EFFECT OF MOLYBDENUM FERTILIZATION ON SEED MOLYBDENUM CONTENT, NODULATION AND YIELD OF GROUNDNUT AND COWPEA GENOTYPES IN A SAVANNA ALFISOL

By

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DECLARATION

I declare that the work in this thesis entitled "Effect of Molybdenum Fertilization on Seed Molybdenum Content, Nodulation and Yield of Groundnut and Cowpea Genotypes in a Savanna Alfisol" has been performed by me in the Department of Soil Science under the supervision of Professor E.O. Uyovbisere and Doctors B.D. Tarfa and S.T. Abu.

The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

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Chairman, Supervisory Committee

CERTIFICATION

This thesis entitled "Effect of Molybdenum Fertilization on Seed Molybdenum Content, Nodulation and Yield of Groundnut and Cowpea Genotypes in a Savanna Alfisol" by Adeogun, Tinuke T.A. meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to God almighty and to my late beloved darling husband, Adebola Oluwole Adeogun.

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ABSTRACT

A study was conducted to evaluate the effects of Mo treatments (Mo levels and methods of application) on seed Mo content, nodulation and yield of cowpea and groundnut genotypes. The supply of Mo to planted grain legumes can be soil or foliar applied. A third possible supply option, the Mo content of the seed (grain), has not been exploited. This third option is expected to provide a more economically viable prospect of the available options. The study had the following objectives: to determine the effects of Mo fertilization and methods of application on the seed Mo content and on nodulation of groundnut and cowpea genotypes. To achieve these, one greenhouse experiment and one field trial were conducted. Treatments consisted of five levels of Mo soil applied (0, 100, 200, 300 and 500g Mo/ha) and one level of Mo applied foliar (200g Mo/ha). The test crops were two groundnut varieties (SAMNUT 23 and SAMNUT 14) and two cowpea varieties (IAR 48 and IT95K-499-35). Agronomic and soil parameters were measured. Results of the study showed that the rate of 200g Mo/ha was optimal for growth, nodulation and good yield of groundnut and cowpea genotypes, though suitable rates for some parameters may range from 100 to 300g Mo/ha. Soil application was generally superior to foliar application, but foliar application seemed to stimulate more root development and Mo accumulation in the seeds of the planted grain legumes. Efficiency of the foliar method or soil method of application varied within genotypes of the crop species. Maximum grain yield of the groundnut genotypes were 700 kg/ha for SAMNUT 23 at 100g Mo/ha and 726 kg/ha for SAMNUT 14 at 300g Mo/ha. For the cowpea genotypes, yield levels were 1218 kg/ha for IAR 48 at 200g Mo/ha soil applied and 1150 kg/ha for IT95K-499-35 at 200g Mo/ha soil applied. Mo application was found to

enhance organic carbon accretion in the soil by 6% under field conditions and 24% in greenhouse situations and the cowpea crop was more efficient in this case. The significance of P and K as well as Cu and Mo for good nodulation and yield of grain legumes were derived from correlation relationship in this study. Soil Mo content enhanced Mo accumulation in the grain. For 200g Mo/ha, the average seed Mo content of the crops were found to be 6.96 mg/kg for groundnut and 6.20 mg/kg for cowpea. Therefore, for good growth, nutrition, nodulation and yield of groundnut and cowpea genotypes, the Mo content of the planted seed should be about 7.00mg/kg and above and this level can be considered adequate for the crops without soil or foliar applied Mo in the management of the planted grain legumes.

CHAPTER ONE

INTRODUCTION

1.1 Background

Production of crop yield (grain legumes) in the Northern Guinea savanna reveal declining yields due to low fertility status which leads to nutrient deficiency (Sarkar *et. al.,*,1998;Vanlauwe *et.al.,2002*). Increase in population has necessitated the need to step up levels of food production, and this has resulted in lands being continuously cropped, with the result of soils being highly depleted of nutrients, especially micronutrients not often considered in the overall crop fertilization program (Mulonguoy ,1976). Therefore solving the agricultural problems of the sub-humid and semi arid savanna calls for a review of the input systems and technologies made available to farmers.

In these ecologies, nitrogen deficiency has been observed to be a major limitation in the production of grain legumes, such as groundnut and cowpea, and this situation has often been associated with low Mo content of the soils (Singh *et al*., 1999). The yield of groundnut and cowpea obtained from farmers fields can be improved if the essential micro-nutrient constraints are satisfied reasonably in addition to the needed macronutrients, such as phosphorus (Jones and Wild, 1975). Molybdenum enhances nodulation in legumes and in effect, nitrogen fixation (Broderick and Giller,1991). Though groundnut and cowpea respond appreciably to nitrogen, the application of inorganic N has often reduced yields in the crops (Mishustin *et al.,*1973). 'Utilizable nitrogen is manufactured directly by the crop, and response to N has often been associated with Mo supply in grain legumes and in nitrogen deficient soils' (Singh *et al.* 1999; Jongruaysup *et al.*, 1994).

Groundnut and cowpea have been shown to fix about 100 and 240kg N/ha/annum respectively (Feakin, 1973). The crops are therefore able to provide much of its own N, and as much as 60-70kg N/ha/annum for the succeeding crop (Singh *et al.*, 1985). Reports from the dry savanna (Sudan/Sahel) have shown that the yield levels of groundnut could be doubled with 200g Mo/ha soil applied (Brent *et.al.,*2005) Molybdenum is known to enhance the utilization of N, P and Fe and it is required by bacteria for nodule formation and N fixation, and in nitrogen assimilation of all higher plants. The supply of Mo to planted grain legume crops can be soil or foliar applied (Anderson and Spencer, 1950). What has not been exploited is the seed Mo content as the source of Mo for the production of a good crop of the grain legume. Considering the minute amount of the Mo element needed to meet the requirement of cultivated grain legume crops for nodulation and N fixation processes, the seed can provide a more economically viable prospect of all the options that can be considered (Broderick *et al.*, 1992; Jongruaysup *et al.*, 1994).

A study was therefore initiated to determine the effects of varying levels of Mo fertilization on the seed Mo content of groundnut and cowpea genotypes, and also of the effects on yield and yield influencing factors such as nodulation and residual N content of soils planted to the crops.

The objectives of this study are:

1. To determine the effects of varying levels of Mo fertilization on the seed Mo content of groundnut and cowpea genotypes.
2. To investigate the levels of Mo in the seed considered adequate for nodulation and N fixation of the crops.

3. To determine the effects of Mo levels on yield and yield related parameters of the crops.

CHAPTER TWO

LITERATURE REVIEW

2.1 The Fertility Status of the Northern Guinea Savanna Soils

The savanna soils are highly weathered, coarse textured, low in organic matter content and cation exchange capacity. They are generally acidic and poorly buffered with respect to most nutrients (Jones and Wild, 1975; Heathcote and Stokinger; 1970, Greenland, 1981). Total P is generally low in the soils with values ranging from 13 to 630ppm. A range of about 100 to 400ppm in savanna soils have been reported, (Mokwunye, 1974).

Savanna soils are generally low in total nitrogen. Values range from 0.08 to 0.290 percent, with a mean of 0.051 percent (Jones and Wild, 1975). This low value is closely linked with low organic matter content of the soils. Potassium content varies widely according to parent materials but compared with other nutrients, amounts are often high. Basement complex rocks contain a mean of 0.08 to 2.2 percent in sandstone (Wild, 1971). Calcium and magnesium are the dominant exchangeable cations in virtually all savanna soils and few deficiencies have been reported.

The dominant soils of the Northern Guinea Savanna are Alfisols and Ultisols. These soils degrade quickly because of the rapid rate of organic matter decomposition, intensive leaching of nutrient and soil erosion on cleared lands, (Mulonguoy *et al.* 1976). The Alfisols covers about 60% of the region; these soils usually have an argillic (clayey) horizon with more than 35% base saturation. They are similar to ultisols except for a considerably higher natural fertility level (Eswaran *et al.,* 1996).

The agricultural value of these soils is usually rated poor to average in terms of nutrient levels, soil moisture deficiency is one of the primary limiting factors to crop growth in soils of these areas, even in the more humid areas, the seasonal distribution of rainfall is an important determining factor for crop growth, depending on the moisture – storage capacity within rooting depth of the particular soil. The effective cation exchange capacity (ECEC) of many savanna soils is low, often 4 $cmol/kg^{-1}$, and is closely related to the organic matter and clay contents of the soils, many of which have variable charge (Sanchez 1976,).

2.1.1 Organic matter status of the Northern Guinea Savanna (NGS)

Organic matter is of critical importance in the savanna soils. Once the vegetation is burned, or the soil is cultivated, soil OM breaks down rapidly, depending on the moisture content. The rate of breakdown is proportional to the temperature (Birch and Friend,1956). Many studies suggest that there is a dominant linkage between molybdenum supply and organic matter delivery. The availability of Mo depends on organic matter supply (Birch and Friend,1956).

2.1.2 Forms of Mo in soils

Mo alone, of all the trace elements, becomes more available in the soil with increasing pH, (Barshad, 1951). The water soluble Mo of the soil increased with increasing pH as observed by Amin and Joham (1958), as well as the soluble molybdate. Mo occurs in soils as three oxides; Mo trioxide (MoO_3), molybdenum dioxide (MoO_2) and the pentoxide (Mo_2O_5). The soluble molybdates are readily available to plants, and the trioxide, while not as much so, are readily rendered soluble by reaction with cations in the soil. Oxidation of the lower oxides tends to increase the availability of Mo while

reduction tends to reduce the availability. Immediate availability depended on the production of soluble molybdates from molybdenum trioxide which would be favoured by increasing pH. Acidifying the soil has the reverse effect. This was done, so that Mo toxicity in plants growing in soils where it was present in excessive quantity, could be alleviated (Walter , 1961).

Molybdenum is present in the lithosphere at average levels up to 2.3mg kg^{-1} but can increase in concentration (300mg kg^{-1}) in shale that contain significant organic matter (Fortescue, 1992; Reddy *et al.*, 1997). In agricultural soils, molybdenum is present as many different complexes depending on the chemical speciation of the soil zone. Mineral forms of molybdenum found in rocks include molybdenite (MoS_2), Wulfenite ($PbMoO_4$) and Ferrimolybdenite [$Fe_2(MoO_4)$] (Reddy *et al.*, 1997). Release of molybdenum from solid mineral forms is through weathering, a process involving continual solution and oxidation reactions (Lindsay, 1979; Gupta 1997 a). Dissolved molybdenum available to plants is commonly found in the soluble MoO_4^- anion form (Lindsay, 1979). Above pH 4.23, MoO_4^- is the common anion, followed in decreasing order by MoO_4^-> HMO_4^-> $H_2MO^O{}_4$> $MoO_2(OH)^+$>MoO_2^{2+} (Lindsay, 1979). Once in solution, the MoO_4 anion is subject to normal anion adsorption/desorption reactions, which are dependent on the specific chemistry of the soil solution. MoO_4^- can adsorb onto positively charged metal oxides (Fe, Al, Mn), clay minerals, dissolved organic compounds and carbonates. The adsorption of molybdenum onto positively charged metal oxides is strongly pH dependent with maximum adsorption occurring between pH 4 and 5 (Gupta, 1997 b).

2.1.3 Phosphorous status of NGS

Phosphorus deficiencies are widespread in the savanna soils and many authorities consider lack of phosphorous to be the primary nutrient limiting crop production in this savanna (Kowal and Kassam 1978). Average total phosphorus contents in surface soils range from about 80-150ppm, which are low compared with temperate soils that have average contents of about 1500-3000ppm. Part of the soil phosphorus is in the form of organic phosphorus, but this tends to be low in most savanna soils with values of 15-60ppm, (Goldsworthy s1963), where Mo supply is low which is known to enhance activity of certain phosphate enzyme which is rapidly hydrolyzed in the presence of molybdate ion.

2.1.4 Nitrogen status of the NGS.

Nitrogen deficiencies are widespread in the savanna farming systems, and are often limiting factors to crop growth (Sanchez, 1976). The most important source of nitrogen is from biological nitrogen fixation (BNF) from the atmosphere, but this can be limited where molybdenum is in short supply *(* Sanchez,1976).

2.1.5 Potassium status of the NGS.

Potassium deficiencies have been reported on certain soil types under intensive cropping, in general they do not appear to be limiting to crop production in most savanna regions (Nye and Greenland 1960). Potassium is returned to the soil in crop residues or other forms of organic matter, and in the ash after burning, so it is easily recycled, but leaching losses can be severe. However, under continuous cropping with the removal of crop residues, potassium could be expected to become limiting to the yields of a number of crops, including cowpeas and groundnut. On the basis of existing literature, deficiency

of potassium also affect efficiency of molybdenum which is a yield limiting factor that has been identifying in this NGS (Fageria *et al.* 1990).

2.1.6 Micronutrient Status of the NGS.

The deficiencies of Micro-nutrients in NGS especially molybdenum which often affects survival and growth of rhizobia, affects nodulation and nodule function are critical to legume production on NGS soils (Foy 1983).

Occasional deficiency of micronutrient such as molybdenum, copper, manganese and zinc have been identified particularly on groundnut and cowpea which are under heavy cropping (Eswaran *et al.,* 1996).

2.1.7 Physical properties of the NGS

The erodibility of savanna soil, or their vulnerability to erosion is generally high because many of the soil are sandy, low in organic matter, and of unstable crumb structure (Kowal and Kassam 1978). It appears that certain types of fine sandy loam or loamy sand soils that are low in organic matter through over cultivation, and therefore have unstable structure, are particularly liable to erosion because of their tendency to crust. When a high intensity rainstorm hits bare soil, the fine soil particles are loosened by rain splash and are washed down into pore spaces, which quickly become blocked once the pore spaces are blocked, the soil surfaces is saturated, run off starts (Chase and Boudouresque 1987), the fine organic and lighter soil particles are the first to be removed by run off. Measurements show that the eroded materials contains two to four times more of the fine particles containing nutrients than the original soil (Jones and Wild 1975, Kowal and Kassam 1978).

There have been relatively few reports of deficiencies of micro nutrients in soils of the Northern Guinea Savanna (NGS). Various reasons may be suggested; Under subsistence farming, yields are low and nutrient removal is low, nutrient in the crops are largely returned in ashes, animal dung, domestic refuse etc. Deficiencies have been overlooked especially where yields have been limited by other factors and if micronutrients were also supplied incidentally because they are often present as impurities in the fertilizers (Olaitan and Lombin, 1984). The two micronutrients most commonly deficient are boron in cotton and Mo in groundnuts. The frequency and severity of occurrence of micronutrients deficiencies are expected to increase as the intensity of agriculture increases (Olaitan & Lombin, 1984).

Mo is one of the micronutrients needed by legumes to enhance the process of nitrogen fixation in soil which is found to be deficient in most soils of the NGS, (Harkness *et al.*, 1976), hence, supplementary micronutrient supplied either as soil applied fertilizer or as foliar are necessary in this region (Jones and Wild, 1975) to improve the low yield levels of cowpea and groundnuts obtained from farmers field.

2.2.0 Molybdenum (Mo) requirement of Legumes

Molybdenum is a soil nutrient found in very small quantities, is a key component that limits nitrogen fixation in agricultural legume crops (Broderick *et al.,* 1992).

Molybdenum is essential for plant growth, Broderick *et al.* (1992) determined that Mo levels effected changes in bean seed size and increases in shoot, root and nodule dry weights. Variations in content by 83-85% and seed production by up to 38%. Mo deficiency affects nodule development by reducing bacteria multiplication and delaying or preventing the onset of nitrogenase activity (Jongruaysup *et al.*, 1994).

Molybdate ion is the predominant form of molybdenum available to plants and is required in very low amount where it is known to participate in various redox reactions in plants as part of the organic pterin complex called the molybdenum co-factor (MoCo), is particularly involved in enzymes, which participate directly or indirectly in nitrogen metabolism. However, MoCo is also uniquely involved in ABA synthesis, where it has a significant effect on Abscisic Acid (ABA) levels in plant cells and consequently, a role in water relations and transpiration rates through stomatal control and in stress related responses. There is significant scope in exploring practices, which optimize molybdenum fertilization in crops where nitrate is the predominant available N source or in nitrogen fixing legumes. There is also a large gap in the understanding of how molybdate enters plant cells and is redistributed between tissues of the plant. For example the mechanism controlling molybdenum transport to nitrogen fixing bacteroids may be a unique control mechanism by which the plant can regulate the symbiosis indirectly through molybdenum availability to support nitrogenase activity (Brent *et al.*, 2005).

The content of Mo in plants are for the most parts low, and it is clear that different species have different capacities for absorbing Mo. Barshard (1951) concluded that members of leguminosae had a greater capacity for accumulating Mo than plants of some other families. As with other nutrients, absorption of Mo increases with increase in the level of its supply, (Barshard *et al.* 1951).

The major role of Mo in leguminous plants is as a component of the enzyme system of N_2-fixation. Thus, legumes relying on symbiotically fixed nitrogen develop symptoms of N deficiency when subject to Mo deficiency in Mo deficient soils. This

hinders the assimilation of atmospheric nitrogen (Pillai, 1967) and in turn inhibits nodulation and reduces yield as a result.

2.2.1 Response of Groundnut to Mo

Molybdenum application to groundnut doubles crop biomass (Broderick *et al.*, 1992) and stimulates root growth leading to better nodulation and increase in nitrogen and Mo contribution to succeeding crop and thereby increasing crop yield (Robitaille, 1975). Addition of Mo to the soil helps the performance and increases the population of rhizobium bacteria, which helps the nitrogen reserve of the soil to be replenished, thereby increasing the grain yield (Wynne *et al.*, 1980).

Legumes such as groundnut have a relatively high Mo requirement for rhizobium symbiosis, since Mo is a key component of the enzyme nitrogenase. Mo deficiency in soils low in N is consequently associated with poor plant performance.

2.2.2 Response of Cowpea to Mo

Cowpea has a high Mo requirement, Mo is reported to stimulate root and plant growth, initiate nodule formation, as well as influence the efficiency of the rhizobium-legume symbiosis (Thomas *et al.*, 1990). It is also involved in reaction with energy transfer, more specifically ATP in nitrogenase activity (Brent *et al.*, 2005)

High bean yields (1,500-2,500kg ha^{-1}) were obtained in the South Eastern region of Brazil, either by applying N as side dressing or as Mo spray (Robitaille, 1975; Veiera *et al.,* 1998a and 1998b).

2.3 Effects of Mo on nodulation and N fixation Processes

2.3.1 Effects of Mo on nodulation

Nodule formation is as a result of interaction between substances produced by the bacteria and the other substances contained by the roots of the host plant (Mushustin *et al.,* 1971). Through field experiments over 4 seasons, seed treatments with a small amount of Mo significantly increased yield of nodule legumes (soya bean) which were grown with a moderate level of applied N-fertilizer (Koji *et al.*, 1976). Mo application increased the Mo content of nodules, which contained the highest level of Mo as compared to other plant tissues. In addition, Mo application resulted in better growth of each nodule and led to a higher nodule weight per plant, (Koji *et al.* 1976).

When there is a Mo deficiency, nodule formation is poor, (Atwal and Sidhu, 1964), the synthesis of free amino acids is disturbed, (Mulder *et al.,* 1959) and that of leghaemoglobin is suppressed, (Mulder, 1948a). Several experiments have indicated that if insufficient molybdenum is available nodulation will be retarded and the amount of nitrogen fixed by the plant will be limited (Reisenover ,1972), speeds up inoculation and activates nodule development (Gurley and Giddens, 1969; Franco and Munns, 1981; Ishizuka,1982).

Mo is localized chiefly in the cell sap of the nodule tissue (Mulder et al., 1959), while there is little in the bacteria about four times less (0.005 percent of dry matter). Molybdenum deficiency affects nodule development by reducing bacterial multiplication and delaying or preventing the onset of nitrogenase activity, (Jongruaysup *et al.*, 1994). Number of nodules per plant significantly increased with increasing levels of phosphorus and Mo.

Molybdate supplied by plant transverse nodule cellular membranes (plasma membrane and the peribacteroid membrane) as well as the bacteroid other and inner membranes to reach the bacterial nitrogenase complex. Legumes also appear to maintain molybdenum concentrations in nodules as the partitioning of molybdenum in common bean and soya bean favors both nodules and developing seeds relative to other tissues (Gurley and Giddens, 1969; Franco and Munns, 1981, Ishizuka, 1982, Broderick and Giller 1991b). Nodules are strong sinks for molybdenum and they accumulate significantly more molybdenum than what is required in order to support bacterial nitrogenase activity and symbiotic nitrogen fixation (Brent *et al.*, 2005).

Application of Mo also showed significant increase in number of nodules per plant. The interaction effect of P and Mo significantly influenced the number of nodules per plant. Results were in concordance with findings of Ali *et al.* (1993) who found that nodule showed positive trend with increasing rates of P and Mo application.

2.3.2 Effects of Mo on nitrogen fixation

Nitrogen content of the atmosphere is about 78%. Groundnut and cowpea are able to benefit from this abundant supply of nitrogen through symbiotic and non-symbiotic nitrogen fixing bacteria present in the soil. Boussingault's (1973) experiment made it clear that fixation of atmospheric nitrogen takes place during the development of legumes whereas these fixation do not occur during the growth of other crop such as wheat. Bacteria (rhizobia) in the root nodule of leguminous plants use atmospheric nitrogen. In the absence of the bacteria, the host (legume) cannot fix nitrogen (Hardy et al.,1977). Mo is found to have an important effect on nitrogen fixation (0.03 to 0.05% per plant). It is estimated that for one part of Mo, 37,000 parts of nitrogen could be fixed. Mo stimulates

the process of symbiotic nitrogen fixation and is used for general metabolism. The symbiotic fixation of nitrogen is of great economic importance. The amount of nitrogen added to the soil by leguminous plants depends entirely upon the abundance of available nitrogen in the soil (Pillai 1967).

Mo has often been studied, its positive effects on symbiotic nitrogen fixation was first noted by Bortels (1960) and confirmed by a series of investigations (for example Anderson and Spencer, 1950; Mulder 1954).

The symbiotic bacteria enzyme nitrogenase is comprised of two subunits, one of which is the MoFe protein directly involved in the reduction of N_2 to NH_3. Supply of molybdenum and iron (Fe) to bacterioids is therefore an important process and most likely a key regulatory component in the maintenance of nitrogen fixation in legumes (Brent *et al*., 2005).

Mo has a major role in symbiotic N fixation as a fundamental component for nitrogenase, (Broderick *et al.*, 1992) and nitrogen fixing activity was estimated by measuring the nitrogenase activity with the acetylene reduction assay. The activity was expressed by the amount of ethylene produced per hour on the basis of a plant or one gram of dry weight nodules since nitrogen fixation correlates to nodule formation. s

Cowpea has been shown to fix up to 240kg N /ha. It is therefore able to provide much of its own nitrogen requirement and also enough for the succeeding crop. Values of up to 60-70kg N/ha derived from the proceeding cowpea crop has been recorded as earlier stated (Singh *et al.* 1997).

2.3.3 Effects of Mo on enzyme synthesis

Mo is required in two key enzymes associated with nitrogen assimilation, nitrate reductase and nitrogenase (Brodick *et al.* 1992). The requirement of Mo in nitrogenase and nitrate reductase is essential to mediate and enhance N metabolism (Marschner, 1998).

Mo has been known to increase: (i) acetylene reduction activity (ii) nitrate reductase activity (iii) and N remobilization during pod filling (Vieira *et al.* 1998a, 1998b).

Molybdenum deficiency affects plant metabolism at many different levels. The responses are strongly linked to the requirement of molybdenum for the various types of molybdoenzymes present in plant. Plant molybdoenzymes can be broken down to those involved in nitrogen reduction and assimilation [i.e. nitrate reduction (nitrate reductase: NR), nitrogen fixation (nitrogenase)], (Brent *et al.*, 2005). Since molybdenum is involved in a number of different enzymatic processes, this is particularly evident in molybdoenzymes involved in nitrogen metabolism where overall reduction in plant growth and health can alter plant development, susceptibility to pest damage, and grain development (Graham and Stangoulis, 2005).

2.3.4 Effects of soil, foliar and seed Mo on yield

From the available works of previous researchers, it can be pointed out that fertilization of Mo on a Mo- deficient soil not only increased the Mo content of the soil, but will also increase the Mo content in the seed, which will be required to meet the need of an otherwise depleted soil, since the amount of Mo required for symbiotic legumes is very small, and some grain legume can store sufficient Mo for adequate nodulation in Mo

deficient soils as reported by Broderick *et al.*, (1992) and Jongruaysup *et al.* (1994). But, in this study, the effects of varying levels of Mo fertilization on seed content will be determined to know the actual level of molybdenum in the seed that will be adequate for maximum nodulation, fixation of N and for optimal yield. Seed treatment with a chemical containing Mo resulted in a highly significant increase of 14.2% in an average yield over four seasons, (Koji *and Yamasaki* 1976).

Results from 16 sites showed that fertilizing with lime and Mo increased seed yields to 370% for the Lanrace Serro Azul. In addition to the increased yield, plant grown with lime and Mo fertilizer had more nodules (Olivera, *et al.*, 1998). The seed yield was significantly influenced by the levels of P and Mo. The application of P increased the seed yield by 25.5, 32.0 and 37.3% with the application of 13, 26 and 39 kg ha^{-1} respectively over control. Similarly, the mean increase on seed yield with Mo application was 9.5, 13.5 and 4.3% over control with 0.5, 1.0 and 1.5 Mop ha^{-1} respectively.

The introduction of nitrogen-containing mineral substances into soil usually suppresses the assimilation of nitrogen by both free living and symbiotic nitrogen-fixing bacteria (Mishushin and ShilNikova 1971).

2.3.5 Effects of Foliar Applied Mo on legumes

In the North of Tvaouane, which was particularly deficient in Mo, the two experiments that was carried out in 1970 in the region showed that 2kg/ha of sodium molybdate increased yield by 785kg/ha and 314 kg/ha respectively. Twenty-three experiments in 1977 confirmed their results with an average response of 200kg /ha from 3kg/ha ammonium molybdate, (Bockele – Morvan, 1978).

Molybdenum fertilization through foliar sprays can effectively supplement internal molybdenum deficiencies and the activity of molybdo-enzymes (Brent *et al.*, 2005). Foliar applied molybdenum to common beans resulted in an 81% increase in nodule and molybdenum levels relative to the 56% increase observed in the shoot (Broderick and Giller, 1991).

Williams *et.al.,(*2004), showed that foliar-applied molybdate was rapidly distributed throughout the plant, including translocation towards stem and roots within 24 hours. Broderick and Giller (1991), have shown good plant responses from foliar molybdenum application in the field.

2.3.6 Economic importance of Groundnut (*Arachis hypogeal)*

Groundnut can fix atmospheric N and also leave some in the soil after the economic yield has been removed. A crop of groundnut is said to leave about 50kg P/ha of N in the soil and cowpea also leaves about 60-70kg/ha of N.

Groundnut can be used for correcting the soil in areas where soil fertility status has declined through continuous cropping, due to rapid organic matter decomposition, intensive leaching and erosion on cleared land. Groundnut has been used in cropping systems for soil improvement throughout most of the recorded history. Under certain condition, a legume cover or green manure crop can provide organic matter, provide protection against soil erosion, improve soil structure, make other nutrients more available, and also interrupt cycles of diseases and insect pest (Mulongoy, 1976).

In a trial to study the influences of groundnuts, sorghum and cotton grown in sequences on their yields, Philips (1961) found that yields were highest after groundnuts and lowest after cotton. In another experiment where maize was grown after legumes,

Lata (1982) found generally higher yields after an initial legume crop, compared to the yield after maize. Also when pearl millet was grown after groundnut, 12.6, 24.2 and 12.1 percent increased in yields respectively than when pearl millet was grown after pearl millet.

The important world producers of groundnut include India, China, U.S.A., Sudan, Senegal, Nigeria and Argentina. According to FAO estimate in 1996, the world production was 29,196,000 metric tones with Nigeria accounting for 1,723,000 metric tones for Africa. The area under production in Africa was 5.8 million hectares, (Gibbon and Pain, 1985). Crop yield are very variable and range from 440-1650kg/ha of unshelled nuts but yields of more than 2200kg/ha are possible (Gibbon and Pain, 1985).

The importance of groundnut in Nigeria lies not only on its role as a potential exchange earner, but also its use as a source of vegetable oil (contain 45 – 50% oil) and protein, which provides 25% of the country's nutritional requirement. Groundnut contributes 5% of the estimated 59.0g crude protein available per head in Nigeria. The minimum daily requirement of adult for protein is 65.0g (Olayide, 1972). Thus, increase in groundnut production can contribute to eliminating the shortfall of protein supply. In addition, groundnut has an important use in the livestock industry. The groundnut haulms and cake serve as excellent sources of food for cattle, sheep and goats.

2.3.7 Distribution of cowpea (*Vigna unguiculata* L. Walp)

Cowpea has been cultivated for human food since ancient times, particularly in Africa for more than 4000 years from where it spread to other parts of the world, (Fans, 1965). Cowpea has been shown to fix up to 240kg N/ha. It is therefore able to provide much of its own nitrogen requirement and also enough fore the succeeding crop. Values

of up to 60-70kg N/ha derived from the proceeding cowpea crop has been recorded (Singh *et al.* 1985). Cowpea is a pulse crop, with about 22% protein (Platt, 1962). It is also used as a quick growing crop under a wide range of climatic and edaphic conditions.

The world production of cowpea is approximately 300,000 tones. Cowpea is the second most important food grain legume crop in the tropics of Africa, the most important being *Phaseolus vulgaris*, the common bean. Nigeria, Niger, Burkina Faso, Uganda and Senegal grow cowpea for the market but they are widely grown as subsistence crop for home use in nearly all African countries South of the Sahara. Cowpea is grown extensively in the South – East Africa and in Latin America and to a lesser extent, in the Southern parts of the U.S.A.

2.3.8 Soil and climatic requirement for groundnut and Cowpea.

2.3.8. 1 Groundnut

The groundnut plant is known to thrive best on well drained, sandy loam soils with a pH range of 5.8-6.2. The plant requires a lot of sunshine and regular rainfall during the growing period. A total of at least 750mm of annual rainfall evenly distributed over a period of about 110 – 140 days (4 – 5 months) is usually adequate for a good crop, (Misari *et al.*, 1982). The optimum day and night temperature for groundnut yield were estimated to be 30 ^{o}C and 20 ^{o}C respectively.

2.3.8.2 Cowpea

Cowpeas are warm - weather annual crops. They withstand heat better than most other legumes and are drought resistant. They are most important in the semi-arid tropics where they are grown mainly for their seeds. Moisture deficiency has an adverse effect on the vegetative growth of plant but not much effect on seed formation. Cowpeas can

be grown with less rainfall and under more adverse conditions than the common bean (*Phaseolus vulgaris*). Cowpea can be grown successfully on a great variety of soils provided they are well drained. Light sandy loam soils are more suitable than heavy soils. Cowpea can tolerate acidity under condition of heavy rainfall.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Site Description

The field research was conducted at the Institute for Agricultural Research Experimental Farm, at Samaru, Zaria in the Northern Guinea Savanna (NGS) zone of Nigeria (within the co-ordinates of longitudes 7^0 38' E, and latitudes 11^0 11N'). With an altitude of 686m above sea level. Samaru is located at the Northern Guinea Savanna (Ogunwole *et al.,*2005;USDA;2006).

3.2 Climate and Geology of the Experimental Site

3.2.1 Climate

The study was conducted in the 2007/2008 rainy season at the Institute for Agricultural Research Experimental Farms at Samaru, Zaria, which is located at latitude 11^o 11'N and longitude 7^o 38'E, with an altitude of 686m above sea level, situated in the Northern Guinea savanna (NGS) agro-ecological zone of Nigeria (Kowal and Knabe, 1972). The rainfall distribution pattern for Samaru is described as monomodal, usually reaching its peak between July – August (Uyovbisere and Lombin, 1991). Figure 4.1 show the climatic data at Samaru during the 2008 cropping season. Figures 1 – 4 shows the rainfall distribution pattern, maximum and minimum temperature, relative humidity and sunshine hours over the months in the year of study.

The mean annual rainfall of the site is about 1060mm (Owonubi *et al.,*1991), falling almost entirely within six months (May-October). Samaru is characterized by distinct wet and dry season with a monomodal rainfall distribution pattern, with a peak in July/August (Kowal and Knabe, 1972). The mean temperature of the growing period is

25^{o}C and the mean temperature of coolest month is 12.8^{o}C (Chude *et al.,* 2001).The region is characterized by two seasons; the first comprising of cold dry period otherwise known as the harmatan (November- December) and hot dry period in April- June, as well as warm rainy seasons (July-September).High relative humidity prevails during the rainy season. It has a Northern Guinea Savanna vegetation of grasslands and woodlands (Jones and Wild, 1975).

3.2.2 Geology and soil type

The soils of the study area have been classified as Alfisol in the USDA soil classification system. The main soil subgroup is Typic Halplustalf, USDA (Soil Survey Staff, 2003) and as Orthic Acrisol by the FAO legend (Valette and Ibanga, 1984). These soils were formed on the drift materials overlying the basement complex rocks (Jones and Wild, 1975). These soils were found to be coarse textured, having low organic matter content, total nitrogen and available phosphorus, but moderate in exchangeable bases (Ca, Mg, Na and K). The soils were also characterized by cation exchange capacity (CEC), poorly structured and the dominant clay type of the Northern Guinea Savanna is kaolinite (Harpstead, 1973).

Figure 1-4 shows the rainfall distribution pattern, maximum and minimum temperature , relative humidity and sunshine hours over the months in the year of study. Generally, rainfall could be fairly continuous from the second decade of October (Appendix1).

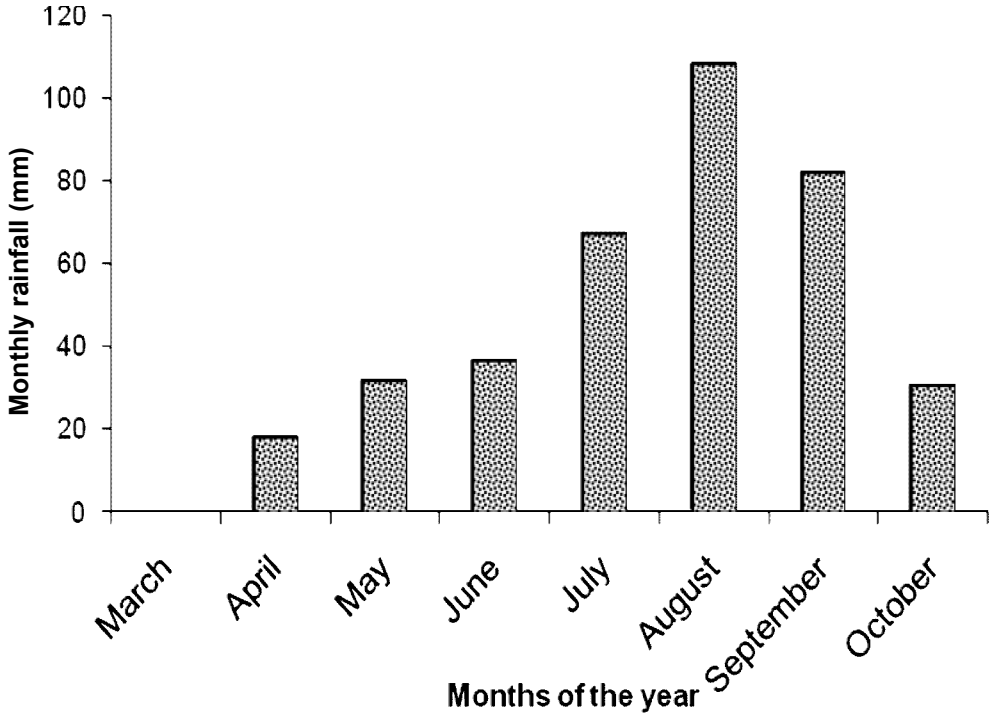

Figure 1: Mean monthly rainfall of the study location for the year 2008

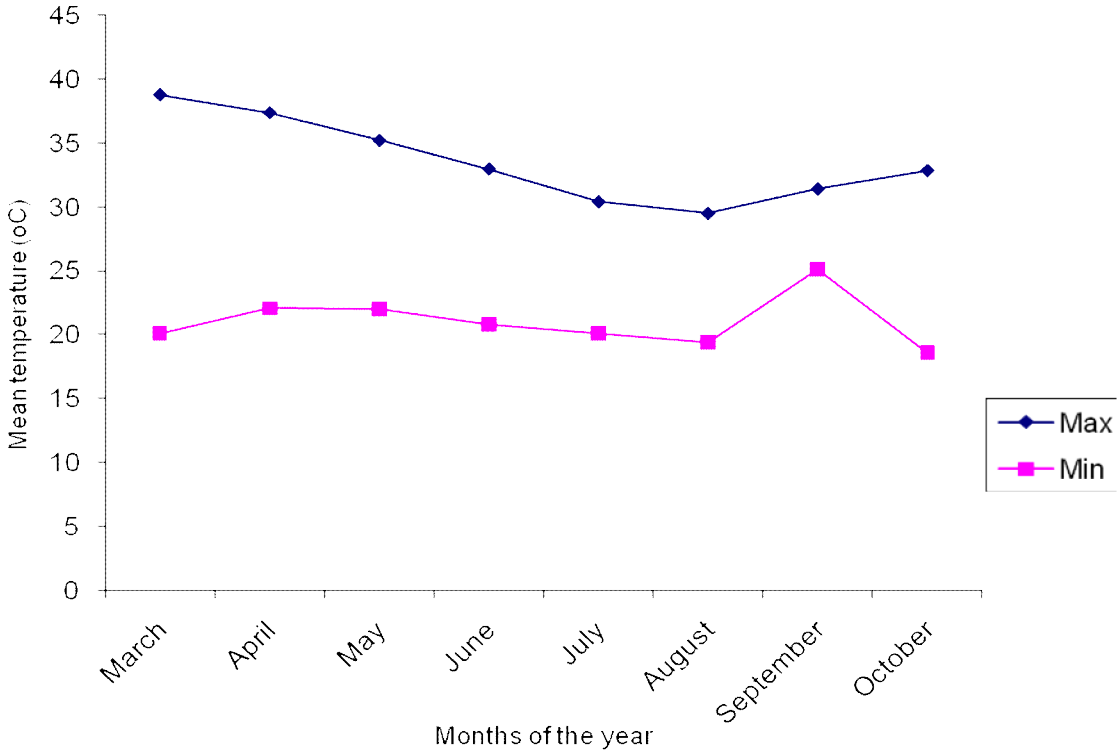

Figure 2: Mean temperature of the study location for the year 2008

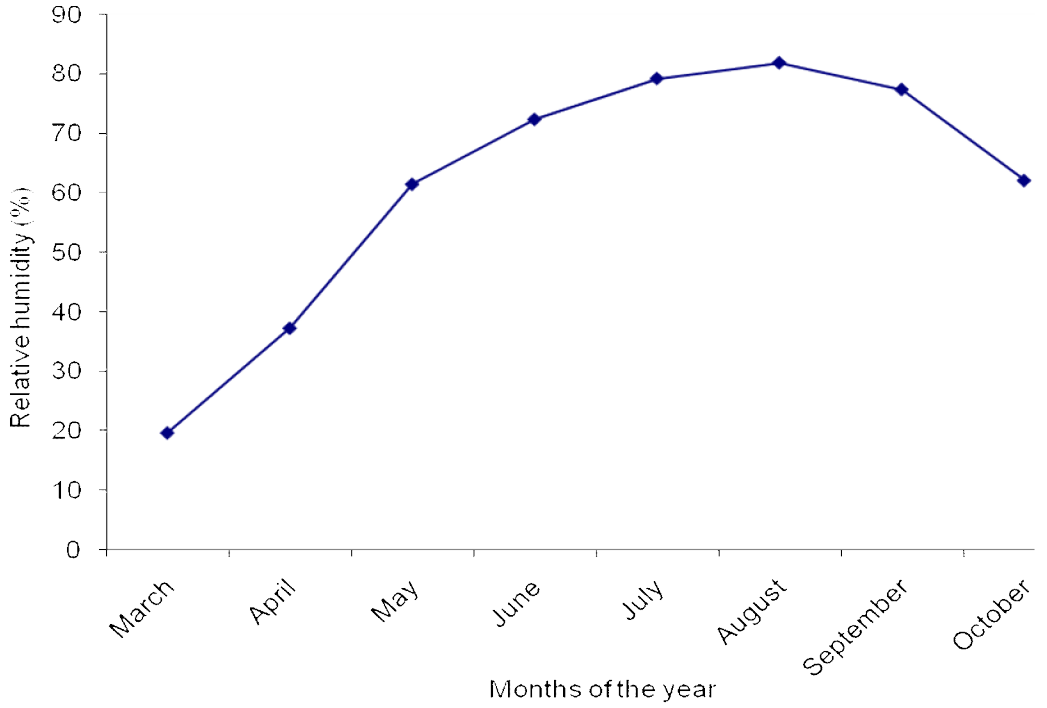

Figure 3: Mean relative humidity of the study location for the year 2008

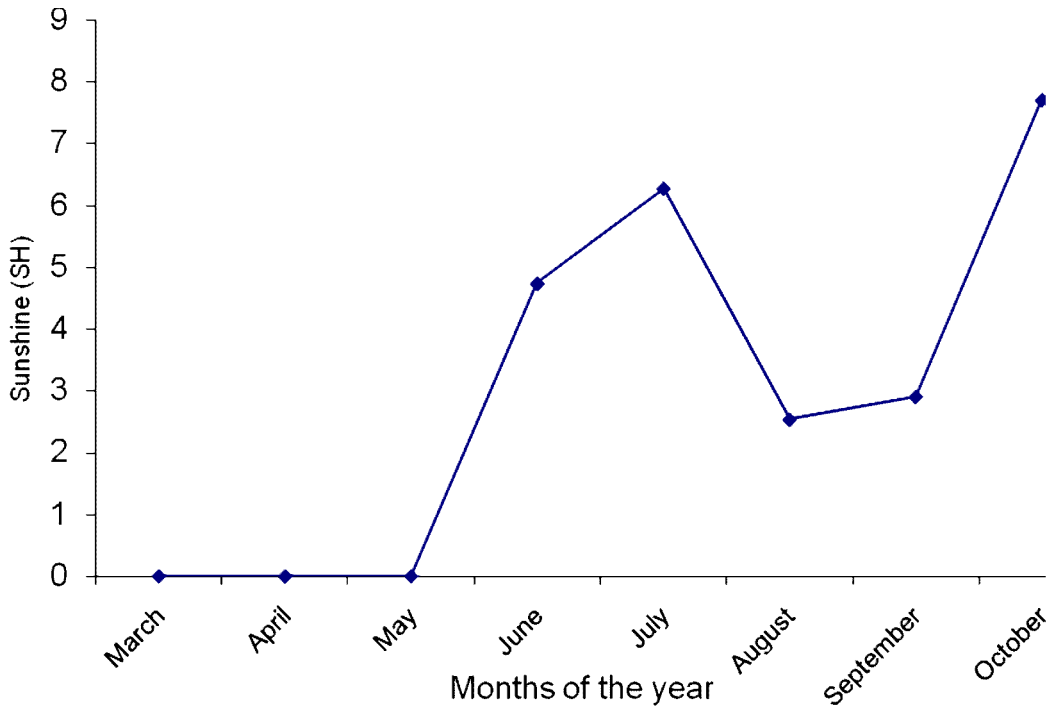

Figure 4: Mean Sunshine hours of the study location for the year 2008

3.3 Soil Sampling, Preparation and Handling

To achieve the objectives of the study, one green house experiment and one field trial were conducted on an Alfisol at the experiment farm of the IAR at Samaru in the Northern Guinea Savanna of Nigeria. The soil used for the greenhouse experiment was collected from a fallow plot of over 5 years from the surface soil at a depth 0 - 20cm within the IAR Experimental farms, Ahmadu Bello University, Samaru Zaria. The soil used for the greenhouse study was at the time of sampling under bush fallow and information was received from the Farm Manager confirmed the soils as fallow soils, as there was no knowledge of recent farming activities on the site, however, the field soils had some history of cropping but have not been cropped intensively. The soil was air dried, crushed and sieved through 2mm mesh sieve. Sub-samples were taken for physical and chemical analysis.

3.4 Soil Characterization

3.4.1 Analysis of soil samples

Particle size distribution was analyzed using the standard hydrometer method as described by the Gee and Bauder (1986) methods. The sand, silt and clay fractions were dispersed using sodium hexametaphosphate as dispersant. The textural class was obtained using the International Soil Textural Triangle. Soil pH was determined in 1:2:5 soil: water ratio and also in 0.01M $CaCl_2$ suspension with a glass electrode pH meter. Available phosphorus was determined by the Bray – 1 (Bray and Kurtz, 1945) and Olsen methods (Olsen and Somers, 1982). Organic carbon was determined by the wet oxidation method of Walkey and Black as described by Juo (1979). Total P was determined by the

acid digestion method using the triple acid mixture (Juo, 1979). The total N was determined by the micro-kjeldahl distillation procedure (Bremner, 1965). Exchangeable acidity was determined by shaking the soil with IN KCl and titrating with 0.5N NaOH as described by Juo (1979). Exchangeable bases were extracted with IN NH_4OAC buffered at pH 7 (Kudensen *et al.*, 1982). Sodium and potassium in extract were determined by flame emission photometer, while Ca, Mg and micronutrients were determined by the atomic absorption spectrophotometer (AAS). The effective cation exchange capacity (ECEC) was determined by summation of exchangeable acidity and exchangeable bases (EA + EB).

3.5 Greenhouse Study

The relationship between yield, Mo treatments and soil properties were obtained by carrying out a green house experiment using the soil collected from the IAR Experimental Farms, Samaru, Zaria.

3.5.1 Treatments and experimental design for the green house trial

The treatments employed for the green house trial consisted of five levels of Mo soil applied (0, 100, 200, 300, and 500g. Mo/ha) and one level of Mo (200g Mo/ha) foliar applied. Phosphorus and potasium fertilizers were applied basally at planting. Two groundnut varieties (Samnut 23 and Samnut 14) and two cowpea varieties (IAR 48 and 1T95k-499-35) were used as test crops. The treatment combinations were tested in a completely randomized design and replicated three times. Phosphorus and potasium were applied as Ca HPO_4. $2H_2o$ and K_2SO_+ respectively with micronutrient Mo applied as $(NH_4)_6$ $M0_7$ $O_{24.}$ $4H_2O$.

3.5.2 Greenhouse procedure.

Four kilogram of the 2mm sieved soil was weighed into perforated plastic pots(5kg capacity). The soils were wetted to field capacity and left to incubate for one day. The plastic containers were perforated to allow for free drainage and adequate root aeration. Plastic receivers were placed under the pots to collect any drained water, which was returned back into the pots. Four seeds were sown in each pot by drilling. Two weeks after germination, the plants were thinned to two plants per pot. The Phosphorus and potasium nutrients were applied once at planting. Molybdenum was applied at planting for the soil application treatment and at four weeks after sowing the foliar was applied. The soils were maintained at field capacity through regular watering.

At the termination of the trial at eight weeks, the above ground part of the plant (2 cm from the soil) was harvested for dry matter estimation. The plant biomass yield was weighed while fresh. It was rinsed with distilled water, placed in an envelope and then dried in an oven at 65^{o}C for 48 hours to constant weight. The oven dried biomass was weighed and values were recorded.

3.6 Green house measurements

Parameters collected from the greenhouse trial included nodules which were detached from the root of the harvested plants and washed to remove soil particles. The nodules were then counted and the numbers recorded.

3.6.1 Nodule number and dry weight per plant (g)

At harvest, the roots were separated from the soil and the nodules were detached from the roots of the sampled plants, washed and cleared of soil particles. The detached

nodules were counted and the numbers recorded. The nodules were kept in an envelop and oven dried at 65 ^{o}C , weighed and recorded.

3.6.2 Fresh and dry biomass weight

The harvested biomass at the termination of the trial was weighed fresh, oven dried at 65 ^{o}C and the dry biomass weight was taken and recorded.

3.6.3 Grain yield (greenhouse) determination

At termination of the trial at 8 weeks, the groundnut and cowpea pods were both harvested by handpicking. These were then counted ,recorded and kept in a polythene bag, labeled and air dried. The weight was taken using a mettler balance.

3.6.4 Dry weight of pods

Pods of both groundnut and cowpea were handpicked from the harvested plants, packed in a polythene bag, labeled and air dried. The weight was taken using a mettler balance.

3.6.5 Analysis of grain samples

3.6.5.1 Grain analysis

The air dried seeds of both the groundnut and cowpea genotypes were processed for analysis. The seeds were ground with a stainless steel mortar and was packed into a polythene bags ands labeled for chemical analysis .

3.6.5.2 Chemical analysis of the grain

The ground grain samples were analyzed for the major elements and micronutrients. Ground grains were digested with a mixture of nitric acid (NO_3), sulphuric acid (H_2SO_4) and perchloric acid ($HClO_4$) on a hot plate (Juo, 1979). The

amount of K in the digest was determined using flame photometer while the of Mg and Ca contents were analyzed using the AAS (Perkin Elmer model 403) . Total N was determined by the micro-Kjeldahl method (Bremner and Mulvaney, 1982). The micronutrient analysis including Cu, Zn, Fe and Mo were determined as described by Juo (1979).

3.7 FIELD STUDY

3.7.1 Experimental site

The response of groundnut and cowpea to Mo rate was evaluated in the field . The site was field S12A Experimental plot of the Institute for Agricultural Research Farm, Samaru, Zaria.

3.8 Treatment, design and cultural practices

3.8.1 Cultural practices

The experimental field was prepared by plowing, harrowing, ridging and marking out of the plots. Soil sample was randomly taken with an auger from each plot a two depths: 0 – 15 cm and 15 – 30 cm. Composite samples were taken at the onset of the trial and from each plot at harvest. This was obtained by bulking five sample points from each plant. The samples were then air dried, crushed and sieved using the 2mm mesh sieve. The sampled soils were characterized as carried out for the green house experiment(3.4).

The land was ploughed, harrowed and ridged at 75 cm row spacing. The trial was laid out in plot sizes of 3m by 4 m (4 ridges x 5m length). Four seeds were sown in hill placement(dribbling) with a spacing of 25 cm for groundnut and 40 cm for cowpea. The groundnut and cowpea seedling were thinned to two plants per stand and were weeded twice. The weeds were kept under control by initially applying a pre-emergence

herbicide Round up, at two weeks before land preparation and Grammazone herbicide one day after planting. The crop was sprayed with Cyper-diforce (insecticide) and benlate (fungicide) against white fly, *Bemisia tabaci* and aphids particularly.

The groundnut was harvested by lifting and handpicking, while the cowpea was picked at maturity.

3.8.2 Design

The experiment was laid out in a split plot design with three replications. Crop varieties were the main plots, and Mo levels and methods were sub plots.

3.8.3 Treatment

The treatment for the field study consisted of 5 levels of Mo (soil applied) and one level of Mo (200 g/ha) foliar applied. Phosphorus and potasium fertilizers were applied at planting. Two varieties each of groundnut (SAMNUT 23 and 14) and cowpea (IAR 48 and IT95K-499-35) were used as test crops as was done in the greenhouse experiment.

The total number of treatments were twenty-four giving total plot number of seventy two. Molybdenum was applied to soil at planting, and applied by foliar at four weeks after sowing using $(NH_4)_6Mo_7O_{24}.4H_2O$ as the Mo fertilizer source. Phosphorus and potasium were applied as SSP and MOP fertilizers respectively.

3.8.4 Agronomic evaluation of the field plants by destructive sampling

At 8 weeks after planting, two plants per plot were selected randomly and sampled by uprooting whole plant. The destructive sampling was designed to evaluate the effect of Mo levels and method of application on the performance of the plant

genotypes at the stage when nodule formation was optimal for the plants, and the nodules can be adjudged to be most active.

The plants were uprooted and the roots washed free of soil with deionised water. The fresh weights were then taken. The cowpea pods and groundnut pods were then removed from the plants and weights recorded. The root containing, the nodules were then separated from the above ground plants. The above ground parts were then weighed again and oven dried at 65^{o} C for 3 days.

The root component and the nodules were separated. The nodules and root only were then weighed fresh and the nodules counted. The roots and nodules were then oven dried for 3 days.

3.8.4.1 Fresh and dry biomass weight

The above ground parts of the harvested plants were enveloped and labeled, these parts were oven dried at 65^{o} C and the dry biomass weight was taken and recorded.

3.8.4.2 Root weight

The harvested plants roots which were separated using the razor blade as presented above, had the nodules removed. The roots were weighed then weighed fresh, recorded and placed in an envelopes which were labeled and dried in an oven to a constant temperature at 65^{0}c. The weights were taken again when dry.

3.8.4.3 Nodule number and nodule weight

The nodules which were detached from the roots of sampled plants, and washed cleaned of soil particles, were weighed fresh, counted and number recorded counted and placed in envelopes labeled and oven dried at 65^{o} C. The nodules were weighed and recorded to obtain the nodule dry weight.

3.8.4.4 Grain yield

At 8 weeks, the groundnut and cowpea plants that were sampled had developing and developed pods removed by handpicking. These were then counted, recorded and kept in a polythene bag, labeled and was air dried. The weights were taken using a mettler balance.

3.8.5 Measurement at field harvest (maturity)

At physiological maturity that is when the groundnut pegs were fully matured and the groundnut pods were dried, the crops were harvested. The groundnut crops were lifted and allowed to dry for a day or two. For the cowpea crop, the pods were harvested at two pickings.

3.8.5.1 Weight of harvested pods

The groundnut pods were handpicked, and shaken and after lifting and allowed to stay on field overnight, and then shaken dry of sand particles and then weighed and recorded. Equally, the cowpea pods were weighed at each recorded.

3.8.5.2 Threshed weight

The groundnut pods and the cowpea pods were threshed and weight of threshed seeds per plot recorded.

3.8.5.3 Haulm weight

The partially dried biomass of the groundnut were estimated for each plot. These were collected at maturity after harvest and weighed fresh, and then placed in envelopes and oven dried at 65^{o} C to obtain a dry haulm weight per plot.

3.8.5.5 Laboratory Analysis

This involved soil and grain analysis as described in section 3.41 above and 3.5.4.2 respectively.

3.9 Statistical Analysis

All data obtained were subjected to statistical analysis of variance (ANOVA) to test the treatment effects for significance as described by Snedecor and Cochran (1967). Significant difference between treatment means were compared using Duncan's Multiple Range Test (DMRT). Correlation analysis was done on appropriate parameters to determine the relationship between treatment and nodule count and also a nodule count and yield. Regression analysis was carried out on Mo rate versus content in grain (uptake).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Characteristics of Soils Used for the Study

The soils used for the greenhouse and field trials were characterized for their physical and chemical properties. The physical and chemical characteristics of the soils are shown in Table 4.1. The soil was silt loam with 10.80% and 10.88% clay content in greenhouse and field top soils respectively. Very fine sand to silt size fractions seem to have been dominant in the soils.

4.1.1 Greenhouse soil

The soils were generally slightly acidic with average pH(H_2O) value of 6.20 and pH($CaCl_2$) value of 4.77. The pH value was lower in $CaCl_2$ suspension, indicating that the net charge in the colloidal complex was negative, which is desired for fertile soil (Balasubramanian *et al.,*1984).The results obtained correspond to some earlier works on the Nigeria Savanna soils (Jones,1972; Esu, 1991) organic carbon content (1.16%) and nitrogen content of the soil (0.03%) were low. Extractable phosphorus was moderate (7.88mg/kg) and effective cation exchange capacity was also low (2.29 cmol /kg), with calcium dominating the exchange complex. Micronutrient contents estimated seemed to indicate moderate amounts, and can be said to be moderately fertile.

4.1.2 Field soil

The soil was generally slightly acidic with average pH values of 6.17 and 5.95 in the top and sub soils respectively. The field soil texture was also classified as silt loam based on particle size distribution (Table 4.2). The mean pH (H_2O) was slightly acidic with a value of 6.06 and organic carbon (0.43%) and nitrogen contents (0.07%) of the

Table 4.1: Chemical and physical properties of the soils used for the study

Parameters	**Green house (0-20)**	**Field (IAR Field Site 12A)**	
		0 – 15	**15 – 30**
Sand (%)	43.12	44.45	43.12
Silt (%)	46.00	44.66	41.70
Clay (%)	10.80	10.88	13.48
Texture	Silt loam	Silt loam	Silt loam
pH (H_2O) 1:2.5	6.20	6.17	5.95
pH ($CaCl_2$) 1:2.5	4.77	5.07	4.95
Organic carbon (%)	1.16	0.50	0.35
Total Nitrogen (%)	0.03	0.03	0.10
Available P (mg/kg)	7.88	7.00	6.42
Electrical cond. (dsm^{-1})	0.22	0.21	0.24
Exchangeable acidity (C mol/kg)	0.36	0.57	0.59
Exchangeable based (C mol/kg)			
Ca	2.33	1.83	1.80
Mg	1.18	0.92	1.80
K	0.28	0.23	0.15
Na	0.43	0.39	0.45
Effective CEC (C mol/kg)	2.29	3.35	4.16
Extractable Zn (mg/kg)	361.64	268.66	286.34
“ Fe (mg/kg)	1111	999.9	333.25
“ Cu (mg/kg)	0.83	1.33	0.75
“ Mo (mg/kg)	7.50	7.17	9.38

Table 4.2: Effects of Mo levels and methods of application on nodule count, nodule weight and root weight for the groundnut and cowpea genotypes in the greenhouse study

Treat. No	Mo rate method (g/ha)	Groundnut						Cowpea					
		Nodule count (g)		Nodule weight (g)		Root weight (g)		Nodule count (g)		Nodule weight (g)		Root weight (g)	
		Sam 23	Sam 14	Sam 23	Sam 14	Sam 23	Sam 14	IAR 48	IT95 K	IAR 48	IT95 K	IAR 48	IT95K
1	0 soil	49.3	132.0	0.17	0.46	1.74	2.08	28.6	26.6	0.18	0.32	1.21	0.97
2	100 soil	51.6	134.3	0.25	0.37	1.39	2.06	56.0	20.0	0.40	0.16	0.99	0.82
3	200 soil	73.3	135.6	0.29	0.37	1.32	2.02	54.3	29.6	0.32	0.20	1.63	0.90
4	300 soil	42.3	70.6	0.14	0.28	1.04	1.86	37.3	33.6	0.25	0.26	1.27	1.02
5	500 soil	39.0	80.0	0.29	0.39	1.23	2.17	37.0	23.6	0.30	0.13	0.98	0.87
6	200 foliar	65.6	69.0	0.39	0.28	1.89	2.73	47.0	23.3	0.28	0.31	1.27	0.89
Mean		42.6	103.6	0.26	0.36	1.44	2.15	43.2	26.1	0.3	0.23	1.23	0.91
SE±0.05		16.76		0.06		0.27		6.02		0.08		0.15	
CV		52.2		50.6		37.3		42.1		43.9		33.1	
R^2		0.53		0.44		0.52		0.50		0.45		0.39	

Where:

Mo rate = Molybdenum rate

soil were low. Extractable phosphorus (6.71mg/kg) was moderate and effective cation exchange capacity (3.76cmol/kg) was low, with calcium also dominating the exchange complex. Micronutrient content indicated moderate amounts and hence fertility of soil can be termed moderate.

4.1.3 General fertility status of the soils

The pH of the soil measured in 0.01M $CaCl_2$ and water (H_2O) indicated moderate to mild acidity. This is typical of savanna soils with pH range of 4 – 6.5 (Jones and Wild, 1975). Organic carbon (OC) content of the soil was low (1.16%), characteristic of savanna ecology due to low density of vegetation, rapid decomposition of organic matter, sandy nature of the soil and annual burning of vegetation.

Electrical conductivity and cation exchange capacity (CEC) were also low (Table 4.2). The low electrical conductivity (EC) indicated low salt content and acute leaching, while the low CEC was expected as the soil is dominated by low activity clay and its organic carbon content was low. The Total nitrogen (TN) content of the soils ranged from 0.03% - 0.10%, with a mean value of 0.07. This low value was closely linked with low organic matter content of the soils which is typical of tropical savanna soils (Jones and Wild, 1975). Micronutrient contents of the soils were determined as an index to further evaluate the fertility of the soils. Results are shown in Table 4.1. The micronutrient values were found to be low in the soils, and have been reported to be deficient in most savanna soils (Harkness *et al.*, 1976).

Calcium (Ca) was the dominant exchangeable cation of the basic cations as characteristic of savanna soils. Magnesium ranked next to calcium as the most abundant on the exchange complex with a mean of 1.36 c mol kg^{-1}. This values show that fertility

rating for exchangeable Mg was medium. The potassium fertility status of the soil was rated medium to high with a mean of 0.19 c mol/kg. The average range of soil K values for the Nigeria savanna soils is 0.5 – 0.25 c mol/kg and this is rated as medium. Values greater than 0.3 c mol/kg are regarded as high (Jones and Wild, 1975). As may be expected for good arable soil, the sodium (Na) content was generally low for the soils. The dispersive property of Na in soils is well known and will render soils unfit for good agricultural practice (Tisdale and Nelson, 1975).

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

4.2 GREEN HOUSE STUDIES

4.2.1 Effects of Mo levels and methods of application on agronomic parameters in the greenhouse study

The effects of treatments (Mo levels and methods of application) on nodule count, nodule weight and root weight for groundnut and cowpea genotypes are shown in Table 4.2.

4.2.1.1 Groundnut

Nodule count for groundnut crop increased for both SAMNUT 23 and SAMNUT 14 consistently up to 200 g Mo/ha soil applied and decreased significantly at higher levels of soil applied Mo. Comparatively, foliar applied Mo at 200 g/ha was consistently inferior for both genotypes of groundnut at the same level of Mo. Though, nodule weight was twice as high for SAMNUT 14 compared to SAMNUT 23, SAMNUT 23 responded more appreciably to Mo application. Nodule count mean values were 42.6 and 103.6 for

SAMNUT 23 and SAMNUT 14 respectively. Though the factor of toxicity may not be implicated at the higher levels of Mo application, 200 g/ha Mo soil applied seemed adequate for both varieties of groundnut. The effects of treatment on root weight for groundnut, revealed decreasing root weight with increasing levels of Mo application, soil applied. It may be inferred that root weight increase could be a response to nutrient deficiency especially in instances of Mo and N deficiency. This was further emphasized by the foliar applied Mo which seemed to stimulate greater root weight than soil applied Mo. The relevance of Mo in the nutrition of groundnut seemed to have been demonstrated.

4.2.1.2 Cowpea

The effects of Mo levels and method of application on nodule count in cowpea seemed to reveal similar trend as it was for groundnut (Table 4.2). However, both varieties responded differently. Nodule count increased up to the first level of Mo soil applied at 100 g/ha for IAR 48, but increased up to 300 g Mo/ha for IT95K, though responses were not significant. With respect to nodule weight, similar trend was observed for IAR 48 as response was only up to the first level of soil applied Mo and foliar applied Mo was inferior to Mo soil applied for IAR 48. With respect to IT95K, nodule weight decreased with increase in level of Mo, though erratically. Foliar applied Mo seemed to have stimulated high value for IT95K. Root weight increased up to 200g Mo/ha and 300g Mo/ha for IAR 48 and IT95K respectively. Foliar applied Mo was still inferior to soil applied Mo in both circumstances. Mean values of root weight was 1.23 g/pots and 0.91 g/pots respectively for both varieties. It seems from the results that there was higher Mo requirement for root weight expression.

Table 4.3: Effect of Mo levels and methods of application on yield parameters (pod weight, grain yield and dry matter yield) in the greenhouse

Treatment No	Mo rate method (g/ha)	Groundnut					
		DMY(g)		Pod wt(g)		Grain yield(g)	
		Sam 23	Sam 14	Sam 23	Sam 14	Sam 23	Sam 14
1	0 soil	6.81	6.40	2.19	1.97	39.6	47.3
2	100 soil	8.00	11.2	1.54	2.33	38.3	37.6
3	200 soil	7.27	9.90	2.90	2.92	42.6	53.5
4	300 soil	8.57	11.1	2.33	1.78	21.6	53.5
5	500 soil	10.3	10.2	1.25	1.20	30.3	37.6
6	200 foliar	16.6	8.49	2.16	1.27	57.0	38.6
Mean		9.60	9.50	2.06	1.91	38.2	44.7
SE		0.93		0.50		5.30	
CV		23.8		61.3		30.8	
R^2		0.71		0.28		0.50	

Where:
Mo rate = Molybdenum rate

Table 4.4: Effect of Mo levels and methods of application on yield parameters (pod weight, grain yield and dry matter yield) in the greenhouse

Treatment No	Mo rate method (g/ha)	Cowpea					
		DMY (g/pot)		Pod wt (g/pot)		Grain yield(g/pot)	
		IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K
1	0 soil	7.51	6.01	1.70	2.47	40.0	42.0
2	100 soil	8.75	8.74	0.84	3.60	32.6	41.6
3	200 soil	9.00	10.6	1.99	2.70	41.6	43.6
4	300 soil	12.9	19.56	1.27	2.15	49.6	39.0
5	500 soil	13.6	10.7	1.17	1.59	36.6	46.0
6	200 foliar	.50	8.70	0.74	1.12	35.3	33.6
Mean		10.2	10.72	1.29	2.27	39.3	41.0
SE		30.86		0.40		3.86	
CV		36.7		59.8		23.5	
R^2		0.44		0.48		0.32	

Where:
Mo rate = Molybdenum rate

From this result, it was noted that root development was in response to nutrient deficiency as it was observed for groundnut. Deriving a suitable level of Mo would therefore ensure good nutrition of grain legumes which could impact on a good crop yield.

4.2.2 Effects of Mo Levels and Methods of application on Dry Matter Yield and Yield Related Parameters in the Greenhouse

The effects of Mo levels and methods on yield related parameters, including pod weight, grain yield and dry matter yield in the greenhouse are shown in Table 4.3.

4.2.2.1 Groundnut

After eight weeks of greenhouse experimentation, response of groundnut dry matter yield to Mo application was highly significant (P = 0.018). Though, there were no differences between the two varieties in response to treatments, the interaction between the Mo levels and groundnut genotypes was highly significant (P = 0.001). But the response of SAMNUT 23 was only up to the first level of Mo soil applied (100g Mo/ha), and foliar application was significantly superior to soil applied at similar levels of Mo application, with dry matter values of 7.27 g per pots for soil applied and 16.0 g for foliar applied at 200g Mo/ha. This could be as a result of rapid utilization of nutrients and correction of observed deficiencies in less time than would be obtain by soil application (Highnett, 1971). SAMNUT 14 showed more dramatic response, with yield values increasing up to 200 g Mo soil applied and the efficiency of foliar Mo applied was equally comparable to soil applied in this case. From this result, we can infer that response and reaction of groundnut to Mo could differ as influenced by the various genotypes of groundnut. The efficiency of foliar applied nutrients to SAMNUT 23 was apparent in this study.

Mean values for groundnut pod weight for both genotypes were 2.06 and 1.91g per pods for SAMNUT 23 and SAMNUT 14 respectively. The mean yield values did not increase significantly for both genotypes, and were not significantly different as influenced by levels of applied Mo. Foliar applied Mo was consistently inferior to soil applied indicating that other factors may have been at play in the high dry matter yield value for the foliar applied Mo was obtained for SAMNUT 23 as earlier stated.

Grain yield followed similar pattern as with the pod yield, with mean value for both genotypes of groundnut being 38.2g and 44.7g per pot respectively for SAMNUT 23 and SAMNUT 14. Some of the factors which might have influenced the variation in yield parameter in SAMNUT 23 were also reflected in the grain yield, as foliar application was significantly superior to soil applied Mo, with yield levels of 57.0g and 42.6g for foliar and soil applied Mo at 200g/ha respectively. It has been shown by earlier workers that with correct application, only slight differences in yield between soil applied and foliar applied fertilizers were observed (Obakun, 1982). Nnadi and Iwuafor (1980) also stated this view when they observed that foliar (liquid) fertilizers, if used properly, would be just as good or even better than solid fertilizers. Numerically, grain yield increased substantially up to 200g Mo/ha which seemed adequate for the crop as shown in the greenhouse. Thereafter, yield decreased with increasing rate of soil applied Mo.

4.2.2.2 Cowpea

Mean dry matter yield values for cowpea genotypes are shown in Table 4.4. These were 10.2g and 10.72g per pot for IAR 48 and IT95K respectively. Dry matter yield response in cowpea increased up to 300g Mo soil applied. Foliar and soil applied methods were comparable in effect in the cowpea crop. The significant response

obtained for cowpea indicate in clear terms that the crop would still respond to higher rates of Mo, and require a good Mo management for good yield. Cowpea pod yield responded only marginally to Mo soil applied, with yield values increasing only up to the second level of Mo (200g Mo/ha) soil applied for IAR 48. Pod yield values showed that IT95K only increase to the first level of Mo applied. In both cases, foliar application was inferior to soil application. This pattern of response was reflected in the ensuring grain yield of both cowpea genotypes. ANOVA data indicated that both varieties responded differently to Mo treatments and grain yield values were best at 300g/ha for IAR 48 and 200g for IT95K. Mean grain yield values for the cowpea variations were 39.3g per pot and 41.0g per pot for IAR 48 and IT95K respectively.

It is pertinent to note from this data that though the groundnut and cowpea crops may have responded differently, the need for Mo application to soil as a crop management strategies was clearly shown by the response data obtained in the study. The most significant response to Mo application was groundnut grain yield with an R^2 value of 0.71.

4.2.3 Effects of Mo Levels and methods of application on Soil Properties in the green house study

The effects of treatments on soil pH, organic carbon, total nitrogen, available phosphorus and total phosphorus are shown in Table 4.5.

Table 4.5: Effect of Mo levels and methods of application on some soil parameters in the greenhouse study

Groundnut

Treat. No	Mo rate method (g/ha)	pH H_2O		pH $CaCl_2$		Org. C(%)		Total N(%)		Av. P $mgkg^{-1}$		Total P(%)	
		Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14
1	0 soil	5.63	5.73	5.33	5.23	1.18	1.26	0.06	009	4.66	7.00	38.8	42.9
2	100 soil	5.23	5.70	5.33	5.43	1.27	1.24	0.09	0.06	5.68	8.16	50.3	44.9
3	200 soil	5.33	5.66	5.33	5.43	1.27	1.30	0.13	0.07	5.25	6.26	53.9	45.0
4	300 soil	5.63	5.86	5.16	5.40	1.39	1.29	0.08	0.07	5.83	6.41	42.7	45.0
5	500 soil	5.73	5.70	5.20	5.23	1.25	1.23	0.08	0.07	6.41	7.00	41.9	55.0
6	200 foliar	5.60	5.40	5.16	5.30	1.30	1.26	0.09	0.07	7.75	6.41	45.8	44.5
Mean		5.53	5.68	5.25	5.33	1.28	1.26	0.08	0.07	5.93	6.87	45.6	46.2
SE		0.09		0.11		0.04		0.008		0.70		1.75	
CV		4.07		4.90		0.48		24.6		26.8		9.31	
R^2		0.84		0.84		0.48		0.56		0.49		0.73	

Cowpea

Treat. No.	Mo rate method (g/ha)	pH H_2O		pH $CaCl_2$		Org. C(%)		Total N(%)		Av. P $mgkg^{-1}$		Total P(%)	
		IAR 48	IT95K	IAR 48	IT95 K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K
1	0 soil	5.23	5.73	5.53	5.30	1.30	1.24	0.07	0.06	6.33	3.50	43.6	42.4
2	100 soil	5.36	5.90	5.73	5.16	1.24	1.27	0.07	0.07	5.83	3.50	47.5	37.3
3	200 soil	5.43	5.66	5.76	5.23	1.26	1.37	0.07	0.09	5.25	2.33	42.4	57.6
4	300 soil	5.50	5.66	5.10	5.10	1.49	1.32	0.10	0.09	4.66	2.91	53.6	43.7
5	500 soil	5.30	5.53	5.70	5.10	1.22	1.31	0.10	0.08	5.25	3.50	48.9	55.2
6	200 foliar	5.13	5.80	5.70	5.10	1.26	1.30	0.07	0.09	5.83	7.00	60.4	38.6
Mean		5.33	5.71	5.59	5.17	1.30	1.30	0.08	0.08	5.48	3.79	49.4	45.8
SE		0.16		0.14		0.04		0.01		0.70		1.19	
CV		7.23		6.30		0.48		29.2		36.8		10.6	
R^2		0.71		0.76		0.48		0.29		0.55		0.76	

Where:

Mo rate = Molybdenum rate

4.2.3.1 Soil pH

Cultivation effects seemed to have reduced the soil pH for both crops, and this was more so for pH (H_2O). Mean values for the groundnut genotypes were 5.53 and 5.68 for SAMNUT 23 and SAMNUT 14 respectively and 5.33 and 5.71 for IAR 48 and IT95K respectively. The pre-cropping soil pH values were found to be higher than that of the cropped soils. This showed that the crop species and genotypes had high nutrient uptake efficiency, especially for the basic cations and so resulted in greater absorption of the basic nutrients (Fageria *et al.*, 1990).

Mean values were significantly different for all factor of variation considered for pH ($CaCl_2$) for the groundnut crops. However, pH differences in H_2O seemed to show that both varieties of each crop responded differently as mean pH values in H_2O were significantly different as affected by Mo rate and method of application.

4.2.3.2 Organic Carbon

Mean effects of treatment on soil organic carbon content was not significantly different in both crops. Both cowpea and groundnut genotypes influenced soil organic carbon content similarly, with mean organic C contents of 1.17% for the groundnut and 1.30% for the cowpea crop. Results showed that organic carbon content was appreciably increased with increasing levels of Mo application up to 300g Mo/ha soil applied for both crops. Though, the mean values were not significantly different, the accretion of soil organic carbon in both crop conditions (under cowpea and groundnut crops) indicated that Mo could improve the soil organic carbon content under good management practices, by such biological activities like N-fixation, nodule formation and deposition of organic substrates during the process of N-fixation and immobilization of soil nutrients by the

soil biota. Values were as high as 1.39% in groundnut and 1.49% in cowpea compared with 1.16% observed in the pre-cropped soils, an average increase of organic carbon of 24.1%.

4.2.3.3 Total Nitrogen

The influence of treatments on soil nitrogen content was not significant for the cowpea crops for all factors considered. However, the effects of crop variety of the groundnut genotypes were highly significant in influencing differences in soil N level (Pr = 0.03). This indicated that both varieties of groundnut were different in their capacity to influence N-fixing properties of the soil. The most efficient of the groundnut genotypes considered was SAMNUT 23, with significant increase in N levels, increasing up to 200g Mo/ha. The effect of N treatment in the soils were however not dramatic for the genotypes on general consideration.

4.2.3.4 Available phosphorus (AVP)

Soil AVP values were significantly influenced by cowpea genotypes, but not by groundnut genotypes as was the case for nitrogen. Results showed that there were appreciable depletion of soil AVP especially in the cowpea crop. Mean soil AVP values were 5.93 and 6.87 mg/kg for SAMNUT 23 and SAMNUT 14 respectively and 5.48 and 3.79 mg/kg for IAR 48 and IT95K respectively. The available P status of savanna soils is a function of P content of the parent materials, which is low for most soils of the NGS (Jones and Wild, 1975). Despite the initial blanket application of P, this level of depletion indicated that more P is required for the management of grain legumes and for good crop yield. Values were even as low as 3.79 mg/kg for IT95K indicating extreme level of P depletion by crop uptake. In all cases, foliar application seemed to ensure

better management of P in soil than soil applied Mo. However, this level of depletion could be due to immobilization by the soil microbial population associated with N-fixing process, but this has to be verified.

4.2.3.5 Total Phosphorus (TP)

The soil total phosphorus values were significantly influenced by both crops under the specified treatments (Mo levels and methods, Table 4.5). The pre-cropping soil data shown in Table 4.1 was low in phosphorus. This indicated that the soil responded to applied P. This is in consonance with the work of Juo (1982). The effects of Mo levels for groundnut was only marginally significant (Pr = 0.07) but the effect of Mo rates and genotypes for groundnut was highly significant (Pr = 0.001). For the cowpea crop, the effects were highly significant at all levels (Mo rates Pr = 0.015, genotypes Pr = 0.014, and interaction Pr = 0.0002). We can infer from this study that P utilization of both crop varieties were not fully accounted for by the AVP fraction. This indicated that different pools of P may have contributed to the P nutrition of the crops, especially the organic fraction that has a strong influence in the dynamics of soil P, which tends to show also that P fertilization of grain legumes in NGS need to be looked at more critically if optimum yield levels are to be obtained. The mean total P values of soils under cowpea was 47.2 mg/kg and for the groundnut crop, mean soil Total P content was 45.9 mg/kg.

4.2.3.6 Exchangeable Basic Cations

The effects of Mo levels and methods on soil exchangeable bases, exchangeable acidity and electrical conductivity (EC) are shown in Table 4.6.

Calcium was the dominant exchangeable cation in all the soil studied. This is expected being the most abundant exchangeable basic cation in savanna soils.

Table 4.6: Effect of Mo levels and methods of application on exchangeable bases, Exchangeable Acidity(EA) and Electrical Conductivity (EC) in the greenhouse study

Groundnut

Treat. No.	Mo rate method (g/ha)	Ex Ca(c mo/kgl)		Ex Mg (c mol/kg)		Ex Na (c mol/kg)		Ex K(c mol/kg)		E.A(c mol/kg)		E.C(dsm^{-1})	
		Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14
1	0 soil	3.06	1.86	1.66	1.75	0.38	0.43	0.38	0.43	0.33	0.32	0.06	0.14
2	100 soil	3.26	3.13	1.68	1.51	0.46	0.48	0.46	0.43	0.34	0.32	0.07	0.15
3	200 soil	3.26	2.26	1.89	1.18	0.43	0.33	0.43	0.33	0.33	0.32	0.10	0.07
4	300 soil	2.66	3.13	1.55	1.73	0.36	0.45	0.36	0.45	0.32	0.33	0.06	0.12
5	500 soil	3.00	3.40	1.52	1.75	0.39	0.34	0.39	0.34	0.34	0.32	0.05	0.09
6	200 foliar	3.53	2.80	1.76	1.55	0.34	0.46	0.34	0.46	0.33	0.33	0.07	0.11
Mean		3.13	2.76	1.68	1.58	0.39	0.42	0.39	0.41	0.33	0.32	0.07	0.11
SE		0.40		0.14		0.05		0.05		1.42		0.02	
CV		33.25		21.8		28.2		28.2		10.5		62.7	
R^2		0.58		0.33		0.35		0.35		0.95		0.32	

Cowpea

Treatment No.	Mo rate method (g/ha)	Ex Ca(c mol/kg)		Ex Mg(c mol/kg)		Ex Na(c mol/kg)		Ex K (c mol/kg)		E.A (c mol/kg)		E.C(dsm^{-1})	
		IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K
1	0 soil	4.20	2.60	0.44	0.39	0.44	0.39	0.14	0.17	0.28	0.32	0.13	0.09
2	100 soil	4.40	2.33	0.45	0.47	0.45	0.47	0.16	0.20	0.29	0.31	0.40	0.13
3	200 soil	3.13	2.33	0.45	0.44	0.45	0.44	0.20	0.19	0.30	0.32	0.13	0.15
4	300 soil	3.46	2.86	0.37	0.43	0.37	0.43	0.17	0.19	0.30	0.60	0.41	0.08
5	500 soil	3.33	3.06	0.43	0.42	0.43	0.42	0.18	0.19	0.29	0.32	0.13	0.14
6	200 foliar	3.20	3.06	0.42	0.55	0.42	0.55	0.17	0.23	0.29	0.32	0.11	0.14
Mean		3.62	2.71	0.43	0.45	0.43	0.45	0.17	0.20	0.29	0.37	0.26	0.12
SE		0.24		0.05		0.05		0.02		12.80		0.17	
CV		17.9		30.4		30.4		27.8		82.5		113.7	
R^2		0.75		0.25		0.25		0.51		0.35		0.33	

Where:

Mo rate = Molybdenum rate

Mean values for Ca under groundnut were 3.13 and 2.76 c mol/kg for SAMNUT 23 and SAMNUT 14 respectively. The Ca content of the soil was not induced as indicated by the mean values, and influence by Mo methods on the Ca content was also not significantly different. However, under cowpea, the effects of genotypes was highly significant on the soil calcium content (Pr = 0.009). The influence of Mo rate on the calcium content under cowpea was also marginally significant. This meant that IAR 48 and IT95K genotypes of cowpea utilized Mo differently.

In both groundnut and cowpea genotypes, foliar application induced higher mean values of calcium, (which were 3.62 and 2.71 for both varieties respectively) for exchangeable calcium content at the level of Mo application.

With respect to the Mg content, there was practically no influence of Mo rate in the soils under groundnut and cowpea as shown by the R^2 values of 0.33 and 0.25 respectively. Mean values for Mg under groundnut were 1.68 and 1.58 c mol/kg for groundnut genotypes, SAMNUT 23 and SAMNUT 14 respectively. Cowpea values were 0.43 and 0.45 c mol/kg for IAR 48 and IT95K respectively. It was interesting to note that cowpea had a huge demand for soil Mg relative to groundnut as shown by the level of soil Mg content under both crops. It has been widely reported that plant species differ widely in their requirement for Ca and Mg (Fageria, 1984).

Mean values of exchangeable potassium was equally not significant with respect to treatments applied to both varieties, and the R^2 values were equally low for both crops, 0.35 and 0.51 cmol kg^{-1} for groundnut and cowpea crops respectively. There were no differences with respect to the K content of the cropped soils between the varieties within each crop. Similarly, exchangeable Na contents were not significantly influenced by

treatments. This was also observed for exchangeable acidity (EA) for both crops. The EC values were significantly influenced by crop variety under groundnut but not under cowpea, as both Mo rate and method did not significantly influence the EC under cowpea. Mean EC values were 0.095 dsm^{-1} for groundnut and 0.173 dsm^{-1} for cowpea. The relevance of the great disparity of the EC under both crops (groundnut and cowpea) are yet to be fully understood, but may be related to the difference in the crop nutrient uptake potential (especially cations), and the supply of soil solution nutrients from which the crops take up its nutrients. The EC of the cropped soils was shown above which appeared to be slightly lower than that obtained from the pre-cropped soil with a value of 0.22dSm^{-1} (Table 4.1). A saline soil should have EC values greater than 4dsm^{-1} (Landon, 1984). These soils may therefore be said, generally, not to be saline based on this parameter considered. In all these soil parameters (exchangeable Na, K, EA, and EC), the groundnut genotypes reacted differently as influenced by method of application. Foliar application in all instances were superior for SAMNUT 14 but the reverse was the case for SAMNUT 23. This consistency tend to tell in clear terms, that the controlling factor was the same for all parameters. Also, under cowpea, similar pattern of response was observed. In all cases, foliar application was superior to soil application under the same level of Mo application for IT95K in all the listed parameters. We can therefore infer that this controlling factor could be relevant to the processes that control the N-fixing processes, as influenced by the Mo element.

4.2.4 Effects of Mo Levels and Methods of application on Soil Micronutrients Content in the Greenhouse Study

The micronutrient elements considered in this study included; Cu, Fe, Zn and Mo. The effects of treatments on the micronutrient content in crops in the greenhouse are shown in Table 4.7.

4.2.4.1 Copper and Iron

Cu and Fe contents were not significantly influenced by Mo treatments in both crops. In these highly weathered tropical soils, it is possible that these nutrient were in good supply in the soil. However, addition of this element in fertilizer treatments in the soil resulted in depletion for Cu under both crop and accretion of Fe. Though the soil Cu content was not influenced by Mo rate and crop variety, the fact that the soil was depleted of Cu, despite addition by fertilization, showed that Cu was a relevant element in the nutrition of grain legumes.

4.2.4.2 Zinc

The effect of treatments on the Zn content of the soils was only influence by crop variety in groundnut but not in cowpea. Empirical data revealed that both varieties of each crop utilized Zn differently, though mean values were not significant for cowpea.

The mean values of soil Zn content were 240.3 mg/kg and 1024.1 mg/kg for SAMNUT 23 and SAMNUT 14 respectively, and for the cowpea crop, the mean values were 1145.3 and 261.5 for IAR 48 and IT95K varieties respectively. It can be derived from this data, that SAMNUT 23 and IT95K utilized Zn intensively. In both SAMNUT 14 and IAR 48 where Zn was not appreciably utilized, the inherent soil content of Zn can be said to be adequate for both groundnut and cowpea genotypes at the assumed optimal

Table 4.7: Effect of Mo levels and methods of application on some soil micronutrient in the greenhouse

Groundnut

Treat.	Mo rate method	Cu (mg/kg)		Fe(mg/kg)		Zn(mg/kg)		Mo(mg/kg)	
No.	(g/ha)	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14
1	0 soil	0.83	1.83	1703.5	1481.3	261.4	883.7	5.25	5.25
2	100 soil	0.66	0.50	1666.5	1148.80	275.7	968.5	6.00	7.23
3	200 soil	0.50	1.00	1555.4	2036.8	282.8	346.3	6.00	6.50
4	300 soil	0.66	0.50	1370.2	1555.4	212.1	942.3	7.00	6.50
5	500 soil	0.66	0.66	1462.8	1703.5	169.6	1504.9	7.00	7.50
6	200 foliar	0.50	0.83	1851.3	1703.5	240.3	1498.8	6.25	7.00
Mean		0.64	0.87	1601.6	1604.8	240.3	1024.1	6.25	6.67
SE		0.26		207.38		266.6		0.45	
CV		83.2		31.6		103.3		17.0	
R^2		0.35		0.55		0.56		0.67	

Cowpea

Treat.	Mo rate method	Cu(mg/kg)		Fe(mg/kg)		Zn(mg/kg)		Mo(mg/kg)	
No.	(g/ha)	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K
1	0 soil	0.66	0.83	1259.1	1185.0	876.6	162.1	5.25	5.00
2	100 soil	0.83	0.66	1370.2	1296.1	928.1	254.5	4.00	5.75
3	200 soil	0.50	1.00	1740.5	1444.3	289.8	205.0	5.25	7.29
4	300 soil	0.66	0.50	1333.2	1073.9	289.8	289.7	5.75	5.75
5	500 soil	0.66	0.66	1555.4	1148.0	275.7	247.4	5.75	6.50
6	200 foliar	1.00	0.60	1370.2	1148.0	145.3	261.5	7.00	5.25
Mean		0.71	0.7	1438.1	1215.8	585.9	236.7	5.50	5.92
SE		0.26		144.2		266.6		0.41	
CV		83.2		26.6		564.4		17.1	
R^2		0.35		0.31		0.37		0.75	

Where:

Mo rate = Molybdenum rate

level of 200g Mo/ha. This observation is pertinent, indicating that higher level of fertilization or over-fertilization of Mo could influence Zn utilization in the grain legumes. How this will impact on the grain nutrition of both crop varieties can be derived. For Zn fertilization, foliar application was not the efficient method for the application of Mo, as soil application was consistently superior for both efficient and non-efficient genotypes of cowpea (Table 4.7).

4.2.4.3 Molybdenum

The effects of treatments on the soil Mo content of the cropped soil was significant under the cowpea crop. Mean values for the groundnut genotypes were 6.25 and 6.67 mg/kg for SAMNUT 23 and SAMNUT 14 respectively. Mean values for the cowpea genotypes were 5.0 and 5.9 mg/kg for IAR 48 and IT95K respectively. The influence of cowpea varieties on soil Mo content was dramatic (Pr = 0.027 with R^2 value of 0.75 relative to 0.60 for groundnut). In both varieties of groundnut, foliar application induced higher soil Mo content, indicating lower rate of uptake from soil sources under foliar application. With respect to the cowpea crop, this observation was similar for IAR 48, but foliar application was found to induce lower Mo content relative to foliar application under IT95K. This indicated that the method of application could be critical in the utilization of Mo by grain legumes. The importance of Mo for the grain legume can be inferred from the low CV values obtained for both crop, 17.0 for groundnut and 17.1 for cowpea which is an indication that the Mo nutrient consistently influenced the nutrition of grain legumes even at the various levels of Mo applied.

4.2.5 Effect of Mo levels and methods of application on nutritional content of the grains in the greenhouse study

4.2.5.1 Total Nitrogen

The effects of Mo levels and application methods on N, P and micronutrient contents of groundnut and cowpea grains are shown in Table 4.8. Mean total N content of the grains were 6.09 and 6.07% for SAMNUT 23 and SAMNUT 14 respectively with a mean of 6.08%. For cowpea, the mean total N content was 6.37 for IAR 48 and 6.29% for IT95K, with a mean of 6.33%. The higher N content of the cowpea grain over groundnut was established. For groundnut, effects on N grain content were not significant, but effect on interaction was highly significant (Pr = 0.008).

For the cowpea crop, the effects on grain were also not significant. Response was only up to the second level of Mo rate applied, that is at 200g Mo/ha. Thereafter the levels of N in the grain decreased for both groundnut genotypes. The effectiveness of methods of application were different. Foliar application was more efficient, inducing N accumulations for SAMNUT 23 but was reverse for SAMNUT 14. For the cowpea crop, mean N content of grains increased consistently to the highest level of Mo soil applied for IAR 48 but this increment with application of Mo soil applied, was only up to 300g Mo/ha for IT95K though, not significant. Foliar application and soil application were equally efficient for the cowpea crop in inducing N-accumulation in the grain.

4.2.5.2 Total Phosphorus

The interactive total P content of the grain were significant for both crops, Pr = 0.001 for groundnut and Pr = 0.0002 for cowpea, indicating that the combined effects of Mo levels and methods were relevant for the accumulation of P in the grain.

Table 4.8: Effect of Mo levels and methods of application on Total Nitrogen(TN), Total Phosphorus(TP) and micronutrients in the greenhouse

Groundnut													
Treat. No.	Mo rate method (g/ha)	Total N %		Total P %		Iron (Fe) (mg/kg)		Copper (Cu) (mg/kg)		Mo(mg/kg)		Zn (mg/kg)	
		Sam 23	Sam 14	Sam 23	Sam 14	Sam 23	Sam 14	Sam 23	Sam 14	Sam 23	Sam 14	Sam 23	Sam 14
1	0 soil	5.72	6.02	38.8	45.05	9.62	11.4	1.66	2.33	6.75	8.00	130.7	236.8
2	100 soil	5.94	6.27	50.3	44.9	7.77	14.8	1.33	1.55	7.50	9.50	137.8	236.7
3	200 soil	6.32	6.24	53.9	42.9	5.55	10.73	1.00	1.00	7.75	8.75	141.4	303.9
4	300 soil	6.02	5.98	42.7	45.01	7.77	12.2	1.33	1.00	8.50	10.16	88.3	190.8
5	500 soil	6.02	5.98	41.9	55.0	9.62	9.99	1.33	0.66	8.50	9.16	116.6	328.7
6	200 foliar	6.53	5.95	45.8	44.5	12.5	15.18	1.00	0.83	7.91	9.00	120.1	169.6
Mean		6.09	6.07	45.6	46.2	8.81	12.38	1.28	1.29	7.82	9.10	122.5	244.4
	SE	0.10		1.75		1.52		0.27		0.57		36.49	
	CV	3.93		9.31		36.5		53.0		16.5		48.7	
	R^2	0.57		0.73		0.47		0.42		0.53		0.64	

Cowpea													
Treat. No.	Mo rate method (g/ha)	Total N %		Total P %		Iron (Fe) (mg/kg)		Copper (Cu) (mg/kg)		Mo (mg/kg)		Zn (mg/kg)	
		IAR 48	IT95K	IAR 48	IT95 K	IAR 48	IT95 K	IAR 48	IT95 K	IAR 48	IT95 K	IAR 48	IT95 K
1	0 soil	5.80	6.06	43.6	42.4	11.1	19.2	1.16	0.66	7.51	7.25	186.6	120.0
2	100 soil	6.09	6.20	47.5	37.3	13.7	12.2	1.33	0.83	8.25	8.50	252.2	123.7
3	200 soil	6.25	6.37	42.4	52.6	16.2	24.4	1.00	1.16	6.25	3.91	144.9	102.5
4	300 soil	6.49	6.47	53.6	43.7	18.8	17.7	1.16	1.00	9.00	3.25	162.6	144.9
5	500 soil	7.20	6.26	48.9	55.2	13.7	22.5	1.16	1.33	7.75	9.91	137.7	123.7
6	200 foliar	6.38	6.37	60.4	38.6	17.4	20.7	0.83	1.16	9.41	9.50	255.7	130.7
Mean		6.37	6.29	49.4	45.0	15.2	19.5	1.11	1.02	8.03	8.72	190.0	124.3
	SE	0.23		2.05		1.92		0.10		0.47		32.1	
	CV	8.78		10.6		27.7		22.8		13.7		50.0	
	R^2	0.40		0.76		0.57		0.57		0.73		0.53	

The effects of Mo rate and crop variety were not significant at 5% level of probability for groundnut but was highly significant for the cowpea crop (Pr = 0.015 for Mo rate and Pr = 0.014 for cowpea variety). Mean values of total P in the groundnut grain were 45.6 mg/kg for SAMNUT 23 and 46.2 mg/kg for SAMNUT14. Response was only up to 200 g Mo/ha for SAMNUT 23, but went up to 500g Mo/ha for SAMNUT 14. This disparity in efficiency for both varieties of groundnut would obviously translate to efficiency in the utilization of the nutrient and adequacy in P nutrition for some varieties of groundnut.

The effects of method of application of Mo on accumulation of P in the groundnut crop were different for both varieties. Foliar application was less efficient than soil application for SAMNUT 23 but the effects of method were similar for SAMNUT 14. As was indicated earlier, the effects on method was not significant and so the mean effect observed for the crop may be due to genetic differences and response of the variety to Mo.

For the cowpea crop, response to method and rate were highly significant. Significant response went up to 300g Mo/ha for IAR 48, and to the highest level of 500g Mo/ha for IT95K. Differences in efficiency of the methods were observed with the cowpea crop. Foliar application was superior at all levels of Mo application for IAR 48 but was very inferior in IT95K. It is possible to assume that there were varieties in which the accumulation of nutrients in the grain was not enhanced by foliar method of application as was observed with IT95K. Mean grain P values for groundnut was 45.93 mg/kg and that for cowpea was 47.21 mg/kg.

4.2.5.3 Micronutrient

The micronutrient contents of the grains were significantly influenced by the factors considered. For groundnut, mean values of the micronutrient contents of Fe, Zn and Mo were significant as influenced by the crop variety. However, with respect to Cu, differences in mean values were due specifically to rate of Mo application. For the cowpea crop, mean values of Cu was significant different at the level of interaction (Pr = 0.03). For Mo, the effects were only marginally significant at the level of interaction but highly significant in response to Mo rate (Pr = 0.043). For Zn, the effects of crop variety influenced differences in crop varieties in the grain. This was also the same for Fe content in the grain. The differences in accumulation of micronutrient in the grain across elements was consistent for the groundnut crop. In all the four micronutrients considered, mean values of all the nutrients were higher in SAMNUT 14, but, the efficiency of soil relative to foliar application methods differed between micronutrient and the varieties being considered. Foliar application was more efficient for SAMNUT 23, but not for SAMNUT 14. For cowpea, foliar application seemed to be a better application method for Mo of higher accumulation of micronutrient in the grains. From these results, it could be derived that both methods and level of application of Mo are important in the accumulation of nutrients in the various genotypes of groundnut and cowpea (grain legumes).

4.2.6 Correlation Studies (Agronomic parameters)

4.2.6.1 Groundnut

The relationships between agronomic parameters as influenced by treatment where derived by simple correlation analysis. The correlation coefficients for groundnut are shown in Table 4.9. The parameters considered included: soils parameters, dry matter yield, nodule count, root weight, weight of pods and grain yield. The established relationship between dry matter yield and agronomic parameters that were significant are as follows: Dry matter yield varied positively and significantly with root weight, nodule weight, unshelled field weight (usfldwt) and grain yield. Factors which influenced this parameters would influence the development of the crop. Positive relationship between dry matter yield (DMY) and root weight (r = 0.321*) indicated that a good rooting system for groundnut was necessary for high yield. Root weight varied positively and significantly with grain yield (r = 0.408*). The effects of treatment on nodule count could not be explained by the variation in any of the parameters listed as relationships were not significant.

These agronomic parameters where also influenced by soil nutrients. DMY was significantly influenced by organic carbon content of the soil (r = 0.372*). DMY did not vary positively and significantly with the total N and AVP. Root weight was only positively influenced by Zn (r = 0.542**) and had a negative relationship with exchangeable acidity. Interestingly nodule count was influenced significantly by AVP and K (r = 0.392*, r = 0.329*) respectively for both nutrients.

Table 4.9: Correlation matrix of soil parameter and agronomic parameter in the greenhouse (Groundnut)

	Ndct	Rtwt	podwt	ndwt	usfldwt	Grain yield	Frbiwt	DMY	Hawmwt	nopod
Org	-0.025	0.277	0.091	0.173	0.325*	0.109	0.133	0.372*	0.130	0.138
Av p	0.392*	-0.084	0.089	0.188	-0.165	0.297	-0.054	0.123	0.106	0.229
EA	-0.019	-0.348*	-0.085	0.163	-0.353*	0.126	-0.094	-0.240	0.022	-0.085
Tot N	0.281	-0.019	0.295	0.092	0.067	0.065	0.176	0.008	-0.160	-0.025
EC	0.231	0.258	0.247	0.131	0.154	0.452*	0.196	0.177	-0.050	0.388*
Tot P	0.072	0.080	-0.158	0.101	0.065	0.202	-0.103	0.181	0.089	0.061
Ex Ca	-0.00002	0.226	-0.020	-0.159	0.252	-0.028	0.025	0.241	0.029	-0.163
Ex Mg	-0.020	0.017	0.026	0.161	0.141	0.290	0.047	0.143	0.114	-0.263
Na	0.088	0.203	-0.100	0.133	0.086	0.053	0.232	-0.027	-0.203	-0.167
K	0.329*	0.048	-0.082	0.148	-0.004	-0.006	0.026	0.047	0.002	0.005
Fe	0.032	-0.150	-0.009	-0.180	-0.330*	-0.101	-0.100	0.237	0.080	-0.073
Zn	0.053	0.542**	-0.042*	0.204	0.299	0.320*	0.227	0.162	-0.020	0.474*
Mo	0.020	-0.234	-0.360*	0.084	-0.234	0.166	-0.163	-0.034	0.005	-0.125
Cu	0.146	0.101	0.017	0.236	0.169	0.058	0.064	0.103	0.047	-0.043
pH H_2O	-0.048	-0.142	0.080	0.312	-0.203	0.204	-0.005	-0.065	0.057	0.112
$CaCl_2$	0.036	0.122	0.054	-0.320*	0.013	-0.302	-0.084	-0.074	0.236	0.050
Ndct	1.000	0.252	0.205	0.325*	0.217	0.253	0.282	0.212	-0.030	0.464*
Rtwt		1.000	-0.030	0.389*	0.748**	0.408*	0.667**	0.321*	0.136	0.466*
Podwt			1.000	0.029	0.023	-0.015	0.172	0.040	-0.166	0.445
Ndwt				1.000	0.437*	0.757**	0.412*	0.494*	0.155	0.402*
Usfldwt					1.000	0.373*	0.738**	0.524**	0.227	0.315
Gyld						1.000	0.363*	0.501**	0.153	0.291
Frblwt							1.000	0.276	0.022	0.466*
DMY								1.000	0.592**	0.141
Hau mwt									1.00000	-0.165
No pod										1.000

nd ct = nodule count; nd wt = nodule weight; us fldwt = unshelled field weight; frbiwt = fresh biomass weight; DMY = dry biomass weight; rt wt = root weight; haum wt = haulm weight; no pod = number of pod

*= 5% level of significance

**=1% level of significance

The significance of P and K for good nodulation of groundnut was established. Grain yield in the greenhouse was positively influenced by Zn (r = 0.203*) and EC. From this study, the factor which influenced the yield indices (DMY, nodule count and root weight) were organic carbon, EC, K content and Zn. Mo was only negatively related with pod weight, indicating that pod weight decreased with increase in Mo level. We can therefore infer that the role of Mo was physiological, which could be linked to the processes that control the nutrition of groundnut such as N-fixation.

4.2.6.2 Cowpea

The correlation matrix for soil P and agronomic parameter for the cowpea genotypes is shown in Table 4.10. The relationship between agronomic parameter for cowpea reveal that DMY did not vary significantly with any of the parameters considered. Grain yield varied with nodule weight and there was no relationship between nodule count and the various agronomic parameters considered. However, root weight was seen to vary positively with nodule weight (r = 0.387*). Soil nutrient content did not seem to vary significant with DMY and grain yield, so that soil fertility status was not the controlling factor in predicting yield in the cowpea crop. However, nodule weight varied positively and significantly with total N, EC and total P at 5% level of probability. These parameters can be said to be relevant in defining nodulation in the cowpea crop. The Mo content of the soil was only related to fresh biomass weight (frbiwt r = 0.338*) and positively related to number of pods (r = 0.346*). From the observation for both groundnut and cowpea, the role of Mo in the growth and yield processes of grain legume, which essentially is physiological, can be said to have been established in the study.

Table 4.10: Correlation matrix of soil parameter and agronomic parameters in the green house cowpea (IAR 48 and IT95K)

	Nd ct	Rt wt	Pod wt	Nd wt	Usfldwt	G/yld	Fr bio wt	DMY	No pod
Org C	-0.015	0.221	-0.227	-0004	0.110	0.12	0.294	0.323	0.359*
Av p	0.175	0.258	-0.254	0.223	-0.321*	0.121	-0.189	0.038	0.177
EA	0.272	0.032	0.044	-0.082	-0.196	-0.164	0.139	0.399*	-0.160
Tot N	0.358*	0.032	-0.200	0.032	-0.204	-0.065	-0.087	0.032	-0.200
EC	0.339*	0.023	-0.093	-0.051	0.101	-0.027	-0.061	0.128	0.003
Tot P	0.339*	0.191	-0.306	-0.051	-0.190	-0.049	-0.360	0.245	-0.037
Ex Ca	0.240	0.096	0.012	-0.146	0.157	-0.088	-0.269	0.063	0.261
Mg	-0.106	0.103	0.158	0.064	0.069	0.063	-0.106	0.010	-0.060
Na	-0.157	0.064	0.033	-.338*	0.114	-0.367	0.374*	-0.280	0.219
K	0.250	.0001	-0.015	0.186	-0.146	0.107	0.250	0.163	-0.125
Fe	-0.105	0.043	0.083	0.266	0.126	0.119	-0.288	0.182	0.212
Zn	0.301	0.183	-0.091	-0.213	0.061	-0.195	0.154	0.021	0.045
Mo	-0.123	0.105	0.103	0.219	-0.180	0.097	0.338*	-0.137	0.346*
Ex K	-0.072	0.146	0.151	-0.039	-0.287	-0.170	-0.048	-0.230	0.129
pH H_2O	-0.152	-.191	0.161	0.032	-0.208	0.177	0.323*	-0.025	-0.170
$CaCl_2$	0.103	0.171	-0.094	-0.105	0.178	-0.293	0.475*	-0.046	0.317*
Ndct	1.000	0.242	-0.302	0.068	-0.270	-0.132	-0.140	-0.039	0.219
Rtwt		1.000	-0.367	0.387*	-0.019	0.223	0.013	0.045	-0.054
Podwt			1.000	-0.053	0.56	0.150	0.139	-0.279	0.264
Ndwt				1.000	0.230	0.552**	0.130	0.252	-0.060
Usfldwt					1.000	0.032	0.249	-0.144	-0.203
g/yld						1.000	0.237	0.178	-0.145
Frblwt							1.000	-0.222	0.464*
Drblowt								1.000	-0.102
Nopod									1.000

Ndct = nodule count; nd wt = nodule weight; us fld wt = unshelled field weight; fr bio wt = fresh biomass weight; DMY= dry biomass weight; Rt wt = root weight; haum wt = haulm weight; no pod = number of pod

*=5% level of significance

**=1% level of significance

4.2.7 Effects of Mo levels and methods of application on the Relationship Between Nutritional Content of the Grain and Agronomic Parameter – Green house

Tables 4.11 and 4.12 show the correlation matrix of agronomic parameter and nutritional content of the grains for cowpea and groundnut genotypes respectively. For the groundnut crop, the only relationship established was dry matter weight and N-content of the grain (r = 0.374*). Nodule count and root weight influenced Zn content of the grain significantly.

The cowpea genotypes reacted differently. No agronomic parameter influenced N-content of the grain significantly. However, nodule count influence total P content of the grain while nodule weight influence the Fe content of the grain. Dry matter weight influence grain Cu content while root weight negatively influence Mo content of the grain. These results would tend to suggest that some other factors play a huge role in the accumulation of nutrients in the grain, especially Mo, and this factor can be derived from the list of conditions that define soil fertility.

4.2.8 Effects of Mo levels and methods of application on the Relationship Between Nutritional Content of the Grain and Soil Parameter – Green house

4.2.8.1 Groundnut

The effects of soil chemical properties on the accumulation of selected nutrients in the groundnut grain is shown in the correlation matrix in Table 4.13. For the micronutrients considered, soil parameters which had significant influence on Fe accumulation in the grain was only EC (r = -0.570**). Total N varied significantly with N-content of grain (Pr = 0.70**), Cu was influenced only by soil Cu content (Pr = 0.330**), Zn was influenced positively by the soil Zn content (r = 0.55**) and

Table 4.11: Correlation matrix of agronomic parameters and the nutritional content of the grains in the greenhouse (groundnut genotypes SAMNUT 14 and 23)

Source of variation	Total P	Fe	Cu	Mo	Zn	Total N
Nd ct	0.072	0.182	0.233	0.101	0.356*	0.003
Rt wt	0.080	0.299	-0.032	0.078	0.331*	0.101
Pod wt	-0.158	-0.066	0.002	-0.236	0.193	0.330
Nd wt	0.101	-0.043	0.130	0.110	-0.067	0.128
Us fld wt	0.065	0.096	0.045	-0.172	0.157	0.167
G/yld	0.202	0.170	0.053	0.187	0.066	0.121
Frblowt	-0.103	0.146	0.017	-0.042	0.179	0.215
DMY	0.181	0.294	0.064	-0.132	0.066	0.374*
Haum wt	0.089	0.018	-0.137	-0.038	-0.054	0.071
No pod	0.061	0.283	-0.163	0.153	0.455	0.210
Tot P	1.000	-0.032	-0.247	-0.209	0.050	-0.169
Fe		1.000	0.021	0.373	0.4333	0.151
Cu			1.000	-0.129	-0.141	-0.108
Mo				1.000	0.153	-0.106
Zn					1.000	-0.078
Tot N						1.000

Nd ct = Nodule count
Nd wt = nodule weight
DMY = dry biomass weight
rt wt = root weight
us fld wt = unshelled field weight
haum wt = haulm weight
pod wt = weight of pod
G/yld=grain yield
no pod = No. of pod

*=5% level of significance

**=1%level of significance

Table 4.12: Correlation matrix of agronomic parameters and the nutritional content of the grains (Cowpea genotypes IAR 48 & IT95K-499-35) in the greenhouse

Source of variation	**Total P**	**Fe**	**Cu**	**Mo**	**Zn**	**Total N**
Ndct	0.339*	-0.182	0.255	0.113	0.263	0.233
Rtwt	0.096	0.019	0.045	-0.374*	0.137	-0.024
Podwt	-0.306	0.045	-0.199	0.079	-0.100	-0.104
Ndwt	-0.051	0.368*	0.071	0.041	0.128	0.014
Usfidwt	-0.190	-0.212	-0.420*	-0.294	0.002	-0.130
G/yld	-0.049	0.510**	0.027	-0.001	0.052	-0.193
Frblowt	-0.360	0.183	-0.081	0.021	-0.144	-0.161
DMY	0.245	-0.092	0.417*	-0.097	0.114	-0.006
No pod	-0.037	-0.155	0.024	0.034	0.124	-0.041
Tot p	1.000	0.170	0.128	0.178	0.245	0.351*
Fe		1.000	-0.018	0.343*	-0.168	-0.009
Cu			1.000	0.165	0.129	-0.065
Mo				1.000	-0.292	0.167
Zn					1.000	-0.133
Tot N						1.000

Where:

Ndct = Nodule count
rtwt = root weight
podwt = weight of pod
Ndwt = nodule weight
usfldwt = unshelled field weight
G/yld= grain yield
DMY= dry biomass weight
haumwt = haulm weight
nopod = No. of pod
*=5% level of significance
**=1%level of significance

Table 4.13: Correlation matrix of agronomic parameter on some grain yield parameter and grain nutrient content in the Green house -SAMNUT14 and SAMNUT 23 (Groundnut genotypes)

	Fe	Total N	Cu	Mo	Zn	Total P
Organic C	0.241	0.110	0.107	0.038	-0.001	0.034
AVP	0.294	0.027	-0.002	0.516**	0.236	-0.169
EA	-0.277	-0.108	0.137	0.414*	-0.439**	-0.266
Total N	-0.167	0.697**	0.046	-0.282	-0.245	-0.178
EC	0.570**	-0.140	0.046	0.273	0.505**	0.058
Total P	-0.032	-0.169	-0.247	-0.209	0.0501	1.00
Ex Ca	0.203	-0.010	-0.097	-0.265	0.212	0.253
Ex Mg	-0.024	-0.166	-0.009	-0.125	0.014	0.209
Ex Na	-0.107	-0.100	0.107	-0.176	-0.026	0.023
Cu	0.056	-0.185	0.832**	-0.117	0.020	-0.187
Fe	0.009	0.090	-0.181	0.331*	0.161	-0.301
Zn	0.508	-0.134	-0.181	0.170	0.554**	0.247
Mo	0.229	-0.143	0.091	0.686**	-0.112	-0.232
Ex K	-0.257	-0.147	-0.033	-0.105	-0.145	0.299
pH (H_2O)	-0.033	0.145	0.183	0.459*	-0.287	-0.206
$CaCl_2$	0.118	0.038	-0.099	-0.376*	0.398*	0.076

*=5%level of significance
**=1%level of significance

EC (Pr = 0.0606**). Exchangeable acidity negatively influenced Zn content just like it was for pH $CaCl_2$ which varied positively with Zn content.

The major interest, which was the Mo content of the grain was influenced positively by AVP, EA, Fe and pH. The effects of soil Mo content was positive and significant in enhancing the accumulation of Mo in the grain (r = 0.686**). This observation is phenomenal, that is it tends to show that Mo application can influence Mo content of the grain, which is in line with our hypothesis.

The mechanism of accumulation of Mo in the grain seemed to be influenced appreciably by soil Fe, P contents and the soil nutrient solution concentration of relevant cations. Most of the exchangeable cations negatively influenced the Mo concentration in the grain.

4.2.8.2 Cowpea

The correlation matrix of the relationships of nutrient content of grain and soil parameter for the cowpea crop, is shown in Table 4.14. Just like it was for groundnut, the exchangeable cation had negative relationship with most of the nutrients, especially Fe and Mo, both of which also influenced the accumulation of Mo in the groundnut grain. The soil parameter that influenced Fe, content in the cowpea grain were pH, $CaCl_2$ and exchangeable Ca. Soil Fe contents did not relate positively with grain Fe content of cowpea. Grain Cu content was influenced only by the soil extractable Cu (r = 0.426*). Zn content was influenced positively only by pH $CaCl_2$. The total N content of the grain was influenced by total N of the soil (r = 0.793**), total P (r = 0.380*), exchangeable K (r = 0.339*).

Table 4.14: Correlation matrix of agronomic parameter and grain content in the Green house – IAR 48 and IT95K (Cowpea genotypes)

	Fe	Total N	Cu	Mo	Zn	Total P
Organic C	-0.045	-0.211	0.030	-0.173	0.052	-0.011
AVP	-0.017	0.107	0.151	0.060	0.316	0.075
EA	0.098	0.151	0.069	0.141	-0.224	-0.082
Total N	0.003	0.793**	0.220	0.231	-0.119	0.380*
EC	-0.205	0.027	0.156	-0.171	0.126	0.180
Total P	0.170	0.351*	0.128	0.178	0.245	1.00
Ex Ca	-0.518**	-0.186	-0.064	-0.446*	0.485*	-0.041
Ex Mg	-0.120	0.006	0.053	-0.158	0.188	-0.028
Ex Na	-0.200	0.207	-0.179	-0.114	-0.106	-0.071
Cu	0.159	-0.152	0.426*	0.190	0.253	0.162
Fe	-0.127	-0.043	0.051	-0.220	0.215	0.115
Zn	-0.150	-0.343	0.245	-0.082	-0.056	0.226
Mo	0.442	0.001	-0.046	0.580**	-0.270	0.068
Ex K	0.055	0.339*	-0.016	0.360*	-0.420*	-0.149
pH (H_2O)	0.287	-0.046	0.220	0.405*	-0.425*	-0.321*
$CaCl_2$	-0.322*	0.174	-0.293	-0.536**	0.455*	0.254

*=5% level of significance ; **= 1% level of significance

The total P content of the grain was only influenced by total N, total P, and was negatively influenced by pH-(H_2O). With respect to Mo content of the grain, soil Mo content was highly correlated with the grain Mo content (r = 0.580**), exchangeable K (r = 0.360*), but was negatively related to extractable Fe. Exchangeable cations were negatively related to Mo content of the grain. This result showed in clear terms that Mo content of the grain can be directly increased by Mo fertilization. And the mechanisms of accumulation of Mo in the grain are very similar for both groundnut and cowpea genotypes and by extension, for all grain legumes.

4.3 Field Studies

4.3.1 Effects of Mo levels and methods of application on growth parameters in the field : Agronomic parameters -Groundnut

The effect of Mo and methods of application on the response of cowpea and groundnut genotypes were studied in the field. For the derivation of some agronomic parameters in the field study, destructive sampling was carried out at 8 WAP, when much of the physiological developments had initiated in both crops. The agronomic parameters considered in this destructive study were based on two plants sampled per plot.

These stands were uprooted, and all data processes were done in the laboratory. The results of this effort are shown in Tables 4.15, 4.16 and 4.17. The agronomic parameter evaluated included; nodule count, DMY, pod weight, nodule weight, grain yield.

4.3.1.1 Nodule Count

Nodule count for groundnut was influenced significantly by Mo rate (Pr = 0.0018) but was not influenced by variety or interaction. Mean values for SAMNUT 23 and SAMNUT 14 were 206.0 and 198.5 per two plants. Response to Mo rate was only up to 200g Mo/ha for both varieties and soil application was far superior to foliar application of

Table 4.15: Effects of Mo levels and methods of application on some agronomic parameters on groundnut and cowpea genotypes on the field at 8 weeks of field growth (destructive sampling)

Groundnut													
Treatment Number	Mo rate method (g/ha)	Nodule count		Nodule weight(g)		Root weight(g)		Number of pod		Weight of pod(g)		Pod yield (kg)	
		Sam 23	Sam 14	Sam 23	Sam 14	Sam 23	Sam 14	Sam 23	Sam 14	Sam 23	Sam 14	Sam23	Sam 14
1	0 soil	211.3	196.3	0.45	0.43	29.4	29.2	37.3	72.0	43.3	30.8	1.57	0.96
2	100 soil	167.6	291.0	0.32	0.63	30.9	27.6	59.0	75.6	52.2	31.2	1.72	1.31
3	200 soil	251.6	326.3	0.51	0.73	31.1	32.6	63.0	74.3	45.1	42.7	1.62	1.11
4	300 soil	268.3	45.3	0.52	0.90	30.8	28.9	69.3	59.6	27.7	35.7	1.65	1.26
5	500 soil	223.3	272.6	0.50	0.52	28.2	28.7	56.6	43.3	42.8	40.9	1.80	0.81
6	200 foliar	113.6	59.6	0.50	0.73	30.2	28.4	54.6	48.0	44.4	29.9	2.08	0.88
Mean		206.0	198.5	0.47	0.66	30.1	29.2	56.6	59.1	42.6	35.2	1.74	1.06
SE		8.15		0.08		0.82		7.35		4.87		0.16	
CV%		37.3		38.9		6.88		31.0		30.6		28.2	
R^2		0.61		0.44		0.44		0.39		0.38		0.63	
Cowpea													
Treatment Number	Mo rate method (g/ha)	Nodule count		Nodule weight(g)		Root weight(g)		Number of pod		Weight of pod(g)		Pod yield (kg)	
		IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K
1	0 soil	31.0	15.6	0.28	0.16	5.70	3.65	29.6	27.6	36.1	49.3	1.60	1.73
2	100 soil	55.3	17.6	0.56	0.21	6.28	5.58	27.3	30.0	49.0	56.2	1.76	1.66
3	200 soil	32.3	27.6	0.39	0.26	5.74	4.59	45.0	36.6	46.4	80.7	1.63	1.80
4	300 soil	18.3	18.3	0.32	0.23	4.85	3.74	30.0	32.0	41.7	53.5	1.66	1.80
5	500 soil	39.3	21.6	0.23	0.19	6.38	4.53	33.3	54.3	45.8	62.0	1.83	1.73
6	200 foliar	32.6	13.0	0.23	0.16	5.08	2.02	31.6	29.3	51.0	55.5	2.06	1.63
Mean		38.1	19.0	0.34	0.19	5.67	4.02	32.8	34.97	45	59.5	1.76	1.73
SE		2.43		0.05		0.40		4.51		6.91		0.10	
CV%		37.8		41.9		34.5		32.58		32.3		13.8	
R^2		0.61		0.63		0.44		0.44		0.43		0.33	

Table 4.16: Effects of Mo levels and methods of application on dry matter yield of the 2 destructively sampled plants in the field (grams)

Treatment No	Mo rate method (g/ha)	Groundnut dry matter yield(g)		Cowpea dry matter yield (g)	
		Sam 23	Sam 14	IAR 48	IT95K
1	0 soil	88.0	66.2	97.2	71.0
2	100 soil	91.2	63.0	101.6	115.0
3	200 soil	81.2	85.1	84.4	111.0
4	300 soil	52.8	69.4	66.0	94.4
5	500 soil	67.0	70.7	79.8	145.6
6	200 foliar	64.2	75.1	115.4	85.8
Mean		72.6	71.6	88.1	103.8
SE			10.3		14.3
CV			34.9		36.2
R^2			0.30		0.34

Table 4.17: Effect of Mo levels and methods of application on groundnut and cowpea on grain yield (Harvest index and haulm weight in the field)

Treatment number	Mo rate method (g/ha)	Harvest index		Haulm weight (kg)	
		Sam23	Sam 14	Sam23	Sam 14
		0.322	0.430	1.94	1.53
2	100 soil	0.407	0.683	2.04	1.89
3	200 soil	0.411	0.768	2.20	2.00
4	300 soil	0.370	0.576	2.05	2.02
5	500 soil	0.346	0.728	1.93	1.68
6	200 foliar	0.298	0.424	2.12	1.70
Mean		0.359	0.602	2.05	1.80
SE					0.10
CV					13.1
R^2					0.57

Treatment No.	Mo rate method (g/ha)	Harvest index	
		IAR 48	IT95K
1	0 soil	0.590	0.590
2	100 soil	0.587	0.630
3	200 soil	0.628	0.639
4	300 soil	0.628	0.609
5	500 soil	0.543	0.572
6	200 foliar	0.560	0.613
Mean		0.589	0.609
SE			
CV			
R^2			

Where:

Mo rate = Molybdenum rate

Mo. Mo is known to enhance the utilization of other mineral element especially nitrogen (N) and it is required by bacteria for nodule formation and N-fixation. Brodick *et al.* (1992) determined that Mo levels affected nodules number. The results in Tables 4.15 and 4.16 showed that there was a significant difference between the control treatment and the other Mo treatments.

4.3.1.2 Nodule Weight

Nodule weight was influenced by genotypes. Mean values for SAMNUT 23 and SAMNUT 14 were 0.47 and 0.66g respectively per 2 plants. Mo application increased Mo content and in addition, resulted in better growth of each nodule and led to a higher nodule weight per plant, Koji *and* Yamasaki (1976) as compared with the control treatment.

4.3.1.3 Root weight

Root weight was not significantly influenced by the factors considered in this study. Pod weight at eight weeks varied with groundnut genotypes and it was observed that significant response went only up to 100g Mo/ha for SAMNUT 23 and 200g Mo/ha for SAMNUT 14. Though these values were not significantly different, it tended to reveal the relative efficiencies of these genotypes and their response to Mo fertilization. The response to foliar application showed that Mo fertilization can effectively supplement soil Mo deficiencies (Brent *et al.*, 2005). William (2004) also showed that foliar applied molybdate was rapidly distributed throughout the plant, including translocation towards stems and roots within 24 hours. Pod weight at eight weeks were 42.6g for SAMNUT 23 and 35.2g for SAMNUT 14.

4.3.1.4 Dry matter yield

Biomass accumulation after eight weeks was not influenced by any factor considered in this experiment. However, maximum response reflected the response of biomass weight to treatments as earlier stated, that is, DMY response at 100g Mo/ha for SAMNUT 23 and 200g Mo/ha for SAMNUT 14. From this study, it was established that Mo rate of 100 to 200g Mo/ha would be good enough for the genotypes considered. With respect to efficiency, SAMNUT 23 was more efficient compare to SAMNUT 14. The mean DMY value for SAMNUT 23 and SAMNUT 14 were 72.6 and 71.6g per two plants respectively.

4.3.2 Effects of Mo levels and methods of application on Growth parameters in the field: Agronomic parameters - Cowpea

4.3.2.1 Nodule count and nodule weight

Nodule count was significantly influenced by cowpea genotypes (Pr = 0.0025) but not by Mo levels or interaction. The mean nodule content values for IAR 48 and IT95K were 38.1 and 19.0g per two plants respectively. Response to Mo application was erratic for both varieties, and the effects of foliar and soil applied Mo were not significant on nodule count. However, nodule weight was influenced by Mo rate and crop variety, with crop varieties having more of the variation (Pr = 0.0498 and 0.0019 for both factor respectively) that is, Mo rate and crop genotypes. Mean nodule weight for IAR 48 and IT95K were 0.34g and 0.19g respectively. For both nodule count and nodule weight, response to applied Mo were 100g Mo/ha and 200g Mo/ha for both varieties respectively (Table 4.15).

4.3.2.2 Root weight

Root weight was significantly influenced by crop genotypes (Pr = 0.0085), indicating that root proliferation in cowpea is directly proportional to nodule formation (production) and crop performance. For both genotypes of cowpea, 100g Mo/ha soil applied produced highest root weight and foliar application was consistently inferior to soil application.

4.3.2.3 Dry matter yield

The pod weight of cowpea obtained at 8 weeks in the field responded only to the first rate of Mo applied to IAR 48 and to the second level of Mo applied to IT95K, and for both crops, values decreased with increase in rate of application of Mo. Again, crop genotypes influenced pod yield significantly (Pr = 0.017). Mean values between both genotypes were 45.0g for IAR 48 and 59.5 for IT95K and soil application was both consistently superior in both varieties.

The effect of crop genotypes were also consistent even for the DMY of cowpea. Mean values for both crop genotypes, at all level of treatments considered, were all marginally significant (Pr = 0.09). However, maximum response for both genotypes was up to 200g Mo/ha, and thereafter declined.

It is pertinent to note from this study for both groundnut and cowpea crops that response of the agronomic parameters considered in nearly all cases did not exceed 200g Mo/ha, which tend to show that this rate, as obtained in earlier studies by some other workers (Broderick *et al*., 1992), would be sufficient for the production of good crops of grain legumes. It is also necessary to note that the acquisition of Mo from the soil and the accumulation of Mo in the seed, which are the relevant point of consideration in the

study, can equally be influenced by this level of treatment. The response of the genotypes to Mo in nearly all cases differed, which tells us that their efficiency of utilization, even within crop genotypes, differed also.

4.4 The Effects of Mo Levels and Methods of application on Field Yield Parameter at harvest

4.4.1 Groundnut

4.4.1.1 Grain yield

The yield of groundnut seeds ranged from 413 to 726 kg/ha for both varieties of groundnut (Table 4.17). Mean yield values were not significantly influenced by Mo rate and crop varieties, but the effects of their interaction was highly significant (Pr = 0.0057). For SAMNUT 23, 100g Mo/ha produced the highest yield (700 kg/ha) but for SAMNUT 14, 300g Mo/ha produced the highest yield of 726 kg/ha. This indicated that both varieties varied in their efficiency in the use of Mo. For both varieties foliar application was consistently inferior to soil application.

4.4.1.2 Field Pod Yield

The field pod yield was not consistent with grain yield. For SAMNUT 23, foliar application produced the highest yield at 200g Mo/ha. However, for soil applied Mo, increase in yield was observed to the highest level of Mo applied. Though the mean values were not significantly different, it seemed that lower levels of Mo were more economically viable as shown by the grain yield response. For SAMNUT 14, foliar application was inferior to soil application, and the highest yield was obtained at 100g Mo/ha. Pod yield values of the genotypes were 1450 kg/ha and 879 kg/ha for SAMNUT 23 and 14 respectively.

4.4.1.3 Grain: Pod ratio

This is an index of translation of resources to economic yield, and values increased up to the first level in SAMNUT 23 but up to 500 g Mo/ha soil applied for SAMNUT 14. The efficiency of this translation was found to be high for SAMNUT 14 and somewhat inexhaustive. The grain: pod ratio was not particularly influenced by method of application.

From this result, we can infer that the ultimate high yield of groundnut can be satisfied by 100g Mo/ha for SAMNUT 23 (700 kg/ha) but response of SAMNUT 14 can go up to 300g Mo/ha (726 kg/ha).

4.4.2 Cowpea

4.4.2.1 Grain yield

The response of cowpea to Mo application was not significant. However, for IAR 48, foliar application was superior to soil application. But for IT95K response to Mo application was not observed even at zero level of Mo applied. This may indicate that the soil Mo level of the unfertilized plot was sufficient for this variety of cowpea. Grain yield values ranged from 943 kg/ha to 1218 kg/ha for both IAR 48 and 990 kg/ha to 1150 kg/ha for IT95K respectively (Table 4.18).

4.4.2.2 Pod Yield and Grain Pod ratio

Mean values were not influenced by any factor considered, and as was observed for grain yield, foliar application was superior for IAR 48 for both parameters. IT95K was not particularly responsive to Mo application in the field. The response limit to Mo fertilization may not have been exhaustively determined, but for the subsoil value of 9.38 mg/kg (Table 4.1) for the field soil seemed to provide an adequate Mo fertility for

Table 4.18: Effects of Mo levels and methods of application on field yield parameter

Groundnut							
Treatment No	Mo rate method (g/ha)	Grain yield (kg/Ha)		Pod yield (kg/ha)		Grain: pod ratio	
		Sam 23	Sam 14	Sam 23	Sam 14	Sam 23	Sam 14
1	0 soil	506.6	418.3	1308	666.7	0.38	0.62
2	100 soil	700.0	636.6	1433	1091	0.48	0.58
3	200 soil	666.6	353.3	1350	925	0.49	0.38
4	300 soil	610.0	726.6	1375	1050	0.44	0.69
5	500 soil	623.3	590.0	1500	675	0.42	0.87
6	200 foliar	620.0	373.3	1733	733.3	0.35	0.51
Mean		621.0	515.3	1450	879.1	0.43	0.61
SE		57.8		-			
CV		23.2		28.20			
R^2		0.56		0.63			
Cowpea							
Treatment No	Mo rate method (g/ha)	Grain yield (kg/ha)		Pod yield (kg/ha)		Grain: pod ratio	
		IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K
1	0 soil	943.3	1020	1333	1441	0.71	0.71
2	100 soil	1046.6	1046	1466	1383	0.71	0.76
3	200 soil	1023.3	1150	1358	1500	0.75	0.77
4	300 soil	1043.3	1096	1383	1441	0.75	0.76
5	500 soil	993.3	990.0	1525	1500	0.65	0.66
6	200 foliar	1218.4	1000	1716	1358	0.71	0.74
Mean		1033.9	1050	1466	1441	0.71	0.73
SE		25.8		-			
CV		0.31		13.88			
R^2		54.8		0.33			

cowpea and IT95K variety specifically. However, the uptake augmentation created by increasing level of Mo fertilization may provide an answer to our hypothesis even for the cowpea crop.

4.5 Effects of Mo Levels and Methods of application on Some Soil Parameters in the Field

The effects of treatments on soil parameter are shown in Table 4.19.

4.5.1 Soil pH

Variations in mean pH values were not significantly influenced under groundnut cultivation but generally, values were higher under the groundnut crop relative to the cowpea crop. For groundnut, values were highest for both crop genotypes at 100g Mo/ha but decreased thereafter to the highest level applied. Mean values for pH (H_2O) were significantly influenced by cowpea genotypes. Mean pH (H_2O) values for IAR 48 and IT95K were 5.30 and 5.51 respectively. This variation may indicate reactivity and so reflected on Mo utilization by the crops. Mean pH values for H_2O and $CaCl_2$ were 5.40 and 4.87 respectively.

4.5.2 Organic Carbon

The variations in organic carbon content were not significantly influenced by treatments, but reactions were consistent as influenced by crop types under the groundnut crop. Organic carbon content increased up to the first level of Mo applied (100g Mo/ha) for SAMNUT 23 but increased up to the highest level applied for SAMNUT 14 indicating that groundnut genotypes have varied level of needs for Mo in influencing organic C build up in groundnut yields. The highest level of organic carbon under

Table 4.19: Effect of Mo levels and methods of application on some soil parameters in the field trial

Groundnut

Treatment No.	Mo rate method (g/ha)	pH H_2O		pH $CaCl_2$		Org. C(%)		Total N(%)		Av. P (mg/kg)		Total P (%)	
		Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14
		5.63	4.86	4.56	4.86	0.38	0.32	0.02	0.03	4.66	4.66	35.7	30.0
2	100 soil	5.83	5.63	4.56	5.83	0.48	0.42	0.03	0.04	3.50	3.50	36.4	31.2
3	200 soil	5.36	5.50	4.33	5.50	0.40	0.45	0.04	0.04	5.25	8.16	37.0	33.3
4	300 soil	5.13	5.43	4.50	5.43	0.38	0.55	0.04	0.05	6.41	2.91	36.2	35.7
5	500 soil	5.73	5.56	4.36	5.56	0.40	0.61	0.03	0.04	4.08	7.58	45.1	37.3
6	200 foliar	5.36	5.56	4.23	5.56	0.42	0.51	0.04	0.04	3.50	5.83	33.9	26.1
Mean		5.51	5.42	4.42	5.46	0.41	0.48	0.03	0.04	4.57	5.44	37.4	32.3
SE		0.16		0.10		4.66		0.01		0.77		2.52	
CV		7.36		0.64		377.7		34.7		37.4		17.5	
R^2		0.51		0.69		0.32		0.38		0.81		0.71	

Cowpea

Treatment No.	Mo rate method (g/ha)	pH H_2O		pH $CaCl_2$		Org. C(%)		Total N(%)		Av. P(mg/kg)		Total P(%)	
		IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K
1	0 soil	5.00	5.53	5.00	4.50	0.40	0.46	0.03	0.02	5.83	7.58	34.4	31.5
2	100 soil	5.16	5.63	5.16	4.40	0.42	0.45	0.04	0.02	5.25	5.41	29.9	32.5
3	200 soil	5.33	5.50	5.33	4.63	0.61	0.48	0.04	0.04	6.41	6.41	39.4	33.1
4	300 soil	5.46	5.30	5.46	4.30	0.42	0.45	0.03	0.03	5.83	7.58	36.5	31.6
5	500 soil	5.46	5.53	5.46	4.46	0.47	0.61	0.04	0.04	4.66	7.00	38.0	34.7
6	200 foliar	5.36	5.56	5.36	4.30	0.48	0.32	0.03	0.02	7.00	5.25	36.7	31.5
Mean		5.30	5.51	5.30	4.43	0.45	0.45	0.04	0.03	5.83	6.41	35.8	32.5
SE		1.43		0.11		0.06		0.04		1.11		1.90	
CV		5.03		5.98		34.7		30.0		46.4		13.5	
R^2		0.72		079		0.31		0.51		0.46		0.70	

Where:

Mo rate = Molybdenum rate

SAMNUT 23 was 0.48% and SAMNUT 14 was 0.61% (Table 4.18). Foliar application was consistently inferior to soil application for the build up of soil organic carbon.

With the cowpea crop, variation in soil organic carbon increased up to 200g Mo/ha for IAR 48 (0.61%) but, increased up to the highest level under IT95K (0.61).

Also foliar application was consistently inferior to soil application under cowpea. Mean organic carbon content of the cropped soils under groundnut was 0.44%, and 0.45% under cowpea compared to 0.42% organic carbon content for the 0-30 cm pre-cropped field soil. This gives an average accretion of organic carbon of 6%. Comparatively, therefore the organic carbon build up was better enhanced under the cowpea crop. This is in line with Paul and Kucy (1971) suggestion that from ^{14}C pulse labeling studies that bean (legume) did compensate for the plant losses of C photosynthesis when rhizobial symbiosis utilized a portion of the total photosynthetic carbon. As was observed for groundnut, there was a wide variation in the capacity to utilize Mo with respect to the build up of soil organic carbon.

4.5.3 Total Nitrogen

Contrary to expectations, total N content of the soil was not significantly influenced by treatment for the groundnut and cowpea crops. Though, total N content increased for both groundnut and cowpea, there were no differences in the soil N content under both crops. This is despite the fact that the contribution of biologically fixed nitrogen to the nutritional needs of the plant.

After harvest, the amount of nitrogen available to subsequent crop also depended on factors like the crop genotype, available soil nitrogen and climate. More nitrogen is often removed in the harvest of seed legumes than what is added from N-fixation

(Herechel *et al.*, 1981; Bezdicek and Kennedy, 1981). Mean total N values of the soils under SAMNUT 23 was 0.03%, and SAMNUT 14 was 0.04%. Similarly under IAR 48 mean total N value was 0.04%, and IT95K was 0.03%. Comparing the level of effects as shown by the R^2 values, cowpea responded better than groundnut to Mo application with respect to the soil N buildup.

4.5.4 Available Phosphorus (AVP)

The AVP content of the soil increased appreciably with rates of application of Mo but mean values were not significantly different. Under groundnut, values varied from 2.91 mg/kg to 8.16mg/kg, and for cowpea, mean values ranged from 4.66 to 7.58 mg/kg. Differences in the AVP content between the crop genotypes were substantial but not significant. Average value for groundnut was 5.00 mg/kg and for cowpea the value was 6.12 mg/kg (Table 4.19).

4.5.5 Exchangeable Bases, Exchangeable Acidity(EA) and Electrical Conductivity (EC)

The effects of treatment on exchangeable bases of the cropped soils are shown in Table 4.20. Generally, mean values of the exchangeable bases under the groundnut crop were not significantly influenced by treatments, except Mg that was influenced by the groundnut genotype. Mean exchangeable Mg value under SAMNUT 23 was 1.01 c mol/kg but was as high as 1.31 c mol/kg (Table 4.20) under SAMNUT 14. It is interesting to note that Mg is normally involved in N-fixation, the relevance of Mg for the groundnut crop can be assumed by the results shown here. For the cowpea crop, mean exchangeable basic cations were not significantly influenced by the factors considered, though the mean calcium content was only marginally influenced by the cowpea

Table 4.20: Effect of Mo levels and methods of application on the exchangeable bases, Exchangeable Acidity (EA) and Electrical Conductivity(EC) of the cropped soils in the field

Groundnut

Treatment No.	Mo rate method (g/ha)	Ex Ca(c mol/kg)		Ex Mg(c mol/kg)		Ex Na c mol/kg		Ex K(c mol/kg)		E.A(c mol/kg)		E.C dsm^{-1}	
		Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14
		2.90	2.26	0.75	1.39	0.43	0.37	0.25	0.31	0.09	0.05	0.03	0.04
2	100 soil	3.26	3.13	1.06	1.30	0.31	0.54	0.27	0.35	0.10	0.05	0.03	0.05
3	200 soil	3.26	2.86	1.29	1.49	0.36	0.30	0.26	0.24	0.10	0.05	0.04	0.04
4	300 soil	2.66	2.86	1.21	1.01	0.22	0.33	0.24	0.23	0.09	0.05	0.04	0.04
5	500 soil	3.00	3.40	0.70	1.12	0.48	0.34	0.29	0.25	0.07	0.05	0.03	0.03
6	200 foliar	3.53	2.80	1.02	1.53	0.43	0.36	0.32	0.25	0.03	0.04	0.04	0.04
Mean		3.10	2.89	1.01	1.31	0.37	0.37	0.27	0.27	0.08	0.05	0.04	0.04
SE		0.48		0.15		0.05		0.07		1.43		0.01	
CV		39.2		32.4		34.4		63.8		33.2		48.9	
R^2		0.41		0.57		0.48		0.46		0.54		0.51	

Cowpea

Treatment No.	Mo rate method (g/ha)	Ex Ca(c mol/kg)		Ex Mg(c mol/kg)		Ex Na(c mol/kg)		Ex K(c mol/kg)		E.A(c mol/kg)		E.C dsm^{-1}	
		IAR 48	IT95K	IAR 48	IT95 K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K
1	0 soil	3.30	2.60	1.02	0.88	0.36	0.36	0.31	0.19	0.10	0.10	0.02	0.03
2	100 soil	3.73	3.30	0.84	1.03	0.35	0.42	0.30	0.20	0.11	0.07	0.05	0.03
3	200 soil	3.63	2.40	1.12	1.13	0.31	0.35	0.25	0.21	0.12	0.09	0.05	0.04
4	300 soil	3.63	2.86	1.04	1.01	0.34	0.30	0.29	0.23	0.12	0.09	0.04	0.03
5	500 soil	3.43	3.06	1.09	1.16	0.32	0.35	0.28	0.25	0.12	0.09	0.06	0.03
6	200 foliar	3.43	3.06	1.42	1.31	0.59	0.36	0.32	0.22	0.11	0.09	0.07	0.04
Mean		3.53	2.88	1.08	1.09	0.38	0.36	0.29	0.22	0.09	0.09	0.05	0.03
SE		0.26		0.16		0.05		0.005		1.43		0.01	
CV		20.0		35.2		33.8		45.0		33.2		47.1	
R^2		0.70		0.22		0.35		0.54		0.54		0.53	

Where:

Mo rate = Molybdenum rate

Table 4.21: Effect of Mo levels and methods of application on the soil micronutrient contents in the field

Groundnut

Treatment No.	Mo rate method (g/ha)	Mi Cu(mg/kg)		Mi Fe(mg/kg)		Mi Zn(mg/kg)		Mi Mo(mg/kg)	
		Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14
		0.66	1.33	944.3	1222.1	2262.4	2403.7	3.75	5.00
2	100 soil	0.66	2.16	1666.5	1481.3	2333.1	2191.7	4.25	6.50
3	200 soil	0.66	1.50	1518.3	1370.2	2262.4	2511.8	4.75	6.25
4	300 soil	0.83	1.50	1333.2	1481.1	2262.4	2403.8	5.75	6.50
5	500 soil	0.83	1.33	1296.1	1303.5	2121.0	2403.8	5.95	5.75
6	200 foliar	0.83	1.83	1444.3	1222.1	2262.4	2403.3	4.80	6.75
Mean		0.75	1.61	1367.1	1413.4	2250.6	2386.4	4.88	6.13
SE		0.65		141.98		72.7		0.34	
CV		135.2		25.02		7.69		18.1	
R^2		0.38		0.50		0.40		0.65	

Cowpea

Treatment No.	Mo rate method (g/ha)	Mi Cu(mg/kg)		Mi Fe(mg/kg)		Mi Zn(mg/kg)		Mi Mo(mg/kg)	
		IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K
		1.13	1.33	1370.2	1444.3	2262.4	2262.4	5.75	4.75
2	100 soil	1.03	1.50	1407.2	1333.2	2333.1	2333.0	6.00	6.25
3	200 soil	0.76	1.00	918.4	1518.2	2229.0	2333.1	7.00	6.00
4	300 soil	1.00	1.50	1185.0	1111.0	2229.3	2191.7	6.50	5.50
5	500 soil	0.66	1.33	1595.4	1296.1	2333.0	2262.4	7.50	5.00
6	200 foliar	1.00	1.60	1592.4	1333.2	2333.0	2403.8	6.75	5.00
Mean		0.93	1.36	1344.8	1339.3	2296.6	2297.7	6.58	5.41
SE		0.17		135.0		30.8		0.36	
CV		35.5		24.6		8.65		14.4	
R^2		0.66		0.42		0.15		0.58	

genotypes. Generally, the exchangeable cation fertility of the soil were adequate for these savanna soils, mean Mg contents of the soils were 1.08 and 1.09.

4.5.6 Exchangeable Acidity (EA)

The EA values of the cropped soil were not influenced by rates and genotypes under groundnut but was significantly influenced by cowpea genotypes (Pr = 0.027). The EA values were lower under SAMNUT 14 relative to SAMNUT 23 and were lower under IT95K relative to IAR 48. The influence of pH on the soil N-fixing processes may therefore not be important for the conditions described in this experiment (Table 4.20).

4.5.7 Micronutrients content of the cropped Soil

The effects of Mo levels and methods on the soil micronutrient content in the field are shown in Table 4.21.

4.5.7.1 Soil Extractable Copper (Cu)

Variation in copper content was influenced by treatments under the groundnut crop but not under the cowpea crop. Genotypes therefore influenced variations significantly. Average values for SAMNUT 23 and SAMNUT 14 were 0.75 and 1.61 mg/kg (Table 4.21) respectively. For the cowpea crop, average values were 0.93 and 1.36 mg/kg for IAR 48 and IT95K respectively.

Results above showed that there was slight increase over the average mean value obtained for the two crop genotypes from that observed on Table 4.1 of pre-cropping soils, which was found to be between 0.75 – 1.33 mg/kg. Cu-uptake rates were lower than for most other micronutrients. The low requirement of many plants for copper was probably the reason why copper deficiencies occur in few soils (Mingel and Barber, 1974). The significant effect of crop genotype under cowpea (Pr = 0.0047) indicated that

the utilization of Cu by cowpea genotype differed significantly. Values were consistently lower at 200g Mo/ha for the cowpea crop, which may reflect the optimum level of applied Mo as it related to N-fixing processes and crop performance. This observation was not emphasized under the groundnut crop.

4.5.7.2 Soil Extractable Iron (Fe) and Zinc (Zn)

Soil extractable Fe was significantly influenced by groundnut genotypes but not by cowpea crop genotypes. Values ranged from 994 to 1666 mg/kg for groundnut crop and 918 to 1595 mg/kg (Table 4.21) for the cowpea crop. Variation in values were not consistent with increase in level of Mo application.

The importance of Fe in groundnut may be emphasized, but the utilization of Fe decrease with rate of Mo application for SAMNUT 23 but was rather erratic for SAMNUT 14 though, the trend decreased with rate of application. For the cowpea crop, lower values of this nutrient were obtained at 200g Mo/ha for IAR 48 (918 mg/kg) and 300g Mo/ha for IT95K (1111 mg/kg). Generally the difference in the Fe content of the cropped soils in cowpea was not significant.

The Zn content was not appreciably influenced by treatment under groundnut and cowpea, and no particular pattern of utilization was observed for both and within genotypes. Three observations can be drawn to this with respect to Zn fertility. The first is that the soil may have being fertile enough not to require Zn fertilization, secondly, the crops may not have required Zn for its metabolic processes, and thirdly, cations do influence Zn uptake, with evidence of such inhibition existing for a number of cations (Chaudry and Loneragan, 1972). Cu has generally been found to inhibit Zn uptake, this is

evident from the result contained in Table 4.21. The average mean values of Zn was quite higher than that obtained for the pre-cropping soils (Table 4.1).

4.5.7.3 Soil Extractable Molybdenum (Mo)

The Mo content of the soil was influenced significantly under the cowpea crop. Differences due to effects of treatments ascribed to crop genotype under cowpea was highly significant (Pr = 0.014). The effect of Mo rate and interaction was only marginally significant (Pr = 0.09 and Pr = 0.06 respectively). Conversely, influence under the groundnut crop was not significant for all the factors considered. Average soil Mo content under SAMNUT 23 was 4.88 mg/kg and SAMNUT 14 was 6.13 ppm. The general trend however, under groundnut was that soil Mo content increased with rate of application. Effects of foliar application was similar to soil application under the groundnut crop. But, for the cowpea crop, average value for IAR 48 was 6.58 mg/kg and 5.41 mg/kg for IT95K. Build up of soil Mo content increased to the second level of Mo applied under cowpea and tended to decrease with rate of application though erratically for IAR 48. For both cowpea genotypes, foliar application was inferior to soil application from the results contained in Tables 4.21 and the pre-cropping sample (Table 4.1). The average mean value of Mo in the cropped soil (Table 4.21) was slightly lower than that obtained for the pre-cropped soil. Mo concentration in plant is a measure of level of available soil Mo. Mo concentration in the seed is usually much higher than in the leaf or in the soil (Lavy and Barber, 1963). This accounted for the decrease in values obtained by cropping (Table 4.21) against that of the pre-cropped soil (Table 4.1).

Table 4.22: Effect of Mo levels and methods of application on grain nutrient content in the field

Groundnut

Treatment No.	Mo rate method (g/ha)	Total P %		Fe(mg/kg)		Cu(mg/kg)		Mo(mg/kg)		Zn(mg/kg)		Total N %	
		Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14	Sam23	Sam 14
		40.9	41.7	13.7	15.1	1.16	0.83	5.75	5.50	445.4	473.6	5.88	5.62
2	100 soil	33.6	42.5	10.7	19.2	1.00	1.00	7.00	7.00	501.9	332.2	6.32	5.85
3	200 soil	60.7	52.3	7.77	12.9	1.16	1.00	7.50	7.25	523.1	395.9	6.04	5.99
4	300 soil	54.0	50.8	9.62	18.1	1.00	1.16	6.50	9.25	452.4	466.6	6.22	5.70
5	500 soil	44.9	53.3	11.1	14.4	1.16	0.83	6.75	7.25	516.1	482.4	5.69	5.51
6	200 foliar	52.0	55.2	14.4	9.99	1.00	1.16	7.50	6.25	410.0	523.1	5.74	5.66
Mean		48.6	49.3	11.2	14.9	1.08	1.00	6.83	7.08	474.8	445.6	5.98	5.72
SE		5.46		1.77		0.13		0.57		37.4		0.24	
CV		27.3		33.1		30.9		20.1		19.9		9.83	
R^2		0.62		0.51		0.55		0.59		0.52		0.23	

Cowpea

Treatment No.	Mo rate method (g/ha)	Total P %		Fe(mg/kg)		Cu (mg/kg)		Mo(mg/kg)		Zn (mg/kg)		Total N %	
		IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K	IAR 48	IT95K
1	0 soil	42.2	48.4	17.7	19.9	1.16	1.00	4.50	5.50	388.8	494.9	5.91	5.84
2	100 soil	56.89	55.5	13.7	11.1	1.16	1.16	6.50	6.50	445.9	459.5	6.23	6.22
3	200 soil	66.1	57.5	9.25	15.5	0.83	1.16	6.00	6.25	459.5	431.2	5.95	6.06
4	300 soil	48.1	56.5	11.4	13.3	0.83	1.00	7.25	6.50	318.1	459.5	5.84	5.65
5	500 soil	53.3	52.0	9.62	14.4	1.00	1.00	6.50	7.00	410.0	577.0	6.52	5.55
6	200 foliar	44.5	54.3	11.4	15.1	1.00	1.00	6.50	6.50	374.7	374.7	6.72	6.26
Mean		51.8	54.0	12.2	14.9	1.00	1.05	6.04	6.40	399.4	466.1	6.20	5.93
SE		4.75		2.17		0.13		0.46		45.6		0.34	
CV		21.9		39.2		32.1		17.6		25.8		13.6	
R^2		0.71		0.45		0.62		0.67		0.74		0.21	

4.6 The Nutrient Contents of the Grain of the field grown crop.

4.6.1 Total Nitrogen

The effects of Mo levels and methods on grain nutrient content in the field are shown in Table 4.22. The total N content of the grain was not significantly influenced by the Mo application nor by the method of application for both groundnut and cowpea crops. The levels of influence on treatment on accumulation of the grain was low (R^2 = 0.23 and R^2 = 0.21) for groundnut and cowpea respectively. However, maximum increase of the grain N-content was induced by 100g Mo/ha for SAMNUT 23 and 200g Mo/ha for SAMNUT 14. Mean values between genotypes of groundnut were 5.96% for SAMNUT 23 and 5.72% for SAMNUT 14. In the cowpea crop, maximum increase was induced by 100g Mo/ha for IAR 48 and 100g Mo/ha for IT95K. Foliar application was not significantly different from soil application in inducing N-accumulation in the grains.

4.6.2 Total Phosphorus (P)

Total P values of the grains were also not significantly influenced by treatment effects but the level of influence by treatment was greater relative to N as shown by the R^2 values (R^2 = 0.62 and R^2 = 0.71) for groundnut and cowpea respectively. Total P of grain content increased to 200g Mo/ha for SAMNUT 23 and 500g Mo/ha for SAMNUT 14 though this responses were not significant. It reflected the level of utilization efficiency for both genotypes. Under cowpea, values increased to 200g Mo/ha for both IAR 48 and IT95K. Mean P values were higher under cowpea than groundnut. In both crops foliar application was inferior to soil application and in the residual P accumulation for the crops.

4.6.3 Micronutrients

The only two micronutrient elements that were influenced by treatments in the accumulation of nutrients in the grain were Fe for groundnut (Pr = 0.016) and Zn for cowpea (Pr = 0.08) but for Cu, it was only marginal significant for cowpea. The influence of treatments on the other micronutrients in the grains were not significant.

The consistency of Fe uptake and soil Fe build up for groundnut indicated preferential need of this nutrient by the groundnut crop. For cowpea the need for Cu was emphasized. However, the influence of Mo rate and method on Mo accumulation on the grain, though not significant in both crops, revealed marginal increase with rate of application for both crops. Grain Mo content increased to 7.50 mg/kg for SAMNUT 23 with application of 200g Mo/ha and 9.25 mg/kg for SAMNUT 14 with 300g Mo/ha(Table 4.22). Average values for SAMNUT 23 and SAMNUT 14 were 6.83 mg/kg and 7.08 mg/kg. Marginal increase was also observed for cowpea and increases were observed up to 7.50 mg/kg with 200g Mo/ha for IAR 48 and 7.00 mg/kg with 500g Mo/ha for IT95K. Mean values were 6.04 mg/kg and 6.40 mg/kg for IAR 48 and IT95K respectively. It would be noted that Mo content of groundnut grain was higher than for cowpea grain by value of about 10%. As was indicated by the preliminary data of the soil, deriving the Mo level of the grain that may enhance a good production of the grain legumes without fertilization, which is pertinent in this study, can be obtained by simple regression studies. It may also be noted that this optimum level of Mo in the seed can vary with the soil fertility and as shown from the study, will differ with crop types and genotypes.

Relating Mo content in the grain to the grain yield obtained in the field, the Mo level desired for the genotypes was estimated to be 7.00 mg/kg for SAMNUT 23 and 7.25 mg/kg for SAMNUT 14. These values could also be 7.00 mg/kg for both genotypes of cowpea. It may also be seen that higher accumulation of Mo in the seed, which may suggests higher level of Mo in the soil, may be detrimental to the crop. Attestation to this fact can be advanced by the declining yields obtained with increase accumulation of Mo in the grains at higher level of Mo application.

4.7 Correlation Studies – Field

4.7.1 Groundnut

The effects of treatments on the relationships of agronomic parameter to soil parameter for the groundnut crop are shown in the correlation matrix in Table 4.23. Relationship among the agronomic parameter revealed that nodule count and nodule weight varied positively, but root weight only influenced haulm weight in groundnut. Pod weight was also influenced by plant biomass (r = 0.43*).

Grain yield varied positively and significantly with haulm weight (r = 0.466**), so we can infer from this relationship that a good crop of groundnut with good biomass production would reflect on a good pod and grain yield for groundnut. The influence of soil parameters in this relationship was not significant with nodule count and nodule weight as no parameter influenced these two characteristics significantly. Field pod yield was negatively influenced by soil exchangeable bases, especially Mg. Grain yield was only positively influenced by Cu, and haulm weight was positively influenced by total N (r = 0.33*). The relationship shown by the regression coefficients for groundnut revealed that N was an important nutrient for the groundnut crop which could only have being

Table 4.23: Correlation matrix of soil parameters and agronomic parameter in the field experiment (groundnut)

	Nd ct	Rt wt	Pod wt	Nd wt	Us fld wt	G/yld	Fr bio wt	DMY	Haum wt	No pod
Org	0.074	0.107	0.047	0.299	-0.185	-0.169	-0.022	-0.084	-0.223	-0.043
Av p	0.156	0.192	0.046	0.150	-0.087	-0.084	-0.004	0.008	0.294	-0.073
EA	0.219	0.154	0.065	0.023	-0.045	-0.122	0.037	-0.021	0.294	-0.181
Tot N	0.156	0.146	-.110	0.084	0.001	0.269	-0.115	-0.103	0.330*	-0.159
EC	0.169	0.148	0.050	-0.004	-0.094	-0.198	-0.089	-0.030	0.400*	0.058
TotP	0.318	0.092	0.049	0.059	0.125	-0.176	0.056	0.064	0.206	0.040
ExCa	0.012	0.107	0.349	-0.002	-0.030	0.161	0.145	0.235	0.043	-0.083
ExMg	0.117	0.039	0.015	-0.093	0.364*	-0.463	0.165	0.204	-0.310	0.108
Na	0.048	0.155	0.026	-0.060	0.114	0.230	-0.214	-0.215	-0.161	0.057
K	0.005	0.061	0.336*	-0.005	0.080	0.245	-0.449	0.085	-0.179	-0.113
Fe	0.004	0.197	0.004	0.012	-0.084	-0.047	0.230	0.094	-0.197	0.032
Zn	0.074	0.100	0.099	-0.090	-0.225	-0.261	-0.009	0.074	-0.252	0.315
Mo	0.089	0.389	0.416	0.206	-0.451	-0.220	-0.432	-0.230	-0.430	-0.002
Cu	0.065	0.044	0.015	0.199	-0.032	0.335*	0.034	0.040	-0.105	0.019
pH H_2O	0.107	0.109	0.351	0.122	0.359*	0.255	0.084	0.118	0.283	0.161
$CaCl_2$	0.023	0.132	0.050	0.216	0.080	0.032	-0.101	-0.097	0.015	0.122
Nd ct	1.000	0.142	0.032	0.320*	-0.286	0.063	0.025	0.057	-0.103	0.155
Rt wt		1.000	0.190	-0.117	0.101	0.122	0.407*	0.265	0.421*	0.094
Pod wt			1.000	-0.020	0.314	0.173	0.555**	0.430*	0.275	0.500**
Nd wt				1.00000	-0.184	0.157	-0.136	-0.142	-0.150	-0.083
Us fld wt					1.000	0.496**	0.117	-0.165	0.534**	0.042
G/yld						1.000	-0.065	-0.014	0.466**	0.086
Fr bio wt							1.000	0.787**	0.228	0.434*
DMY								1.000	0.116	0.552**
Haum wt									1.000	0.099
No pod										1.000

*= 5% level of significance

** = 1% level of significance

achieved by fixation and direct utilization. The micronutrient factor was also shown by the relationship of grain yield with Cu (r = 0.385*). No particular pattern of relationship of agronomic parameter and soil parameter was observed with groundnut, which may tend to reveal that the nutritional factors were relevant in the growth and yield of groundnut which were influenced appreciably by other processes such as physiological and N-fixation processes.

4.7.2 Cowpea

The correlation matrix of soil parameter and agronomic parameter of cowpea is shown in Table 4.24. The ultimate yield of pods in the cowpea crop was seen to relate positively with biomass production which corroborate the result shown for groundnut. Grain yield varied significantly with unshelled field weight (r = 0.725**), indicating that pod filling was good. The soil factors that influenced the relative soil parameters for cowpea where exchangeable K, which influenced unshelled field weight positively (r = 0.467*). Grain yield was only negatively influenced by Zn. The influence of Cu on the cowpea biomass was established by this study (r = 0.347*). Within limits of variation in weather conditions of the field on which the trial was conducted, there was no strong influence of soil parameter, indicating that nutrition of grain legumes may not particularly be responsive but may be controlled by physiological and N-fixing processes as shown for groundnut and now for cowpea.

4.7.3 The Effects of Agronomic Parameter on Grain Nutrient Content (Field studies)

The relationship between grain nutrient content and agronomic parameter are shown in the correlation matrix in Table 4.25. Mo accumulation in the grain was only influenced by Cu for groundnut but was not influenced by any other agronomic parameter measured.

Table 4.24: Correlation matrix of soil parameter and agronomic parameters in the field experiment (cowpea)

	Nd ct	Rt wt	Podwt	Nd wt	usfldwt	G/yld	Frbiowt	DMY	No pod
Org	0.148	0.263	-0.120	0.119	0.017	-0.128	-0.071	0.068	-0.094
Av p	0.010	-0.011	0.029	-0.099	-0.016	0.069	-0.033	-0.049	0.203
EA	0.336*	0.049	-0.085	0.315	0.145	0.225	-0.041	-0.072	-0.124
Tot N	0.270	0.235	-0.043	0.013	0.405	0.303	0.063	-0.091	0.070
EC	-0.146	-0.174	-0.263	0.084	0.267	0.124	-0.147	-0.207	-0.449
Tot P	0.150	0.310	-0.288	0.251	0.059	0.019	-0.299	-0.196	0.030
Ex Ca	-0.189	0.250	-0.162	-0.130	-0.067	-0.154	0.230	-0.120	-0.104
Ex Mg	-0.230	0.036	-0.117	-0.126	0.297	0.121	0.147	0.053	0.001
Na	-0.228	-0.201	0.057	-0.005	0.253	0.072	0.044	-0.066	-0.152
K	-0.172	0.096	-0.201	-0.123	0.467*	0.238	-0.002	-0.153	-0.162
Fe	-0.243	-0.016	0.080	-0.193	0.093	-0.039	0.080	-0.239	-0.207
Zn	-0.184	0.373*	-0.061	0.166	-0.214	-0.330*	-0.240	0.148	-0.159
Mo	-0.042	0.435	-0.219	0.165	0.158	0.053	0.009	0.427*	-0.105
Cu	0.096	0.071	0.102	-0.017	-0.066	0.083	-0.078	0.347*	0.129
pH H_2O	0.132	-0.205	0.047	0.196	0.102	0.216	-0.318*	0.224	0.021
$CaCl_2$	0.362*	0.073	-0.094	0.187	0.116	0.311	-0.029	0.067	-0.009
Ndct	1.000	0.351*	-0.045	0.303	0.089	0.032	-0.046	0.151	0.034
Rtwt		1.000	-0.020	0.170	0.129	0.134	0.358*	-0.043	0.165
Podwt			1.000	0.462*	0.175	0.335*	0.631**	0.342*	0.626**
Ndwt				1.000	-0.204	-0.269	-0.364*	-0.212	-0.173
Usfldwt					1.000	0.725**	0.128	-0.096	0.242
g/yld						1.000	0.207	0.057	0.236
Frbiowt							1.000	0.333*	0.440
DMY								1.000	0.268
No pod									1.000

*= 5% level of significance

** = 1% level of significances

Table 4.25: Effect of correlation matrix of agronomic parameters and grain parameter in the field trial (SAMNUT 14 & 23) (Groundnut genotypes)

Source of variation	Total P	Fe	Cu	Mo	Zn	Total N
Ndct	-0.010	0.035	-0.129	0.292	-0.09	-0.297
Rtwt	0.004	-0.300	0.010	-0.267	0.010	0.387*
Podwt	-0.150	-0.029	0.132	0.096	0.163	0.261
Ndwt	0.246	0.188	-0.040	0.108	-0.028	0.112
Usfidwt	-0.005	-0.071	0.218	0.050	0.059	0.392*
g/yld	-0.096	0.324*	-0.088	0.094	-0.363*	0.301
Frbiowt	-0.201	-0.087	-0.066	0.090	0.004	0.306
DMY	-0.195	0.015	0.103	0.069	-0.106	0.160
Hawmwt	0.133	-0.151	0.234	0.194	0.004	0.413*
Nopod	-0.225	0.123	0.328*	0.293	-0.011	-0.122
Totp	1.000	-0.359*	0.375*	0.259	0.389*	-0.006
Fe		1.000	-0.136	0.032	-0.454*	-0.121
Cu			1.000	0.415*	0.467*	-0.013
Mo				1.000	0.293	-0.094
Zn					1.000	-0.079
TotN						1.000

Where:

Nd ct = Nodule count	rt wt = root weight	pod wt = weight of pod
Ndwt = nodule weight	usfldwt = unshelled field weight	G/yld=grain yield
DMY = dry biomass weight	haumwt = haulm weight	nopod = No. of pod

*= 5% level of significance : ** = 1% level of significances

Table 4.26: Effect of correlation matrix of agronomic parameters and grain parameter in the Green house (IAR 48 & IT95K-499-35) (Cowpea genotypes)

Source of variation	Total P	Fe	Cu	Mo	Zn	Total N
Ndct	-0.148	-0.075	0.286	0.089	0.189	-0.068
Rtwt	0.080	-0.404	-0.060	-0.157	0.047	-0.129
Podwt	0.019	-0.180	0.016	0.000	0.134	-0.090
Ndwt	-0.139	0.122	0.132	0.330*	0.042	0.027
Usfidwt	-0.188	-0.048	-0.196	0.179	0.051	0.109
g/yld	-0.194	-0.129	-0.034	0.332*	0.126	-0.067
Frblowt	0.177	-0.538**	-0.170	-0.316*	-0.003	-0.113
DMY	-0.091	-0.099	0.220	0.166	0.385*	-0.177
Hawmwt	-0.057	-0.122	-0.036	-0.145	0.069	-0.314
Nopod	0.260	-0.0003	-0.182	-0.051	0.043	-0.088
Totp	1.000	-0.317	-0.628**	-0.561**	-0.53**	-0.077
Fe		1.000	0.321*	0.278	0.371*	0.259
Cu			1.000	0.510*	0.631**	0.026
Mo				1.000	0.458*	0.057
Zn					1.000	-0.040
TotN						1.000

Where:

Ndct = Nodule count	rtwt = root weight	podwt = weight of pod
Ndwt = nodule weight	usfldwt = unshelled field weight	g/yld= grain yield
DMY= dry biomass weight	haumwt = haulm weight	nopod = No. of pod

*= 5% level of significance; **= 1% level of significance

Root weight influenced total N accumulation in the grain (r = 0.387*) and Cu was seen to influence number of pods in groundnut. The effects of agronomic parameter on accumulation of nutrients in the cowpea crop was much more dramatic. Mo accumulation in the grain was influenced by nodule weight (r = 0.330*), grain yield and Cu content of the grain (Table 4.26). This means that for both groundnut and cowpea crops, Cu varied positively with Mo and so may be involved in similar processes in the metabolism of the grain legumes.

4.7.4 Effects of soil properties on grain nutrient contents (Field studies)

4.7.4.1 Groundnut

Tables 4.27 and 4.28 showed the correlation matrix of soil properties and nutrient content of grain for both groundnut and cowpea crops respectively. Total P accumulation in the groundnut grain was significantly influenced by AVP content of the soil and negatively influenced by the exchangeable bases. Total N content in the groundnut seed was only influenced negatively by soil Mo (r = -0.55**). Fe accumulation was positively influenced by soil Cu content, soil Mo content, exchangeable Mg and negatively influenced by EA and pH, Cu content of the groundnut grain was influenced by AVP and pH (H_2O and $CaCl_2$). The exchangeable bases negatively influenced Cu content of the grain. The Zn content of the groundnut grain was also negatively influenced by exchangeable cation and was influenced positively by pH. The Mo content of the groundnut grain was only influenced by pH ($CaCl_2$). Most other factors had negative relationship with Mo content of the seed especially the exchangeable bases.

Table 4.27: The effect of soil properties on the nutritional content of the grain – correlation matrix for SAMNUT 23 and SAMNUT 14 (groundnut genotypes) in the field.

	Total P	Fe	Cu	Mo	Zn	Total N
Organic C	0.190	0.055	0.145	0.233	0.173	-0.078
AVP	0.511*	-0.122	0.343*	0.180	0.156	0.170
EA	0.488*	-0.490*	0.120	0.211	0.309	0.218
Total N	0.115	0.061	-0.180	0.263	-0.080	-0.093
EC	-0.077	0.023	-0.075	-0.300	-0.122	-0.217
Total P	0.321*	-0.035	0.249	0.190	0.098	0.035
Ex Ca	-0.209	0.289	-0.327*	-0.242	-0.377*	0.015
Ex Mg	-0.291	0.332*	-0.329*	-0.238	-0.460*	0.003
Ex Na	-0.397*	0.145	-0.195	-0.271	-0.314	-0.137
Cu	-0.043	0.409*	-0.208	-0.127	-0.207	-0.029
Fe	-0.188	0.119	-0.031	-0.040	0.035	-0.263
Zn	-0.081	0.069	0.096	0.043	-0.705	-01.310
Mo	0.055	0.321*	0.107	0.069	-0.054	-0.550**
pH (H_2O)	0.204	-0.106	0.330*	0.181	0.055	0.202
$CaCl_2$	0.253	-0.021	0.580**	0.425*	0.421*	0.192
Ex K	-0.244	0.187	-0.101	-0.268	-0.408*	-0.160

*= 5% level of significance

**= 1% level of significance

Table 4.28: The effect of soil properties on the nutritional content of the grain – correlation matrix for IAR 48 and IT95K (cowpea genotypes) in the field.

	Total P	Fe	Cu	Mo	Zn	Total N
Organic C	0.260	-0.0003	-0.182	-0.051	0.043	-0.088
AVP	0.080	-0.239	-0.117	0.0193	-0.200	-0.408*
EA	-0.291	0.041	0.337*	0.498*	0.327*	0.252
Total N	-0.403*	0.147	0.198	0.155	0.143	0.251
EC	-0.203	0.133	0.046	0.250	0.203	0.433*
Total P	-0.263	0.0004	0.102	0.143	-0.007	0.085
Ex Ca	0.604**	-0.319*	-0.641**	-0.498*	-0.505**	0.071
Ex Mg	-0.027	0.087	-0.337	-0.159	0.003	-0.052
Ex Na	-0.055	0.264	0.040	0.164	0.075	0.701**
Cu	-0.584**	0.237	0.550**	0.288	0.344*	-0.197
Fe	0.069	0.277	-0.038	-0.029	0.136	0.468*
Zn	-0.341*	0.359*	0.327*	0.294	0.156	0.243
Mo	0.029	-0.041	-0.102	-0.093	-0.057	0.195
pH (H_2O)	-0.671**	0.273	0.646**	0.673**	0.529**	0.131
$CaCl_2$	-0.614**	0.207	0.683**	0.579**	0.427	0.097
Ex K	-0.046	-0.167	-0.176	-0.105	-0.118	0.046

*= 5% level of significance
**= 1% level of significance

4.7.4.2 Cowpea

The influence of soil parameter on the accumulation of nutrients in the cowpea seed (Table 4.26) revealed that Fe accumulation was negatively influenced by pH and positively influenced by Zn. Cu accumulation in the grain on the other hand was highly influenced by EA, Cu content of the soil, Zn content of the soil and pH. Zn content was influenced by exchangeable acidity, Cu content of the soil and pH. The Mo content of the grain was also influenced by EA and pH and negatively influenced by exchangeable cation. Mo content of the soil did not influence the accumulation of Mo in the cowpea seed as it was for groundnut. These relationships, though influenced by variations in weather conditions, can be properly quantified by regression and related to effects observed in the greenhouse.

4.8 Regression Studies

4.8.1 The influence of soil Mo application on Mo build up in the soil

Tables 4.29, 4.30 and 4.31 contains the regression equation derived from the regression analysis of the sampled data. Table 4.29 shows the estimation of soil Mo content from the influence of application levels for both crops and genotypes. Results revealed that for the field estimation Mo enrichment declined with Mo rate soil applied except for SAMNUT 23. However, for the greenhouse estimation, there was be a consistent buildup with the application of Mo for all crops except IT95K. The implication of this is that on the general assessment under field condition the soil Mo content have to be augmented by application for good crop performance. This is because of depletion due to plant uptake though, under greenhouse condition where conditions are less stressful.

Table 4.29: Estimation of soil Mo content as influenced by rate of application (Field and green house estimates)

	Crop genotypes	Equation	R^2	Grain Mo at 200 g Mo/ha (Soil applied Mo)
Field estimates	SAMNUT23	SM = 4.36+0.001R	0.12	4.56 mg/kg
	SAMNUT14	SM = 6.19-0.0008R	0.02	6.03 mg/kg
	IAR 48	SM =6.25-0.002R	0.17	5.85 mg/kg
	IT95K	SM = 6.61- 0.003R	0.20	6.01 mg/kg
Greenhouse	SAMNUT23	SM= 5.96+0.001R	0.05	6.17 mg/kg
estimates	SAMNUT14	SM = 6.28+0.001R	0.03	6.48 mg/kg
	IAR 48	SM = 4.76+0.001R	0.07	4.96 mg/kg
	IT95K	SM= 6.59-0.0006R	0.004	6.47 mg/kg

The accumulation of Mo in the soil due to application was consistent as shown by the regression coefficient of 0.001 for all crops except IT95K.

4.8.2: The influence of soil Mo content and accumulation of Mo in the grain

Table 4.30 shows the regression equations for the estimation of grain Mo as influenced by soil Mo content. Estimates revealed negative regression coefficient for all crops except SAMNUT 14 in the field estimation. However, under greenhouse conditions a consistent build up was observed and expected for grain Mo with increase in soil Mo content as all coefficient were positive. Again this might be due to less stress condition with respect to growth conditions in the green house. Under field conditions, soil Mo contents should be an average of x to supply adequate Mo for grain legumes. The cowpea varieties were more efficient in Mo use.

4.8.3: Influence of Mo levels on grain Mo content

Table 4.31 showed the estimation derived from the relationship of grain Mo content with application rates. It is interesting to note that a negative coefficient was obtained for groundnut under field conditions but positive coefficient for cowpea. Under greenhouse condition these coefficients were positive. The calculated values for the grain Mo content for each crop showed the amount of seed Mo content that would be considered adequate for a good crop. These values ranged from 5.88ppm for IAR 48 to 7.20ppm for SAMNUT 23. Grain Mo content was higher under green house conditions.

Table 4.30: Estimation of grain Mo content as influenced by soil Mo content

	Crop genotypes	Equation	R^2	Grain Mo at 200 g Mo/ha (Soil applied Mo)
Field estimates	SAMNUT23	GrMoC = 8.81-0.367SM	0.04	7.14 mg/kg
	SAMNUT14	GrMoC = 3.43+0.64SM	0.09	7.27 mg/kg
	IAR 48	GrMoC = 9.21-0.47SM	0.06	6.45 mg/kg
	IT95K	GrMoC = 6.77-0.036SM	0.0008	6.55 mg/kg
Greenhouse	SAMNUT23	GrMoC = 1.67+0.96SM	0.97	7.59 mg/kg
estimates	SAMNUT14	GrMoC = 5.91+0.47SM	0.24	9.02 mg/kg
	IAR 48	GrMoC = 5.31+0.47SM	0.10	7.64 mg/kg
	IT95K	GrMoC = 4.25+0.67SM	0.43	8.58 mg/kg

GrMoc= Grain Mo content, R= Mo rate (200 g Mo/ha), SM= Soil Molybdenum

Table 4.31: Estimation of grain Mo content as influenced by Mo rate (field and green house estimates).

Field estimates

	Crop genotypes	Equation	R^2	Grain Mo at 200 g Mo/ha (Soil applied Mo)
Field estimates	SAMNUT23	GrMoC = 7.40-0.001R	0.02	7.20 mg/kg
	SAMNUT14	GrMoC = 6.92-0.001R	0.01	6.72 mg/kg
	IAR 48	GrMoC =5.28+0.003R	0.15	5.88 mg/kg
	IT95K	GrMoC = 6.33+0.0009R	0.01	6.51 mg/kg
Greenhouse	SAMNUT23	GrMoC =7.32+0.002R	0.08	7.72 mg/kg
estimates	SAMNUT14	GrMoC = 8.66+0.002R	0.06	9.07 mg/kg
	IAR 48	GrMoC = 7.57+0.0008R	0.007	7.73 mg/kg
	IT95K	GrMoC = 7.61+0.001R	0.19	7.81 mg/kg

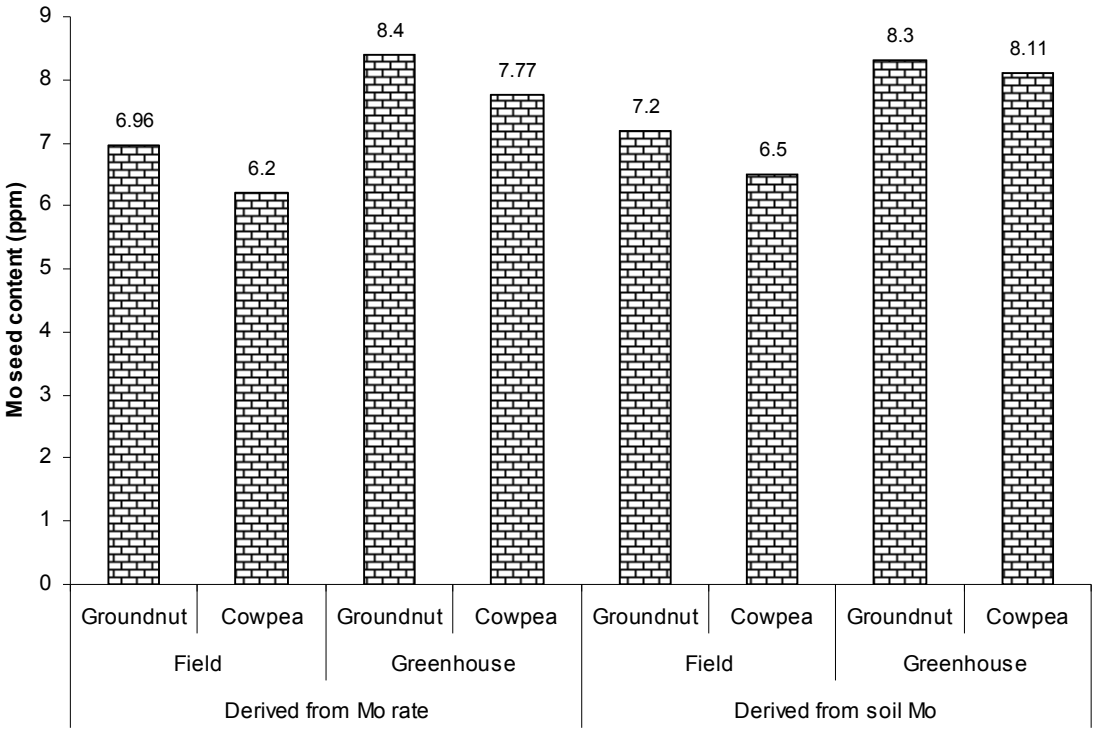

Fig. 5: Calculated mean seed (grain) Mo content of the cowpea and groundnut genotypes derived from the field and greenhouse studies.

CHAPTER FIVE

5.0 SUMMARY AND CONCLUSION

5.1 Summary

A study was conducted to evaluate the effect of molybdenum treatments,(Mo levels, methods of application, soil or foliar applied) on seed molybdenum content, nodulation and yield parameters of groundnut and cowpea genotypes in a Northern Guinea savanna (NGS) Alfisol. Generally, production figures of grain legumes in the NGS have shown declining trend due to nutrient deficiencies, especially N which is the major constraint for the production of grain legumes in tropical savanna. This situation is associated with low Mo content of this tropical soil. Mo enhances nodulation in legumes and in effect N fixation. However, utilizable N in legumes is manufactured directly by the crop and response to N have often being associated with Mo supply to grain legumes in N deficient soils. The supply of Mo to planted grain legume crop can be either soil or foliar applied. A third method, which is the Mo content of the seeds of planted grain legumes, has not being exploited for this purpose. Considering the amount of the Mo element required to meet the needs of the crops for good nodulation and N fixation is small, it is expected that the amount of Mo in the seed would provide a more economically viable prospect of the three options listed. The study therefore had the following objectives: (1) To determine the effects of varying levels of Mo fertilization on the seed Mo content of groundnut and cowpea genotypes, (2). To investigate the levels of Mo in the seed considered adequate for nodulation,(3). To determine the effect of Mo levels on yield and yield related parameters of the crops.

To achieve the objectives of the study, one greenhouse and one field trial were conducted to determine the optimum Mo levels on yield and yield related parameters of the groundnut and cowpea genotypes and on the accumulation of Mo in the grain. The soils used for the study

(green house and field) were Alfisols. The soils were slightly acidic with low organic matter content, low total N and AVP content. Treatments consisted of 6 Mo treatments, which consisted of 5 levels of Mo (0, 100, 200, 300 and 500g Mo/ha) soil applied and one level of Mo (200g Mo/ha) applied foliar. Two groundnuts varieties, SAMNUT 23 and SAMNUT 14 and two cowpea varieties IAR 48 and IT95K-499-35 were used as test crops.

The results obtained from the study can be summarized and conclusions drawn as follows:

1. Nodule count – for adequate nodulation of both groundnut and cowpea genotypes, 200g Mo/ha soil applied was found to produce optimum number of nodules. Foliar application was consistently inferior to soil application. The average numbers of nodule produced by the crops were 203 for both groundnut genotypes. Values varied for cowpea, and were 38 for IAR-48 and 19 for IT95K.
2. Nodule weight varied between genotypes of groundnut and cowpea genotypes, and 200g Mo/ha was optimally adequate for all genotypes, though response was found to vary between 100 – 200g Mo/ha. Mean nodule weight values per plant were 0.57 for groundnut and 0.27g per plant for cowpea.
3. The effect of Mo levels on root weight was not significant for both crop genotypes. Mo levels seemed to depress root weight in groundnut, while for the cowpea genotypes, response ranged from 100 – 300g Mo/ha. Foliar applied Mo stimulated more root development in groundnut but not in cowpea. Result showed that root development was in response to nutrient deficiency and deriving suitable level of Mo supply would ensure good nutrition of grain legumes.

4. For earliness in phenotypic maturity, as shown by the crop performance at 8 weeks of planting (green house and destructive sampling), expressed by DMY, pod yield and grain yield at 8 weeks, 200g Mo was adequate for groundnut for all the parameters mentioned and foliar application was superior for SAMNUT 23 and not for SAMNUT 14. With regard to cowpea, response went up to 300g Mo/ha soil applied for both genotypes. From the results, the need for soil applied Mo as a management strategy for the genotypes was demonstrated.
5. Results revealed that preferences for foliar or soil applied Mo methods can vary even within same genotype of crop species by values as high as 50%. DMY of groundnut genotype, SAMNUT 23 in the greenhouse was 7.27 g/pot for soil applied and 16.00 g/pot for foliar application at similar level of Mo application.
6. Optimum grain yield for groundnut was 700 kg/ha for SAMNUT 23 at 100g Mo/ha and 726 kg/ha for SAMNUT 14 at 200g Mo/ha. In both cases, soil application was superior to foliar application. Optimum grain yield for the cowpea genotypes were 1218 kg for IAR-48 at 200g Mo/ha foliar applied, and 1150 kg/ha for IT95K at 200g Mo/ha soil applied. The crop species varied in both Mo use efficiency and preferential method of Mo application for optimum performance.
7. Pod yield values of the crop species revealed that for SAMNUT 23 and IAR-48 varieties of groundnut and cowpea, Mo use can be better managed by foliar application at 200g Mo/ha, whereas SAMNUT 14 and IT95K can be better managed by soil application under field conditions where factors influencing crop grown can vary widely.
8. Mo application resulted in organic carbon accretion in soil by an average value 24.1% in the greenhouse soil and 6.1% in the field soil, and in both situations, the potential was better

under cowpea. Mo could therefore improved organic carbon content under good management practices.

9. The effect of Mo levels on soil N building up was not significant for both crop species. Results however revealed on comparative terms, that the cowpea crop was most efficient in influencing N -build up in the soil.
10. Soil Mo content varied significantly with treatments under cowpea and was not significantly influenced under groundnut. This indicates the degree of relevance of Mo for grain legumes under field condition. Mean depletion of Mo occurred at all level of Mo application for both groundnut and cowpea genotypes.
11. Results also revealed that both methods and level of application of Mo were important in the accumulation of nutrients in the grain of the various genotypes of groundnut and cowpea. In general, foliar application induced higher Mo accumulation in the grain. Mo rate significantly influenced Mo content in the grain.
12. With rates of between 100-200g Mo/ha, grains Mo content were 7.75 mg/kg and 9.50 mg/kg for SAMNUT 23 and SAMNUT 14 respectively, and 8.25 mg/kg and 8.50 mg/kg for IAR-48 and IT95K respectively (green house).
13. Result derived from the correlation studies revealed that a good rooting system in groundnut and cowpea were necessary for high pod and grain yields, and the significance of P and K for good nodulation and yield of the grain legumes were established.
14. Results also revealed that the role of Mo and Cu were physiological, and were both involved in the processes that control nutrition and N-fixation and yield in the crops. Both nutrients varied positively with each other, and so could be said to be involved in similar processes in the metabolism of the grain legumes.

15. Results showed that the effect of soil Mo content was positive and significant in the accumulation of Mo in the grain (r = 0.69**) and this therefore revealed that Mo application influenced the grain Mo content, which is in line with the hypothesis of the study.
16. Generally, 200g Mo/ha was derived as Mo rate adequate for planted grain legumes in this study. Results also revealed that with 200g Mo application/ha, the average grain Mo content for groundnut was 6.95 mg/kg and 6.20 mg/kg for cowpea, for the field grown groundnut and cowpea genotypes.

5.2 Conclusion

In conclusion, the study revealed that 200g Mo/ha, soil applied in most cases was adequate for the cowpea and groundnut genotypes, and a seed Mo content of 7.00 mg/kg could suffice in place of soil or foliar Mo application for Mo management of the field grown grain legumes in the savanna Alfisol.

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APPENDIX

Appendix 1. Mean decade climate data in Samaru during 2008 cropping season

Month	Decade	Rainfall (mm)	Max (^{o}C)	Min (^{o}C)	SH	RH (%)
March	1	0	38.4	18.8	NA	16
	2	0	38	19.5	NA	9.2
	3	0	40	22.0	NA	34
April	1	2.4	37	22.0	NA	25.4
	2	0	39.1	21.2	NA	30.5
	3	52.2	36.1	23.0	NA	56
May	1	7.5	37.8	23.0	NA	47.8
	2	34.8	34.6	21.5	NA	64.2
	3	52.9	33.3	21.4	NA	72.4
June	1	68	33.3	20.4	NA	72.0
	2	27.9	33.6	21.3	7.4	69.6
	3	13.1	32.1	20.8	6.8	75.5
July	1	61.0	30.7	19.6	5.6	78.1
	2	7.5	30.1	20.4	6.6	78.0
	3	133	30.5	20.3	6.6	81.6
August	1	124.4	29.5	19.4	4.4	81.8
	2	116.5	29.5	19.5	3.2	80.2
	3	83.2	29.6	19.4	NA	83.6
September	1	144.6	31.2	24.6	NA	79.1
	2	56.6	31.0	25.0	2.2	77.3
	3	44.9	32.1	25.7	6.5	75.8
October	1	68.8	31.5	20.7	6.2	77.2
	2	22.5	33.1	19.6	7.3	70.3
	3	0	34.0	15.5	9.6	40.8

Appendix 2.Analysis of variance table for the response of some grain yield parameters as function of treatment effect in the field (Samnut 23 and 14)

Source of variation	Df	Mean square values					
		Tot P	Fe	Cu	Mo	Zn	Tot N
Rep	2	2487.9**	25.9	1.18**	16.7**	48551.6*	0.10
Morate	5	265.0	17.2	0.01	2.57	4108.5	0.22
Cropvar	1	4.31	127.5*	0.06	0.56	7663.5	0.60
Morate * cropvar	5	53.8	36.0	0.07	3.52	16442.3	0.05

Appendix 3.Analysis of variance table for the response of some grain parameters as function of treatment effect in the Greenhouse (IAR 48 and IT95K)

Source of variation	Df	Mean square values					
		Tot P	Fe	Cu	Mo	Zn	Total N
Rep	2	26.1	62.7	0.17	22.4**	35594.1	0.47
Morate	5	91.9*	29.0	0.07	3.67*	54916.1	0.45
Cropvar	1	179.9*	167.9*	0.06	4.31	33848.7*	0.05
Morate * cropvar	5	204.5**	50.3	0.19*	2.88	3893.1	0.28

Appendix 4. Analysis of variance table for the response of some grain parameters as function of treatment effect in the Greenhouse (Samnut 23 and Samnut 14)

Source of variation	Df	Mean square values					
		Tot P	Fe	Cu	Mo	Zn	Total N
Rep	2	159.6**	13.8	0.25	10.6*	58068.2*	0.06
Morate	5	42.71	21.9	1.00	2.10	7795.7	0.06
Cropvar	1	3.67	115.3*	0.02	14.6*	133824.8**	0.002
Morate * cropvar	5	109.9**	8.85	0.31	0.79	4854.9	0.23*

Appendix 5. Analysis of variance table for the response of some grain parameters as function of treatment effect in the Field IAR 48 and IT95K

Source of variation	Df	Mean square values					
		Tot P	Fe	Cu	Mo	Zn	Total N
Rep	2	2951.3**	83.1	1.79**	20.9	331120.3**	0.04
Morate	5	18.8	41.6	0.04	1.71	11553.2	0.42
Cropvar	1	40.4	66.3	0.02	1.56	400063.3	0.66
Morate * cropvar	5	85.5	14.2	0.04	1.30	10026.7	0.24

Where
Rep = Replicate
Morate = Molybdenum rate
Cropvar = Crop variety

Appendix 6. Analysis of variance table for the response of some agronomic parameters as function of treatment effects in the field (IAR 48 and IT95K)

Source of variation	Df	Mean square values								
		ndct	rtwt	podwt	ndwt	usfldwt	sthwt	frblowt	drblowt	nopod
Rep	2	1661.6*	0.07	333.0	0.02	0.05	25336.1	11846.3*	1196.4	19.0
Morate	5	692.1	4.18	207.7	0.03*	0.03	6044.4	2889.0	952.9	182.9
Cropvar	1	5088.4*	23.5*	1894.4*	0.16**	0.01	3211.1	192.1	3898.5	42.2
Morate * cropvar	5	679.6	0.89	251.6	0.02	0.07	20037.7	4536.8	784.7	233.6

Appendix 7. Analysis of variance table for the response of some agronomic parameters as function of treatment effects in the field (Samnut 23 and Samnut 14)

Source of variation	Df	Mean square values									
		ndct	rtwt	podwt	ndwt	usfldwt	sthwt	frblowt	drblowt	harwt	nopod
Rep	2	4581.7	1.88	11.09	0.02	0.29	4433.3	4440.6	588.2	0.33**	260.0
Morate	5	35515.3**	7.90	107.0	0.03	0.06	23513.3	3436.5	407.7	0.11	567.5
Cropvar	1	2304.0	6.97	494.6	0.20*	4.25**	4444.4	2386.8	12.2	0.53*	56.2
Morate * cropvar	5	6880.2	4.68	178.9	0.06	0.16	90131.1*	5098.0	575.9	0.03	246.2

Where: Rep = Replicate; Morate = Molybdenum rate; Cropvar = Crop variety

Appendix 8. Analysis of variance table for the response of some agronomic parameters as function of treatment effects in the greenhouse (Samnut 23 and 14)

Source of variation	Df	Mean square values								
		ndct	rtwt	podwt	ndwt	usfldwt	sthwt	frblowt	drblowt	nopod
Rep	2	47.0	1.64*	0.74	0.07	86.9	235.5	44.9	21.8*	6.86
Morate	5	2369.6	0.51	1.42	0.02	15.7	226.1	61.7	18.1*	6.51
Cropvar	1	22450**	4.67*	0.19	0.09	25.2	529.0	247.4*	0.005	266.7**
Morate * cropvar	5	1565	0.06	0.89	0.01	5.24	340.0	30.3	32.2**	8.37

Where
Rep = Replicate
Morate = Molybdenum rate
Cropvar = Crop variety

Appendix 9. Analysis of variance table for the response of some agronomic parameters as function of treatment effects in the greenhouse (IAR 48 and IT95K)

Source of variation	Df	Mean square values								
		Ndct	rtwt	podwt	ndwt	usfldwt	sthwt	frblowt	drblowt	nopod
Rep	2	103.3	0.01	0.09	0.01	576.2*	52.0	257.5	3.31	21.1*
Morate	5	189.0	0.10	2.45	0.01	139.8	46.8	93.7	13.0	18.1
Cropvar	1	2516.6*	0.87*	8.80*	0.03	258.2	25.0	637.5*	27.8	40.1*
Morate * cropvar	5	229.4	0.07	0.52	0.01	163.7	116.1	58.4	19.7	11.3

Where
Rep = Replicate
Morate = Molybdenum rate
Cropvar = Crop variety

Appendix 10. Analysis of variance for the response of some soil parameters as function of treatment effect in the greenhouse (Samnut 23 and 14)

Source of variation	Df	Mean square values														
		Org C	AVP	EA	Tot N	EC	Ex Ca	Ex Mg	Ex Na	Mic Cu	Mic Fe	Mic Zn	pH H_2O	pH $CaCl_2$	Ex K	Tot P	Mic Mo
Rep	2	0.04*	16.2*	2916.7**	0.0008	0.0001	10.8**	0.06	0.03	0.13	2649812.9**	1895806.4*	2.50**	3.81**	0.003	159.6**	18.8**
Morate	5	0.006	1.97	0.67	0.001*	0.0008	0.53	0.02	0.07	0.49	151424.3	247191.9	0.09	0.03	0.001	43.7	2.66
Cropvar	1	0.001	8.02	3.12	0.001	0.01*	1.21	0.08	0.004	0.56	87.6	5528917.3**	0.20	0.05	0.0001	3.67	1.00
Morate * cropvar	5	0.01	2.92	0.58	0.0005	0.002	0.77	0.18	0.010	0.31	1999214.1	3256164	0.08	0.01	0.004	109.9*	0.58

Appendix 11. Analysis of variance for the response of some soil parameters as function of treatment effect in the field (Samnut 23 and 14)

Source of variation	Df	Mean square values														
		Org C	AVP	EA	Tot N	EC	Ex Ca	Ex Mg	Ex Na	Mic Cu	Mic Fe	Mic Zn	pH H_2O	pH $CaCl_2$	Ex K	Tot P	Mic Mo
Rep	2	0.01	125.6**	190.3**	0.0003	0.003	9.04	0.98*	0.05*	1.04	653252.5*	48108.2	0.74*	1.27**	0.08	683.4**	1.02
Morate	5	0.008	7.43	12.2	0.0001	0.0001	0.22	0.16	0.02	2.35	175789.1	13667.2	0.22	0.08	0.02	55.2	1.93*
Cropvar	1	0.04	6.89	75.1	0.0001	0.0001	0.26	0.82*	0.00006	6.67	19293.2	152750.6*	0.06	0.10	0.00006	176.0*	12.2**
Morate * cropvar	5	0.02	10.1*	7.16	0.0002	0.0002	0.52	0.12	0.02	2.79	107341.4	33605.1	0.22	0.01	0.05	32.2	0.83

Appendix 12. Analysis of variance for the response of some soil parameters as function of treatment effect in the field (IAR 48 and IT95K)

Source of variation	Df	Mean square values														
		Org C	AVP	EA	Tot N	EC	Tot P	Ex Ca	Ex Mg	Ex Na	Mic Cu	Mic Fe	Mic Zn	Mic Mo	pH H_2O	pH $CaCl_2$	Ex K
Rep	2	65.8	24.0*	117.5**	0.0005*	0.002*	440.2**	6.87**	0.01	0.003	1.94**	226511.6	23444.6	0.04	1.61**	2.69**	0.004
Morate	5	240.0	9.84	1.31	0.00006	0.0003	23.0	0.41	0.15	0.019	0.22	99623.4	10285.8	1.75	0.03	0.04	0.03
Cropvar	1	8.96	0.01	68.8*	0.0003	0.001	87.5*	3.48*	0.00002	0.002	1.64*	219.4	27040	5.64*	0.38*	0.04	0.05
Morate * cropvar	5	8.99	8.79	2.40	0.0001	0.0007	14.17	0.41	0.02	0.017	0.09	159364.5	11700.5	2.00	0.09	0.09	0.02

Where
Rep = Replicate
Morate = Molybdenum rate
Cropvar = Crop variety

Appendix 13. Analysis of variance for the response of some soil parameters as function of treatment effect in the field (IAR 48 and IT95K)

Source of variation	Df	Mean square values														
		Org C	AVP	EA	Tot N	EC	Ex Ca	Ex Mg	Ex Na	Mic Cu	Mic Fe	Mic Zn	pH H_2O	pH $CaCl_2$	Ex K	Tot P	Mic Mo
Rep	2	0.070*	4.66	348.4	0.00008	0.01	5.62**	0.43	0.03	0.34*	33258.0	20465003	3.36	2.80	0.02*	26.1	19.3**
Morate	5	0.01	5.68	853.0	0.00007	0.02	0.83	0.11	0.05	0.04	122334.9	21282602	0.03	0.11	0.01	91.9*	1.54
Cropvar	1	0.0001	27.1	1280.7	0.000002	0.08	4.98**	0.003	0.006	0.00	444355.5	22218541	1.36	1.60	0.005	179.9*	5.61*
Morate * cropvar	5	0.017	3.41	824.6	0.0003	0.03	0.43	0.014	0.006	0.13	25508.3	2126380	0.06	0.09	0.0009	204.5**	3.12*

Where
Rep = Replicate
Morate = Molybdenum rate
Cropvar = Crop variety