment. However, in 1993 the response to zinc rates were not statistically different. The mean of the two years did not have any meaningful trend. When the yields of the two years were combined the varieties TZBSR-Y_1 and mega hybrid did not show any statistical difference. But the Ag-Kaduna showed some statistical difference in terms of their yield response to different level of zinc treatments (Table 17).

The yield response at 2.5kgZnha^{-1} was statistically different from the yield at 5.0kg Znha^{-1} and 7.5kgZnha^{-1} since the effect of zinc on the variety was not statistically different from each other. The linear regression model did not fit the data so also was the

multiple regression model. Nevertheless, when the yield data were subjected to quadratic regression the following prediction equation were observed for the three varieties.

V_1 $Y = 38.80Zn + 2.01Zn^2 + 3180.06 (R^2 = 92.13^{**})$

V_2 $Y = -217.83Zn + 36.98Zn^2 + 4048.69 (R^2 = 70.12^{**})$

V_3 $Y = -217.05\ Zn + 16.03Zn^2 + 4428.81 (R^2 = 86.03^{**})$

From the above it was observed that all the R values are highly significant for the three varieties with R value for TZBSR-Y, higher than the other two varieties.

Table 18 showed the relative yield that in 1992 the variety Ag-Kaduna had a relative yield of 82.5% which was the best for the year while in 1993 cropping season the TZBSR-Y had a relative yield slightly higher than the other two varieties. But the mean of the two years showed that Ag-Kaduna still had a relative yield higher than the other two i.e (78.23%).

The % yield reduction with zinc deficiency which is used as the susceptibility index is shown in Table 18, Variety Ag-Kaduna was less susceptible to zinc deficiency with 11.51%.

The varieties are susceptible to zinc in this order.

SI = TZBSR-Y > mega Hybrid > Ag-Kaduna

Mean values being 30.37 > 21.32 > 11.51.

The combined yield effect showed that the $0Znkgha^{-1}$ produced yield that was not statistically different from

the 7.5KgZnha^{-1} for all the varieties. This is saying that it is more economical to plant at the zinc level of the soil than apply any high level of zinc. This is in accordance with Pam, 1990 who did not observe any response to zinc at Samaru in his field trial with maize.

Similarly Abdullahi (1984) did not observe any response to zinc in his maize trials in a similar soil. This report is in contrast to Osiname et al (1973b) who reported a zinc response of 2.0kg Znha^{-1} in his field trails in south western Nigeria. Iwuafor et al, (1981) also reported an optimum rate of 1.0kgZnha^{-1} in their trials carried out in Samaru.

Table 15: The effect of variety means on grain yield of maize cultivars.

Variety	Grain Yield $Kgha^{-1}$ 1991/92	1992/93	Mean
TZBSR-Y	2982b	3092b	3037
Mega Hybrid	3423b	3697ab	3560
Ag-Kaduna	4596a	4294a	4445
LSD (0.05)	518.92	646.14	

Table 16: The effect of different levels of zinc on grain yield of three maize cultivars

Variety	Grain Yield $Kgha^{-1}$ 1991/92	1992/93	Mean
0	2971b	4816	3893.5ab
1.0	3318ab	4012	3665.0b
2.5	3682ab	3971	3826.5ab
5.0	3082b	4083	3582.5b
7.5	3859a	4055	3957.0a
LSD (0.05)			
SE ±	231.40	288.05	

Values within columns followed by the same letters or no letters are statistically different at 5% level according to Duncans multiple range test.

Table 17: The effect of varieties x zinc level yield of maize

Zn levels Kg $Znha^{-1}$	Variety	Grain yield $Kgha^{-1}$ 1991/92	1992/93	Combined
0	TZBSR-Y	2290b	3403	3137
1.0		3116ab	3413	3265
2.5		3237a	3984	3327
5.0		2789ab	3934	3606
7.5		3478a	3734	3606
0	mega Hybrid	2989	4216	3697
1.0		3153	4355	4010
2.5		3603	5036	4094
5.0		3229	4188	3709
7.5		4139	4952	4546
0	Ag-Kaduna	3471	3478b	4144ab
1.0		3847	4268ab	4058ab
2.5		4207	5518a	4498a
5.0		3228	4122ab	3675b
7.5		3959	4081ab	3719b
LSD (0.05)		1160.60	1444.86	
SE ±		400.78	498.94	319.94

Table 18: Yield reduction with Zn deficiency

Varieties	Relative increase				
	191/92	92/93	Mean	1991/92	1992/93
T2BSR-Y	51.88	8.86	30.37	65.84	85.42
Mega	27.78	14.86	20.82	72.22	83.72
Ag-Kaduna	12.33	10.70	11.51	82.50	73.96

4.8 Relationship between grain yield and other yield parameters

There was significant correlation between the grain yield and the net weight of 1000 grains, ($r = + 0.7252^{**}$) Cob yield ($r = 0.9955^{**}$), Stover yield ($r = 0.3646^{*}$), Cob length ($r = +0.6253^{**}$) and plant height ($r = + 0.5560^{**}$). The positive significant correlation of all these yield parameters with grain yield indicates that the yield parameters contributed significantly to the grain yield.

4.9 Effect of zinc application on nutrient concentration in the leaves.

4.9.1 Effect of zinc application on the Concentration of zinc.

The effect of zinc application on the concentration of zinc was determined in index leaves at 50% silking and in dry grain after harvest. (Table 20). There was significant increase in zinc rates in the leaves and also in the grains. This is in accordance with Osiname et al (1973b). He observed significant increase in zinc concentration with increase in the rates of zinc fertilizer applied. This is due to the application of zinc increasing the labile pool from which the plant readily absorbed the zinc.

The highest to leave zinc concentration irrespective of treatment for the year 1991/92 and 1992/93 were 43.33 ppm and 93.30ppm. The least concentration are 31.67ppm and 47.30ppm.

Thus it appeared that tissue zinc concentration of 31.67ppm seem to represent acute deficiency level. Safaya and Gupta, (1979) reported a critical limit of 20ppm zinc in 6-week old maize plants while Shulka et al (1973) reported a limit of 19.5ppm zinc in 6-week old sorghum plants. Chapman (1966); Gladstones and Loneragan, (1967) had reported earlier that the normal concentration of Zn in plants ranged from 10-100ppm for most crops.

There was correlation amongst the zinc concentration and other yield parameters. There is a positive correlation ($r = 0.3705^{*}$) between the zinc concentration and 1000 grain weight, Cob yield ($r=0.5907^{**}$) grain yield ($r=0.5986^{**}$), Cob length ($r=0.3738^{**}$) Cob diameter ($r=0.5380^{**}$) and plant height ($r=0.4519^{**}$).

4.9.2 Copper Concentration

The effect of zinc on the concentration of Cu in the leaves and grain of maize cultivars presented in Table 21. There was no explainable trend to the values; therefore there was no statistical difference amongst the concentration of copper as zinc concentration increases from Okg $Znha^{-1}$ to 7.5kg$Znha^{-1}$.

There was no correlation effect between the zinc concentration and copper concentration in the tissue. Millikan (1953) reported a decrease in copper concentration in plants as a result of zinc deficiency in

alfalfa and subterranean clover. Olsen (1972) also suggested that careful control is require in the rate of zinc application in areas of zinc and Cu deficiency.

4.9.3 Iron Concentration

The effect of zinc on the concentration of Fe in the leaves at 50% silking and grain of maize cultivars. (Table 23) shows that as zinc rates increased, there was a markedly decrease in the concentration of iron. The main interaction effect was not statistically different from each other. But there was a negative correlation (r=0.3150*) between the zinc concentration and iron concentration.

Ulrich, (1964) reported 917ppm Fe in sugar beet leaves of low zinc status but with the addition of zinc from 0-12ppm, the Fe was lowered in the leaves to 94ppm.

4.9.4 Phosphorus concentration.

There was a decrease in the concentration of P as zinc rate increases. This was contrary to Osiname et al, (1973b) who observed an increase in P concentration as zinc rates increased. This relationship may be due to either interaction in the soil which makes the phosphate less available or a metabolic disorder within the plant due to imbalance between the two elements. (Olsen, 1972). There was a positive correlation ($r=0.3320^{*}$) between the zinc concentration in the tissue of the plant and P concentration.

There was no statistical difference amongst all other nutrients.

Table 19: Simple Correlation Matrix between yield components and grain yield.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Net wt. of 1000 grains	1.000																
2. Shelling %	0.3711 **	1.0000															
3. Cob yield	0.7003 **	0.1430	1.0000 **														
4. Grain yield	0.7252	0.2326	0.9955 *	1.0000 *													
5. Stover yield	0.2830 **	0.0966 *	0.3660 **	0.3646 **	1.0000 *												
6. Cob length	0.4890	0.3656	0.6004	0.6253	0.3089	1.0000											
7. Cob diameter	0.1723 **	0.0511 **	0.2788 **	0.2847 **	-0.2444	-0.0107 *	1.0000 **										
8. Plant height	0.4209 *	0.4375	0.5268 **	0.5560 **	0.1556	0.3405 *	0.4084 **	1.0000 **									
9. Conc of Zn	0.3705	0.1216	0.5907	0.5986	0.1273	0.3738	4.5380	0.4519	1.0000								
10. " of Cu	0.1260	-0.0524	-0.0074 *	-0.0039 *	0.2714	0.0175 *	0.0520	0.0388	0.0630	1.0000							
11. " " Mn	0.1057	0.1714	0.3214	0.3346	0.0883	0.3315	0.1206	0.2886	0.1810 *	-0.0421	1.0000						
12. " " Fe	0.2056	-0.1697	-0.2384	-0.2531	-0.0895	-0.1282	-0.0367	-0.0880	-0.3150	0.1170 *	-0.1058	1.0000					
13. " " Na	0.1508	0.0875	0.2462	0.2419	0.1434	0.0385	0.0024	0.1767	0.1030	0.3663	0.0032	-0.1300	1.0000				
14. " " Ca	0.2637 *	0.0875	0.1842 *	0.1897	0.1933 *	0.3329 *	-0.0641	0.1747	0.0120	0.0372	0.2131	0.0692	-0.0307	1.0000			
15. " " Mg	0.3267	0.0437	0.1022	0.1024	0.1429	0.3028	0.0961	0.1003	-0.0620	0.0482	-0.0263	0.0139	0.1572	0.5141	1.0000		
16. " " K	0.0864	-0.2398 *	0.1404 *	0.1134 *	-0.1708 **	-0.1951 **	0.0199	-0.0988	0.1180	-0.0979	-0.1446	0.0284	-0.0616	0.0968	-0.0415	1.0000	** **
17. " " P	0.0802	0.0659	0.4603	0.4634	0.1321	0.2122	0.1878	0.3514	0.3320	-0.1489	0.5089	-0.1880	0.0513	0.1637	-0.1149	0.0380	1.0000

** Significant at 1%
* Significant at 5%

Table 20: Effect of Zn on the concentration of zinc in the leaves and grains of maize cultivars.

Zn levels $KgZnha^{-1}$	Variety	LEAVES 1991/92	LEAVES 92/93	LEAVES Mean	GRAINS 1991/92	GRAINS 92/93	GRAINS Mean
		- $mgKg^{-1}$ Zn -			- $mgKg^{-1}$ Zn -		
0		35.67	47.30	41.49	22.30	23.00	22.65
1.5		35.67	55.00	45.34	23.00	20.35	21.68
2.5	TZBSR-Y[1]	36.00	58.30	47.15	26.30	23.50	24.90
5.0		36.33	60.70	48.52	26.30	24.20	25.25
7.5		39.33	62.00	50.67	34.70	29.00	31.85
0		31.67	50.00	40.84	22.30	26.10	24.20
1.0		34.33	50.00	42.17	22.30	23.00	22.65
2.5	mega Hybrid	35.00	50.00	42.50	23.60	29.00	26.30
5.0		38.33	50.70	44.52	26.70	26.40	26.55
7.5		38.67	93.30	65.92	35.70	22.00	28.85
0		37.00	53.00	45.00	25.00	24.57	24.79
1.0		39.00	57.70	48.35	24.30	23.67	23.99
2.5	Ag-Kaduna	40.00	58.30	49.15	27.00	28.10	27.55
5.0		41.33	59.00	50.17	25.70	26.00	25.85
7.5		43.33	63.33	53.33	29.00	28.50	28.75
Zn x Variety		NS	NS			NS	

Table 21: Effect of Zn on the concentration of Cu in the leaves and grains of maize cultivars.

Zn levels KgZnha^{-1}	Variety	LEAVES 1991/92	92/93	Mean	GRAINS 1991/92	92/93	Mean
		- mgKg^{-1} Mn --			- mgKg^{-1} Mn -		
0		21.3	12.00	16.66	10.57	10.00	10.29
1.5		19.3	6.67	12.98	7.97	6.90	7.44
2.5	TZBSR-Y[1]	10.0	7.00	8.66	7.30	7.20	7.25
5.0		10.0	7.33	8.66	7.60	6.80	7.20
7.5		11.3	5.33	8.32	8.00	5.25	6.63
0		10.7	8.67	9.69	9.63	8.60	9.12
1.0		11.3	6.67	8.99	6.17	5.51	5.84
2.5	mega Hybrid	10.3	6.67	8.49	7.67	7.60	7.64
5.0		13.3	3.33	8.32	9.33	9.30	9.32
7.5		10.7	10.80	10.35	7.35	6.25	6.80
0		11.0	6.00	8.50	9.23	9.00	9.12
1.0		13.3	4.00	8.65	9.50	8.25	8.88
2.5	Ag-Kaduna	10.3	5.33	15.63	8.70	8.50	8.60
5.0		19.3	6.00	12.65	9.77	9.90	9.84
7.5		12.0	6.67	9.34	11.40	10.00	10.70

Table 22: Effect of zinc on the concentration of Mn in the leaves and grains of maize cultivars

Zn levels KgZnha^{-1}	Variety	LEAVES 1991/92	92/93	Mean	GRAINS 1991/92	92/93	Mean
		- mgKg^{-1} Fe --			- mgKg^{-1} Fe -		
0		69.30	79.30	74.30	8.73		
1.5		72.00	74.70	73.35	7.40		
2.5	TZBSR-Y[1]	68.00	91.30	79.65	16.00		
5.0		66.70	70.00	68.35	7.67		
7.5		60.00	59.30	59.65	6.93		
0		99.30	69.30	84.30	6.87		
1.0		16.00	74.00	45.00	8.13		
2.5	mega Hybrid	108.00	74.70	91.35	14.80		
5.0		98.00	64.70	81.35	6.60		
7.5		110.00	97.30	103.65	5.47		
0		108.00	65.30	86.65	7.20		
1.0		94.70	91.30	93.00	6.27		
2.5	Ag-Kaduna	93.30	68.70	81.00	6.60		
5.0		98.00	97.30	97.65	6.60		
7.5		98.00	57.30	77.65	8.33		

Table 23: Effect of zinc on the concentration of Fe in the leaves and grains of maize cultivars at Samaru.

Zn levels KgZnha^{-1}	Variety	LEAVES 1991/92	92/93	Mean	GRAINS 1991/92	92/93	Mean
		- mgKg^{-1} Fe --			- mgKg^{-1} Fe -		
0		273	106.0	189.5	40.00	40.20	40.10
1.0		235	102.5	168.75	46.70	42.50	44.6
2.5	TZBSR-Y[1]	243	103.3	173.15	57.30	55.20	56.25
5.0		167	100.0	133.50	42.70	40.52	41.61
7.5		150	90.0	120.00	47.30	45.20	46.25
0		257	166.0	211.50	43.70	43.00	43.35
1.0		223	136.7	179.85	65.70	52.00	58.85
2.5	mega Hybrid	237	113.7	175.35	39.70	35.60	37.65
5.0		217	116.7	166.85	47.00	45.00	46.00
7.5		160	106.7	213.35	81.70	80.00	80.85
0		233	176.7	204.85	53.70	54.60	54.15
1.0		207	116.7	161.85	53.00	52.00	52.00
2.5	Ag-Kaduna	217	123.3	170.15	66.30	68.30	67.30
5.0		170	116.3	143.15	45.70	42.50	44.10
7.5		133	113.3	123.15	44.30	45.60	44.95
Zn x Cultivar			NS			NS	

CHAPTER FIVE

5.0 SUMMARY AND CONCLUSION

In this study, three maize cultivars were used in studying the relationship between differential susceptibility to zinc deficiency and nutrient composition of plants, with five rates of zinc namely 0, 1.0, 2.5, 5.0 and 7.5Kg $Znha^{-1}$ with 120KgN, 60kg P_2O_5 and 60Kg K_2O were applied. The soil was a sandy loam, slightly acidic, low in P, N. K.

The maize plants were grown to maturity and during growth, plant height and index leaves were sampled at 50% silking. The yield and other yield parameters were also taken, the effect of zinc on the concentration of P, K. Ca Mg, Fe, Cu, Mn and Zn were measured in the leaves and grain of the maize.

There were response in maize cob length, diameter and 1000 grain weight with increase in zinc rates although the increase were not significantly different from each other. The linear and multiple regression models did not fit the yield data obtained. But when the yield was subjected to quadratic regression, the model best explained the relationship between the treatments and the yield data.

There was significant correlation amongst grain yield and the net weight of 1000 grain, cob yield, stover

yield, cob length and plant height. The susceptibility index which is the percentage yield reduction with zinc deficiency showed that Ag-Kaduna was less susceptible. Comparing the susceptibility index (SI) with relative increase or decrease of nutrient composition, the multiple regression model did not fit, therefore no prediction could be made about which of the nutrient concentrations bear a definite relationship with the relative susceptibility of the maize cultivars to zinc deficiency. A rate of 1kg $Znha^{-1}$ is suggested to maintain fertility status of the soil of Samaru. The variety Ag-Kaduna being the best variety among the others.

From the above, it could be concluded that the cultivars differed in their susceptibility to zinc deficiency, but the degree of variation and the exact relationship between the zinc deficiency and tissue concentrations were not known.

A more detailed study should be conducted in the future to relate zinc deficiency with tissue concentration of the element and more maize cultivars should be use.

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