AN ASSESSMENT OF LANDUSE PRACTICES INDUCING SEDIMENTATION IN KUSALLA RESERVOIR, KARAYE LOCAL GOVERNMENT AREA, KANO STATE NORTH WEST NIGERIA.

BY

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DECLARATION

I, declare that the work in thesis titled **''AN ASSESSMENT OF LANDUSE PRACTICES INDUCING SEDIMENTATION IN KUSALLA RESERVOIR, KARAYE LOCAL GOVERNMENT AREA, KANO STATE NIGERIA''** has been carried out by me in the Department of geography, Ahmadu Bello University , Zaria under the supervision of Prof. E. O. Iguisi and Dr. A. L. Bello.

The information derived from the literature has been dully 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.

ELISHA Bulus Gimba	______________	_________
Name of student.	**Signature**	**Date**

CERTIFICATION

This thesis titled ‘‘AN ASSESSMENT OF LANDUSE PRACTICES INDUCING SEDIMENTATION IN KUSALLA RESERVOIR, KARAYE LOCAL GOVERNMENT AREA, KANO STATE NIGERIA’’ by Bulus Elisha Gimba meets the regulations governing the award of masters of science of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I whole heartedly dedicate this work to God Almighty the only ruler who has the unending tenure and no one can contest His office with Him.

ACKNOWLEDGEMENT

Trillion thanks to God Almighty who is the source of every good thing, the Alpha and Omega, I call Him Jehovah the I am that I am, who by His infinite mercy have kept me alive without sickness or any accident as I travel around getting materials, in the course of my study.

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ABSTRACT

The purpose of this study is to improve the productivity of the Kusalla reservoir towards a sustainable domestic water supply and irrigation activities in the area. The aim of this study is to assess the level of sedimentation in the reservoir, and this was achieved by determining the current depth of the reservoir, the characterization of the land use within the catchment area of *the reservoir as well as the effect of landuse changes on the sedimentation rate of the reservoir. The reservoir is located in karaye local government of kano state of Nigeria. The Level of sedimentation of the reservoir was determined by carrying out depth measurement of the reservoir from the surface to its bed during the dry season of 2011. The result obtained shows the reservoir has loss. 7.74 m depth to sedimentation, indicating 50.79% loss in installed capacity to characterize land uses changes over the catchment of Kusalla reservoir satellite imageries including lansat M.S.S 32 m resolution for 1970's, 1980's, 1990's, and 2000's were obtained and analyzed using G.I.S procedures. From the analyses of the satellite imageries, the result reveal that cultivated area increased from5662.71Hectare to10750.05Hectares; built-up area from 23.85Hectare to 654.66Hectare, from 1970's to 2000's respectively while water body show a reduction of 132.48 Hectare to 88.02 Hectares, bareland 3272.94 Hectares to 588.96 Hectares and vegetation from 3670.38Hectares to 725.67 Hectares from 1970's to 2000's respectively. The statistical analysis reveals a significant relationship between land use changes and sedimentation rate of the reservoir. The depletion of storage capacity has implication for future water supply to the resident of Karaye Getso, Dederi and Gwarzo.Watershed management,dredging and proper project monitoring among others was recommended.*

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CHAPTER ONE

1.0 Introduction

Groundnut (*Arachis hypogaea* L.) is an annual herbaceous, self-pollinating legume belonging to the family Leguminosae and sub-family Papilionaceae. It is native to South America and is one of the world's most popular and universal crops. It is grown in diverse environments in more than 100 countries on 6 different continents (Nwokolo, 1996; Sharma and Mathur, 2006).

Groundnuts are grown throughout the tropical and warm temperate climates of the world and the top ten producing countries are China (43.7 %), India (24.5 %), Nigeria (7.7 %), USA (4.9 %), Sudan (4.6 %), Burma (3.6 %), Indonesia (3.0 %), Argentina (2.6 %), Tanzania (2.0 %) and Senegal (1.8 %) where Nigeria ranks third (FAOSTAT, 2013). The estimated world production figure of unshelled groundnut as at 2013 was 45.3 million tonnes, with Nigeria producing 3 million tonnes from 2.36 million ha (FAOSTAT, 2013).

Groundnut is the thirteenth most important food crop of the world, fourth most important source of edible oil and the third most important source of vegetable protein (Taru *et al.,* 2008). It contains 48-50 % oil and 26-28 % protein, and it is a rich source of dietary fiber, minerals and vitamins (Ntare *et al*., 2008). It has a tremendous potential for mitigating the protein malnutrition in poverty ridden countries of the world.

Groundnut has high economic and nutritional potential and is an important cash crop for peasant farmers in poor tropical countries including Nigeria. Industrially, the oil produced from the kernel is used in the manufacture of lubricants and other items ranging from shaving cream and soap to plastics. The seed cake is used as livestock feed and fertilizer, and shells are utilized as filler for wallboards and insulators (Onwueme and Sinha, 1991). Groundnuts also play an extremely important agronomic role in the traditional farming system as a nitrogen fixer in crop rotation (Ustimenko-Bakumovsky, 1993). Being a leguminous crop, it can fix atmospheric nitrogen in soils through root nodule bacteria and thus improves soil fertility.

1.1 **Justification and Objectives of the Study**

The nutrients which play important role in the nutrition of groundnut are sulphur, phosphorus and calcium (Kumaran *et al.*, 2000). Calcium is among the most critical elements in the growth and development of groundnut seeds and is the major limiting factor to groundnut production in many parts of the world. Perhaps it can be said that calcium is one of the most important and vital elements in groundnut production, especially in the Virginia large seeded types (Safarzadeh, 1999; Slak and Morrill, 1972). The insufficient soil calcium in the root zone has been associated with low productivity of some soils in Nigeria (Osemwola *et al.,* 2003). Declining soil fertility, particularly calcium, has been implicated as possible cause of the low yield problem in groundnut; the deficiency results in lower yield and reduces percentage of sound mature kernel. Calcium requirement of groundnut plant is quite high and it is more during the pod filling stage and to get good quality groundnut pods, adequate amount of calcium should be present in the soil from early flowering of the crop onwards. Gypsum which is calcium sulphate is the cheapest source of calcium and sulphur and it is a by-product of fertilizer factories. Sulphur plays a role in the formation of chlorophyll and protein synthesis and it is also directly involved in the biosynthesis of oil. For these reasons, it will be of relevance if gypsum can be used to increase the quality of groundnut kernels and as such improving groundnut production.

Most soils are experiencing decline in nitrogen (N) which results from its continual depletion from the soil pool by processes such as volatization, leaching and, perhaps most importantly, removal of nitrogen-containing residues from the land (Bohlool *et al.,* 1992). Replenishment of nitrogen in agricultural soils has depended largely on the addition of inorganic fertilizers or by the activity of biological nitrogen fixation (BNF) systems. The use of inorganic nitrogen fertilizer has been useful such that today, land area under cultivation has shrunk by 4 % but production has increased by 32 % compared to 25 years ago (Smil, 2001). Unfortunately, this productivity increase has not been without consequences. The prolonged applications of large quantity of N inorganic fertilizers are manifesting themselves in environmental degradation such as leaching of nitrates into the ground water and development of soil acidity (Agbenin and Goladi, 1997; Ridley *et al*., 2004).The economic and environmental costs of inorganic nitrogen fertilizers in agriculture are a global concern and makes it mandatory for alternatives to be urgently sought. Biofertilizers are the source of microbial inoculants, which have brought hope for many countries both economically and environmentally. Therefore, in a developing country like Nigeria, biofertilizers can solve problems of high costs of fertilizers and thus save the economy. The application of organic manure and biofertilizers are frequently recommended firstly, for improving biological, physical and chemical properties of the soil, and secondly to get high and clean agricultural produce free from undesirable high doses of heavy metals and other pollutants (Veeramani and Subrahmaniyan, 2011). Rhizobial inoculation is a cheaper and usually more effective agronomic practice for ensuring adequate nitrogen supply. Thus, yields of grain legumes have been increased substantially by inoculation with the right strains of rhizobia. However, smallholder farmers in Africa have not taken full advantage of free atmospheric nitrogen input by biological nitrogen fixation to enhance legume productivity and soil health. In recognition of this, a project known as N2Africa which is being led by the Wageningen University, Netherlands is currently being executed in eight countries in sub-saharan Africa (including Nigeria) to put nitrogen fixation to work for smallholder farmers through identification of niches for nitrogen fixing legumes and support of inoculums production. This project introduced a commercial inoculant (legume fix) to farmers in Kano state for soybean production. When farmers observed that this inoculant was very effective on soybean, they started using it on groundnut (personal communication). It is of interest to investigate the response of groundnut to this inoculant as some workers have shown the possibility of cross inoculation. Moreso, as commercial groundnut inoculant is not presently in Nigeria.

Improved seed is a necessary vehicle for achieving high groundnut yields among the farming communities. Farmers using modern varieties have derived significant yield gains of 23 %, 43 % and 31 % over local varieties in Mali, Niger and Nigeria respectively (ICRISAT, 2011). SAMNUT 22 and SAMNUT 23 are new improved groundnut varieties released by the Institute for Agricultural Research, Samaru. For proper adoption of these varieties, more researches as regards the agronomic information will be required including their response to gypsum and rhizobial inoculation. The use of appropriate varieties for a particular ecology is very important in groundnut production and it is in this light that this work aims to determine the performance of these varieties in two agro-ecological zones.

The objectives therefore are:

1. To determine the optimum gypsum level on the growth, yield and seed quality of groundnut varieties.

2. To determine the effect of rhizobial inoculation on the growth, yield and seed quality of groundnut varieties.

3. To determine the variety that is better adaptable to either of the ecological zones.

CHAPTER TWO

2.0 Literature Review

2.1 Effect of Calcium on Growth and Yield of Groundnut.

Calcium is one of the less mobile nutrients in plants. In groundnut, there is little translocation from the main plant body into the forming pods (Zharare *et al*., 1998). Gascho and Davis (1994) also stated that groundnut is unique in one aspect of its nutrition: the seed develops via nutrients it gathers directly from the soil rather than those translocated from roots to shoots and back to the seeds. This unique aspect has guided the application of nutrients, especially calcium, for maximum yield, quality and seed germination. Calcium must be added to slightly acidic soils to correct pH and improve the quality of the seed (Ntare *et al*., 2008). Calcium deficiency leads to a high percentage of aborted seeds (empty pods or “pops”) and improperly filled pods (Ntare *et al*., 2008). It also leads to aborted or shriveled fruit, including darkened plumules and production of pods without seeds (Singh and Oswalt, 1995). Gascho and Davis (1994) also stated that for groundnut production in acid soils, calcium is the essential element most commonly deficient. While the most important consequence of calcium deficiency for groundnut productivity occurs in the reproductive stages of development, some indication of calcium deficiency may be evident in the vegetative growth (Gascho and Davis, 1994). Megdoff and Bartlett (1980) reported that adsorption of a basic cation like calcium ion on the exchange complex will increase the availability of nutrients due to cation exchange.

Calcium supplements have been shown to improve yield, total sound mature kernels (Hallock and Allison, 1980) and germination (Sorenson and Butts, 2008).The works of Bell *et al*. (1998) showed that the application of gypsum at 500 kg ha^{-1} increased germination of groundnut significantly and produced taller plants, more number of branches and maximum dry matter.

Germination was limited by inadequate soil calcium as observed in four different runner-type peanuts where the soil calcium ranged from 235-252 mg kg^{-1} (Adams *et al*., 1993). According to Alva *et al*., (1989) and Rao and Narayan (1990), there was a positive influence on yield, total oil content and percent sound kernel with the application of up to 672 kg ha^{-1} of gypsum. Application of 500 kg ha^{-1} of gypsum at the pegging stage produced higher pod yield compared to basal application (Agasimani *et al*., 1992). Incorporation of gypsum at 270 kg ha^{-1} 30 days before sowing increased the pod yield significantly (Sharma *et al*., 1992). Application of 500 kg ha^{-1} of gypsum in addition to NPK application significantly increased the shelling percentage and pod yield compared to NPK application alone (Sushila, 1992). Davidson *et al*. (1983) reported that application of gypsum to groundnuts grown in Georgia increased germination and reduced aflatoxin content by 40 %. Duangpatra (1987) found that seeds with high calcium and phosphorus content were high in germination percentage and seed vigour while seeds with high potassium were low in seed germination and vigor. Rahman (2006) observed that calcium significantly influenced plant height and that tallest plants were obtained from the 150 kg ha^{-1} Ca whilst the shortest plants were from the control plot. The author also noted that calcium fertilization influenced the number of branches per plant significantly with the highest number of branches produced by the 150 kg ha^{-1} Ca treatment. The works of Rahman (2006) also showed that calcium had a positive effect on the number of mature pods per plant and shelling percentage. Murata (2003) reported that increasing Ca application rates increased the pH of the soil thereby eliciting positive effects on the growth and productivity of groundnut. The results of Gajanan *et al*. (1991) and Zhang and Zhao (1995) revealed that when calcium was deficient, application of calcium gave small seed increase. Similar results were also obtained by Rahman (2006). Velasquez and Ramirez (1985) reported that calcium had a positive effect on shell of fruits and it increased weight of kernels. The most readily available index of calcium deficiency is provided by the shelling percentage. Hartmond *et al*. (1993) reported a positive correlation between the percentage of locules that filled and shelling percentage; confirming the value of shelling percentage as an index of calcium deficiency.

2.2 Effect of Calcium on the Seed Quality of Groundnut

Ranjit *et al*. (2007) reported that the oil content of groundnut differed significantly with the application of different levels of lime and that the lime level of 100 % LR recorded higher oil content (48.5 %) compared to other lime levels. Walker *et al.* (1976) found that application of gypsum to soils low in calcium increased the percentage of oil in all peanut cultivars while nitrogen content was reduced. . Rahman (2006) also found that calcium significantly affected all the yield attributes and quality up to 150 kg ha^{-1} and then declined. There was an increasing trend in qualitative characteristics like percentage of oil and protein content of groundnut with the increase in the level of calcium from 0-100 kg ha^{-1}. Works of Alireza *et al*. (2012) showed that the application of 90 kg ha^{-1} of calcium gave the highest oil content. Positive properties of gypsum and its high solubility in the soil and presence of elements such as calcium and sulphur in its combination (Ritchey and Snuffer, 2002; Gascho and Parker, 2001; and Safarzadeh, 2004) could cause an increase in the oil content of peanuts (Alireza *et al*, 2012). Application of gypsum (1.5 t ha^{-1}) at flowering was found to be most effective in increasing the oil content (Lee *et al.*, 1990).

2.3 Effect of Rhizobial Inoculation on the Growth and Yield of Groundnut

All plants must have nitrogen for proper growth. Approximately, 110 million tonnes of nitrogen is required for the world annual food production, but only 7 million tonnes are supplied by fertilizer industries, while the rest come from legumes which have special bacteria in their root system that fix atmospheric nitrogen (USDA, 2009). Biofertilizers which are cultured micro organisms packed in some carrier material for easy application are used in crop production (USA, 2003). Some identified biofertilizers that are used in crop production include: *Rhizobium, Azobacter, Azospirillium*, phosphate solubilizers, blue algae and *Mycorrhiza* (NBDC, 2000).

Rhizobia are symbiotic bacteria that are contained in the roots of specific legume hosts with the formation of new organs i.e. nodule within which the bacteria proliferate, differentiate into bacteriods and subsequently fix the atmospheric nitrogen into ammonia (Pushp *et al.*, 2011). Nodules formed by the native strains may not fix nitrogen or their fixation rate may often be inadequate. It has been suggested that the lack of response to nodulation and low yield in groundnut are probably due to competition from strains in the soil which are ineffective with this host. According to Catroux *et al.* (2001), the aim of inoculating is to provide sufficient number of viable/effective rhizobia to induce rapid colonization of the rhizosphere whereby inoculation takes place as soon as possible after germination which produces optimal yield. Recent studies have shown that inoculation with an effective rhizobium strain increased the yield as well as the oil content in groundnut (Basu, 2010). Thus inoculation helps to meet the additional demand of plant, by increasing nodulation and nitrogen fixation so as to realize the yield potential of the plant.

Subba Rao (1976) observed that rhizobium inoculation resulted in increased yields in national trials conducted at several locations. Van der Merwe *et al.* (1974) conducted 11 seed inoculation trials over three seasons in different location in South Africa where groundnuts had been cropped intensively. They obtained increased yield only in one trial, conducted at Buffelsport, so they suggested that "seed inoculation may be superfluous under the existing agricultural practices". In

Sudan, inoculation of two groundnut varieties with rhizobium strains did not result in increased yield (Hadad *et al*.,1982).

2.4 Effect of Rhizobial Inoculation on the Seed Quality of Groundnut

The results of El sheikh and Mohamedzein (1998) showed that bradyrhizobium *sp* strain TAL 100 significantly increased the protein content of groundnut seeds compared to the control in the presence or absence of nitrogen and phosphorus treatments. In India, Arora *et al.*(1970) observed that the protein content was increased by inoculation. Rahman (2006) showed that *Bradyrhizobium* inoculation affected the oil content of the groundnut seeds in India.

2.5 Effects of Calcium and Rhizobial Inoculation on the Growth, Yield and Seed Quality of Groundnut

Deficits of calcium and low pH are the most important factors limiting growth and production of groundnut. Calcium increases the growth and survival of the symbiotic bacteria in groundnut, especially in acid soils and thus, has a positive effect on nitrogen fixation (Evanylo, 1989).

Working with pea at different soil pH levels, Rice *et al*.(2000) reported that the nodule number and nodule weight increased with increasing soil pH. Lack of response to rhizobial inoculation is attributed to soil pH (Vinuesa et al., 2003; Shamseldin and Werner, 2005; Shamseldin, 2007). Acidity related factors (high Al, low Ca and low P) have direct impact on rhizobial growth and persistence as well as nodule initiation and N fixation effectiveness (Coventry and Evans, 1989). The failure of legumes to nodulate under acid-soil conditions is common, especially in soils of pH less than 5.0 (Zahran, 1999). Here, calcium serves as a liming agent thereby creating a favorable environment for nodulation, which in turn influences yield. Calcium is important for nodule formation especially at the first step of infection (Giller, 2001) which has direct and indirect effect on yield. Combined application of gypsum and biofertilizer increased the total plant dry weight in groundnut (Lee *et al*., 1990). The combined application of gypsum and biofertilizer (rhizobium) increased the chlorophyll content, nitrogen uptake and nitrogen content (Lee *et al*., 1990). The work of Rahman (2006) showed that the interaction of calcium and inoculation did not affect seed quality.

CHAPTER THREE

3.0 Materials and Methods

3.1 Experimental Site

Field trials were conducted in the wet season of 2012 at the experimental farm of the Institute for Agricultural Research, Samaru (lat 11^0 11'N; long 7^0 38' E and 686m above sea level) which is located in the Northern Guinea Savannah ecological zone of Nigeria and in the 2012/2013 dry season at the Irrigation Research Station, Kadawa (lat 11^0 39'N; long 08^0 27' E, 500m above sea level) of the Institute for Agricultural Research which is located in the Sudan Savannah ecological zone of Nigeria.

3.2 Treatments and Experimental Design and Plot Size

The treatments consisted of factorial combination of two varieties of groundnut (SAMNUT 22 and SAMNUT 23), five levels of gypsum (0, 50, 100, 150 and 200 kg ha^{-1}) and two levels of rhizobial inoculation (inoculated and uninoculated). These treatments were arranged in a randomized complete block design (RCBD) and replicated three times. The gross plot size of $18m^2$ which consisted of 6 ridges, each 4m long and the net plot size of $6m^2$ which consisted of 2 ridges, each 4m long were used.

3.3 Varieties and their Description

The seeds of the two groundnut varieties, SAMNUT 22 and SAMNUT 23 were sourced from the Seed Unit of the Institute for Agricultural Research, Samaru.

SAMNUT 22

SAMNUT 22 is a dual purpose variety with a maturity period of 110-120 days. This variety produces good proportion of both seeds and haulm. It requires early sowing. It is high yielding with a spreading growth habit and its seed coat is brown or tan in color. The variety is resistant to rossette. It has a potential yield of 2400 kg ha^{-1} (Echekwu, 2000).

SAMNUT 23

SAMNUT 23 has a maturity period of 90-100 days. It is an early maturing variety. The leaves shed when crop mature, but not completely. It can be sown much later than SAMNUT 22 without much effect on yield. It is high yielding; coat color is red, has a semi-erect growth and it is rossette resistant. It has a high potential for oil yield. It has a potential yield of 2000 kg ha^{-1} (Echekwu, 2000).

3.4 Cultural Practices

3.4.1 Land preparation

The land was harrowed twice and ridged at a spacing of 75cm. The field was then marked out into 60 plots.

3.4.2 Planting

Planting was done on the 18th July 2012 in Samaru and 14th February 2013 in Kadawa. Uninoculated seeds were first planted manually at the rate of two seeds $hill^{-1}$ at a depth of about 5 cm and intra-row spacing of 20 cm. Then, for the inoculated treatment, 100 g of the commercial inoculant (legume fix) was evenly mixed with 25 kg of seeds. The inoculants was made into a slurry form using water and the seeds thoroughly mixed with it to ensure proper coating and planted as soon as it was mixed. Three weeks after sowing (WAS), the crop was thinned down to one seedling $hill^{-1}$.

3.4.3 Fertilizer application

The experimental area received 54 kg P_2O_5 (23.8 kg Pha^{-1}) and 30 kg K_2O (24.9 kg Kha^{-1}) as single superphosphate (18 % P_2O_5) and muriate of potash (60 %K_2O) respectively which was carried out at planting. Gypsum was applied as per the treatment, 40 days after sowing (peak flowering stage) (Daughtry and Cox, 1974); and earthening up was done.

3.4.4 Weed control

Weeds were controlled by using glyphosate (round up) at the rate of 4 L ha^{-1} (1.4 kg a.i ha^{-1}) a forthnight prior to land preparation. Also, butachlor at 4 L ha^{-1} (1.4 kg ai ha^{-1}) as a pre-emergence herbicide was applied a day after sowing and two hoe-weedings were carried out 3 and 6 weeks after planting.

3.4.5 Harvesting

The crop was harvested when the vine turned yellow and older leaves started to shed. At this period, 70-80 % of the inside of the pod shells had dark markings and the kernels were well formed with color characteristic of that variety.

3.5 Soil Analysis

Prior to the establishment of the trial in each location, a composite soil sample of the experimental unit was taken randomly at depths of 0-30 cm using a soil auger. The soil samples were analyzed in the laboratory for physical and chemical properties.

Particle size analysis

Particle size distribution was determined by the hygrometer method using calgon as dispersing agent (Day, 1965). The textural class was determined by the use of standard textural triangle.

Total soil nitrogen

Total soil nitrogen was determined using Macro-Kjeldahl procedure (Bremner, 1965). Five grams of air-dry soil was put in a Macro-Kjeldahl digestion flask with 30 ml of concentrated H_2SO_4, mercury tablet and 10 gram of potassium as catalyst. The flask was heated gently for 3-5 minutes. The digest was distilled into 5 ml boric acid using 150 ml of 10 N NaOH. The distillate was then titrated against 0.01 N hydrochloric acid until it changed from green to pink.

Available Phosphorus

Five grams of less than 2 mm diameter of the air-dry soil sample was put into an extracting bottle and 100 mls of extraction solution (0.5 m) $NaHCO_3$ at pH 8.5 and on teaspoon of carbon black (Darco E60 quality) was added to the extraction bottle. This was shaken for 30 minutes in a centrifuge at the speed of 600 rmp. The supernatant solution was decanted into a clean vial and the extracted phosphorus was determined calorimetrically using molybdenum blue method (Bray and Steinerz, 1945).

Potassium

The potassium content of the soil was determined by the wet oxidation method of Walkley-Black as described by Allison (1965).

Exchangeable bases

The exchangeable bases were determined by extraction with neutral 1N ammonium acetate (NH_4OAC). Potassium (K) in the extract was determined using the atomic absorption spectrophotometer.

Cation exchange capacity

Five grams of 2 mm of air-dry soil was sieved and weighed into a centrifuge tube and 30 mls 1N ammonium actetate (NH_4OAC) solution was added using a measuring cylinder of 50 mls volumes. The tubes were then placed on a mechanical shaker and shaken for 1- 2 hours at about 2500 rpm. The extract was carefully decanted from the soil. Using a pipette, the clean clear solution was put into a clean glass vial. The sample was read alongside working standards on Aqueous Standard Solution ASS (for Ca Mg Mo) and flame photometer (for Na and K), the cation exchange capacity was then calculated.

Soil pH

Soil pH was determined in 0.01 M $CaCl_2$ and in water, using a soil solution ratio of 1:2 by means of a Philip analogue.

3.6 Meteorological Data

Records of rainfall, sunshine hours, relative humidity and temperature of the experimental sites were collected from the meteorological stations of IAR, Samaru and Irrigation Research Station of IAR, Kadawa (Appendices I and II).

3.7 Crop Growth Parameters

Five plants were tagged at random within each net plot to assess the growth and yield parameters. The destructive samples were taken outside the net plot area.

3.7.1 Stand count

This was measured by counting the number of plant stands in the net plot at 3 WAS and at harvest.

3.7.2 Days to 50 % flowering

This was determined by counting the number of days from the day of sowing to when 50% of the plants in each plot produced flowers.

3.7.3 Plant height (cm)

This was determined by measuring with a meter rule the height of the 5 tagged plants in each plot from ground level to the tip of the main stem at 3, 6, 9, 12 WAS and at harvest. At each sampling period, the mean height was expressed in cm.

3.7.4 Number of branches

This was determined by counting the number of branches from the 5 tagged plants at 3, 6, 9, 12 WAS and at harvest and thereafter mean expressed on per plant basis for each sampling period.

3.7.5 Number of leaves

This was determined by counting the number of leaves on the 5 tagged plants at 3, 6, 9, 12 WAS and at harvest and the mean later determined.

3.7.6 Dry matter accumulation (g)

This was done using 5 plants chosen randomly from outside the net plots at 3, 6, 9 and 12 WAS. This was done using a narrow- bladed hoe to lift up the plant carefully. The samples were placed in envelopes and dried to a constant weight for 48hours at 70^{o}C in the oven and later weighed using a Mettler balance model SB16001 and the mean recorded.

3.7.7 Crop growth rate (gm^{-2}wk^{-1})

The crop growth rate is the measure of the increase in dry matter per unit area of land per unit time, calculated from the formula as described by Watson (1952) and Radford (1967).

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times 1/G \quad (g.m^{-2}.wk^{-1})$$

where W_2 and W_1 refer to total dry weights per plant at times t_2 and t_1 in weeks respectively, G refer to the ground area covered by the plants.

3.7.8 Relative growth rate ($gg^{-1}wk^{-1}$)

The relative growth rate is the increase in plant material per unit of initial material per unit of time as described by Radford (1967).

$$RGR = \frac{logeW_2 - logeW_1}{t_2 - t_1} \quad (g.g^{-1}\ wk^{-1})$$

where W_2 and W_1 refer to the dry weights per plant at times t_2 and t_1 in weeks respectively

3.7.9 Number of nodules plant^{-1}

This was done at 6WAS for SAMNUT 23 and 8WAS for SAMNUT 22 by lifting up 2 plants from the border rows. The difference in the sampling periods was due to their different maturity periods. The roots of the plants were carefully cut off and washed to remove soil clods. The nodules were then counted and the mean value expressed on a per plant basis.

3.7.10 Weight of nodules plant^{-1} (mg)

This was done by detaching the nodules from the roots of two groundnut plants, washing them and placing them in envelopes to be dried to a constant weight in the oven. The nodules were weighed with a sensitive balance (Citizen electronic balance, Model MP 300) and the mean recorded on a per plant basis.

3.8 Crop Yield Parameters

3.8.1 Number of mature pods plant^{-1}

This was determined by counting the number of mature pods from the 5 tagged plants harvested and the mean recorded.

3.8.2 Number of immature pods plant^{-1}

This was assessed from the 5 tagged plants by counting the number of immature pods and the mean recorded.

3.8.3 100 kernel weight (g)

100 dried kernels were randomly taken from the harvested bulk per plot and weighed and the value recorded.

3.8.4 Pod yield plant^{-1} (g)

This was assessed by picking the pods from the 5 tagged plants and weighed using a Mettler balance model SB 16001 and the mean recorded.

3.8.5 Kernel yield plant^{-1} (g)

This was assessed by shelling the pods from the 5 tagged plants, the kernels weighed with a Mettler balance model SB16001 and the mean recorded.

3.8.6 Shelling percentage

This is the ratio of the kernel weight to the pod weight expressed as a percentage.

$$\text{Shelling percentage} = \frac{\text{weight of kernel}}{\text{weight of pods}} \times 100$$

3.8.7 Pod yield (kg ha^{-1})

Plants in the net plot were harvested, sun dried and the pods plucked and weighed to record pod yield per plot. The value obtained was then converted into pod yield per hectare by using the formula:

$$\text{Pod yield (kg ha}^{-1}) = \frac{\text{Pod yield/plot}}{\text{Net plot area (m}^2)} \times 10000\text{m}^2$$

3.8.8 Haulm weight plant^{-1} (g)

The haulm was taken from the 5 plants in the net plot and sun-dried and weighed. The average haulm weight per plant was obtained by dividing the total weight by the number of plants.

3.8.9 Haulm yield (kg ha^{-1})

This was determined by weighing the haulms from the net plot and the value converted to haulm yield in kg ha^{-1}.

3.9 Seed quality

To determine the crude protein in seeds, Kjeldahl's digestion and distillation procedure was followed to determine the total nitrogen in seeds. The percentage of protein in seeds was calculated by multiplying the nitrogen percentage by 6.25 (AOAC, 1999). Oil content of the seeds was determined using the standard extraction procedure (AOAC, 1990) using the soxhlet apparatus.

3.10 Statistical Analysis

The data collected were subjected to analysis of variance as described by Snedecor and Cochran (1978). Where F-value was significant, treatment means were compared using Duncan Multiple Range Test (DMRT) (Duncan, 1995). Correlation analysis was carried out to find the magnitude and nature of association between growth and yield parameters (Little and Hills, 1978).

CHAPTER FOUR

4.0 Results

4.1 Soil Analysis

The physical and chemical properties of the soils of the experimental sites is presented in Table 1. The soil textural class was loam and sandy loam in Samaru and Kadawa respectively and had the characteristics of high nitrogen content, medium and low organic carbon in Samaru and Kadawa respectively. Soils from both Samaru and Kadawa had high calcium content and the pH of the soils from both locations was slightly acidic.

4.2 Stand Count

The effect of gypsum rates, inoculation and variety on stand count during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa is shown in Table 2.

In Samaru, application of gypsum rates had significant effect on the stand count only at harvest where 0 kg ha^{-1} and 150 kg ha^{-1} of gypsum had the highest stand count only when compared to applied 50 kg ha^{-1} of gypsum but comparable with 100 kg ha^{-1} and 200 kg ha^{-1}. At Kadawa, application of gypsum had no significant effect at 3WAS and harvest.

At 3WAS in Samaru, stand count of the uninoculated treatment was significantly higher than the inoculated treatment. However, by time of harvest, these differences were no longer significant. At Kadawa, no effect of gypsum application was observed.

The varieties used were not significantly different in their stand count both at 3WAS and harvest in both locations.

No significant interaction of treatment factors on stand count either at 3WAS or at harvest was observed for both locations.

Table 1: Physico-chemical properties of soils at experimental fields during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

Location	**Samaru**	**Kadawa**
Soil depth(cm)	**0-30(cm)**	**0-30(cm)**
Soil characteristics		
Physical composition (g kg^{-1})		
Sand	440	600
Silt	360	320
Clay	200	80
Textural class	Loam	Sandy Loam
Chemical composition		
pH in H_2O (1:2.5)	6.41	6.98
pH in 0.01M $CaCl_2$ (1:2.5)	6.23	6.49
Organic carbon (g kg^{-1})	11.2	5.90
Available phosphorus (mg kg^{-1})	1.42	3.82
Total nitrogen (g kg^{-1})	4.00	6.30
Exchangeable bases(cmolkg^{-1})		
Ca	6.00	5.30
Mg	2.00	0.12
K	0.11	0.21
Na	1.60	0.54
CEC	6.60	4.30

Soil samples as analyzed in Agronomy Department, Ahmadu Bello University, Samaru, Zaria.

Table 2: Effects of gypsum and rhizobial inoculation on the stand count of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	SAMARU		KADAWA	
Treatments	**3WAS**	**HARVEST**	**3WAS**	**HARVEST**
Gypsum(kg ha^{-1})				
0	32.33	23.92a	27.67	27.33
50	31.25	20.50b	29.41	29.25
100	32.67	23.42ab	26.17	26.17
150	32.58	24.33a	28.75	28.75
200	31.75	22.25ab	27.83	27.83
SE±	0.551	1.080	1.325	1.358
Rhizobial Inoculation				
Uninoculated	32.63a	23.50	28.33	28.13
Inoculated	31.60b	22.27	27.60	27.60
SE±	0.349	0.683	0.838	0.859
Variety				
SAMNUT 22	32.07	23.73	28.50	28.37
SAMNUT 23	32.17	22.03	27.43	27.37
SE±	0.349	0.683	0.838	0.859
Interaction				
G*I	NS	NS	NS	NS
G*V	NS	NS	NS	NS
I*V	NS	NS	NS	NS
G*I*V	NS	NS	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. NS= Not Significant.

4.3 Plant Height (cm)

The effect of gypsum rates, inoculation and variety on plant height per plant during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa is shown in Table 3.

Application of gypsum influenced plant height only in Kadawa at 3, 6 and 12 WAS, where at 3WAS, 0 kg ha^{-1} and 150 kg ha^{-1} produced significantly taller plants than 50 kg ha^{-1} but at par with 100 kg ha^{-1} and 200 kg ha^{-1}. At 6WAS, applied 150 kg ha^{-1} produced taller plants than 50 kg ha^{-1} and 200 kg ha^{-1} but comparable with 0 kg ha^{-1} and 100 kg ha^{-1}. However at, 12WAS, 0 kg ha^{-1} produced significantly taller plants only than 100 kg ha^{-1}.

Inoculation did not affect plant height across all the sampling periods in both locations.

In Samaru, the varieties used exhibited significant differences in all the sampling periods except at 9WAS, where at 3WAS and 6WAS, SAMNUT 22 resulted to taller plant than SAMNUT 23 but at 12WAS and harvest, SAMNUT 23 produced taller plants than SAMNUT 22. However in Kadawa, SAMNUT 22 was significantly taller than SAMNUT 23 across all the sampling periods. There were no significant interactions among the treatments.

4.4 Number of Branches

The effect of gypsum rates, inoculation and variety on the number of branches per plant during 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa is shown in Table 4.

Application of gypsum was found to be significant on the number of branches only in Kadawa at 6, 12 and harvest sampled periods. At 6WAS, applied 150 kg ha^{-1} produced more branches than 50 kg ha^{-1} and 200 kg ha^{-1} but at par with 0 kg ha^{-1} and 100 kg ha^{-1}. At 12WAS, 150 kg ha^{-1} produced more branches than 200 kg ha^{-1} but at par with 0 kg ha^{-1}, 50 kg ha^{-1} and 100 kg ha^{-1}.

Table 3: Effect of gypsum and rhizobial inoculation on the plant height (cm) of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Plant height (cm)									
	Samaru					Kadawa				
Treatments	**3WAS**	**6WAS**	**9WAS**	**12WAS**	**HARVEST**	**3WAS**	**6WAS**	**9WAS**	**12WAS**	**HARVEST**
Gypsum(kg ha^{-1})										
0	8.12	13.82	29.54	35.68	37.99	7.43a	13.78ab	25.83	40.83a	49.83
50	7.93	13.67	29.12	36.10	39.33	6.10b	12.41b	24.83	39.03ab	49.50
100	8.33	13.86	28.90	35.03	38.19	7.01ab	13.22ab	24.14	35.56b	47.86
150	8.64	13.03	28.74	34.57	38.07	7.60a	14.83a	25.67	38.75ab	51.27
200	8.05	13.6	29.86	36.09	39.08	6.93ab	12.46b	25.78	39.47ab	49.69
SE±	0.273	0.415	0.543	0.728	0.933	0.361	0.565	0.970	1.318	2.700
Rhizobial Inoculation										
Uninoculated	8.10	13.51	29.49	35.71	38.81	6.73	12.86	24.92	38.26	50.01
Inoculated	8.33	13.68	28.97	35.27	38.25	7.30	13.82	25.58	39.20	49.26
SE±	0.172	0.263	0.344	0.460	0.427	0.228	0.358	0.613	0.833	1.708
Variety										
SAMNUT 22	9.01a	14.92a	29.72	34.49b	37.66b	7.95a	14.76a	27.00a	41.61a	53.60a
SAMNUT 23	7.42b	12.27b	28.74	36.50a	39.40a	6.07b	11.92b	23.50b	35.84b	45.67b
SE±	0.172	0.263	0.344	0.460	0.427	0.228	0.358	0.613	0.833	1.708
Interaction										
G*I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G*V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I*V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G*I*V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. NS= Not Significant.

Table 4: Effect of gypsum and rhizobial inoculation on the number of branches of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Number of branches									
	SAMARU					KADAWA				
Treatments	**3WAS**	**6WAS**	**9WAS**	**12WAS**	**HARVEST**	**3WAS**	**6WAS**	**9WAS**	**12WAS**	**HARVEST**
Gypsum(kg ha^{-1})										
0	3.19	12.29	22.97	26.50	31.00	2.00	7.47ab	15.31	20.69ab	43.58a
50	3.29	11.96	23.93	29.08	32.25	1.83	6.36b	12.92	21.36ab	25.25b
100	3.23	11.81	26.84	31.50	35.00	1.83	7.17ab	14.33	21.47ab	37.08ab
150	3.25	12.02	24.58	28.58	32.75	1.94	8.17a	16.58	25.47a	36.61ab
200	3.19	13.13	27.49	31.92	36.17	1.89	6.72b	14.36	17.92b	27.39ab
SE±	0.093	0.572	2.389	2.204	2.113	0.076	0.402	1.475	2.035	5.356
Rhizobial Inoculation										
Uninoculated	3.26	12.56	26.51	31.00	34.70	1.87	6.90	13.73	20.63	31.17
Inoculated	3.20	11.93	23.82	28.03	32.17	1.93	7.46	15.67	22.13	36.80
SE±	0.059	0.362	1.511	1.394	1.336	0.048	0.254	0.933	1.287	3.387
Variety										
SAMNUT 22	3.34a	13.48a	29.39a	33.20a	36.80a	1.91	7.81a	21.49a	33.29a	40.55a
SAMNUT 23	3.12b	11.00b	20.93b	25.83b	30.07b	1.89	6.54b	7.91b	9.478b	27.41b
SE±	0.059	0.362	1.511	1.394	1.336	0.048	0.254	0.933	1.287	3.387
Interaction										
G*I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G*V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I*V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G*I*V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. NS= Not Significan

However at harvest, the control significantly produced more branches only than 50 kg ha^{-1} but comparable with the rest of the rates of gypsum.

Inoculation did not affect the number of branches across all the sampling periods. The varieties used indicated that SAMNUT 22 had significantly higher number of branches than SAMNUT 23 at all the sampling periods and in both locations except at 3WAS in Kadawa where no significant difference was observed.

There were no significant interactions among the treatment across all the sampling periods in both locations.

4.5 Number of Leaves

Table 5 shows the effects of gypsum rates, inoculation and variety on the number of leaves during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

There was no significant effect of the gypsum rates on number of leaves across all the sampling periods in both locations except at 6WAS in Kadawa where 150 kg ha^{-1} produced more leaves than 50 kg ha^{-1} but at par with 0 kg ha^{-1}, 100 kg ha^{-1} and 200 kg ha^{-1}. Inoculation did not influence number of leaves across all the sampling periods in both locations.

In Samaru, there was no significant difference between the two varieties across all the sampling period except at 6WAS where SAMNUT 22 produced more leaves than SAMNUT 23. In Kadawa, SAMNUT 22 also produced more leaves than SAMNUT 23 across all the sampling periods except at 3WAS where no significant difference was observed.

There was no significant interaction among all the treatments across all the sampling periods in both locations.

Table 5: Effect of gypsum and rhizobial inoculation on the number of leaves of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Number of leaves									
	SAMARU					KADAWA				
Treatments	**3WAS**	**6WAS**	**9WAS**	**12WAS**	**HARVEST**	**3WAS**	**6WAS**	**9WAS**	**12WAS**	**HARVEST**
Gypsum(kg ha^{-1})										
0	13.69	49.12	79.07	89.07	79.83	8.69	29.19ab	108.33	241.94	373.28
50	13.98	47.90	72.05	82.05	72.33	8.14	25.28b	93.72	197.33	310.22
100	14.00	47.27	77.90	87.90	79.17	8.39	26.69ab	94.44	216.64	358.33
150	13.40	47.98	73.99	83.99	76.67	8.69	31.36a	115.50	251.72	324.53
200	13.96	52.42	73.85	83.85	74.25	8.42	27.92ab	100.83	207.56	285.97
SE±	0.357	2.300	4.027	4.027	4.014	0.274	1.733	7.653	23.815	37.646
Rhizobial Inoculation										
Uninoculated	13.87	50.20	78.05	88.05	78.50	8.41	26.86	96.24	205.48	325.53
Inoculated	13.74	47.70	72.70	82.70	74.40	8.47	29.32	108.89	240.60	325.80
SE±	0.226	1.454	2.547	2.547	2.538	0.173	1.097	4.840	15.062	23.809
Variety										
SAMNUT 22	13.81	53.91a	75.13	85.13	75.90	8.58	30.64a	139.09a	329.93a	444.41a
SAMNUT 23	13.80	43.99b	75.61	85.61	77.00	8.30	25.53b	66.04b	116.14b	216.92b
SE±	0.226	1.454	2.547	2.547	2.538	0.173	1.097	4.840	15.062	23.809
Interaction										
G*I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G*V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I*V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G*I*V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. NS= Not Significant.

4.6 Days to 50% flowering

Table 6 shows the effects of gypsum, inoculation and variety on the number of days to 50% flowering during the 2012 rainy season and 2012/2013 dry season in Samaru and Kadawa respectively.

Days to 50 % flowering was not influenced by application of gypsum rates in both locations and in Samaru, inoculation had no influence on the days to 50 % flowering, while in Kadawa, inoculated treatment took more days to 50 % flowering than the uninoculated. The variety used indicated that SAMNUT 22 took more days to reach 50 % flowering than SAMNUT 23 in both locations. There was a significant interaction between gypsum and variety in Samaru (Table 7). While holding variety constant and varying the gypsum rates from 0 kg ha^{-1} to 200 kg ha $^{-1}$, the results showed there was significant effect on the days to 50 % flowering only in SAMNUT 22 where the control delayed flowering when compared only to applied 100kg ha^{-1} of gypsum. At each of the gypsum level, SAMNUT 22 was observed to delayed days to 50 % flowering than SAMNUT 23 only at the control.

4.7 Dry matter accumulation (g)

Table 8 shows the effects of gypsum rates, inoculation and variety on the dry matter accumulation during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

Gypsum rates did not have significant effect on the dry matter accumulation across all the sampling periods in both locations except at 3WAS and 6WAS in Samaru, where at 3WAS, 200 kg ha^{-1} of gypsum produced more dry matter than 50 kg ha^{-1} which was at par with 0 kg ha^{-1}, 100 kg ha^{-1} and 150 kg ha^{-1}. Application of 50 kg ha^{-1} and 100 kg ha^{-1} produced the highest dry matter which was at par with 0 kg ha^{-1} and 200 kg ha^{-1} but higher than 150 kg ha^{-1} at 6WAS.

Inoculation did not have significant effect on the dry matter accumulation across all the sampling periods in both locations.

There were no significant difference in dry matter accumulation by the two varieties across all the sampling periods except at 12WAS in both locations where SAMNUT 22 produced heavier dry matter than SAMNUT 23.

There was no significant interaction among all the treatment factors across all the sampling periods in Samaru while in Kadawa, there was significant interaction between gypsum and variety (Table 9), and inoculation and variety on the dry matter accumulation at 9WAS (Table 10).

Varying the gypsum rates shows that there was no significant difference among the rates under SAMNUT 22 but under SAMNUT 23, the dry matter increased up to 50 kg ha^{-1} and declined at 150 kg ha^{-1} thereafter the effect was not significant. Looking at the varieties under gypsum rates, SAMNUT 22 was significant higher than SAMNUT 23 under 0 and 150 kg ha^{-1} but were at par under the other gypsum rates.

SAMNUT 22 and SAMNUT 23 were similar when they were not inoculated but a significant difference was observed in the varieties when inoculated, with SAMNUT 22 accumulating more dry matter. However, at each of the variety, SAMNUT 23 had heavier dry matter when not inoculated.

Table 6: Effect of gypsum and rhizobial inoculation on days to 50 % flowering of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Days to 50% flowering	
Treatment	**Samaru**	**Kadawa**
Gypsum(kg ha^{-1})		
0	38.00	38.58
50	36.92	38.58
100	37.33	38.83
150	36.75	38.80
200	38.00	38.58
SE±	0.504	0.254
Rhizobial Inoculation		
Uninoculated	37.57	38.10b
Inoculated	37.23	39.23a
SE±	0.319	0.161
Variety		
SAMNUT 22	38.17a	39.63a
SAMNUT 23	36.63b	37.70b
SE±	0.319	0.161
Interaction		
G*I	NS	NS
G*V	*	NS
I*V	NS	NS
G*I*V	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. *=Significant, NS= Not Significant.

Table 7: Interaction of gypsum and variety on days to 50 % flowering in the 2012 rainy season in Samaru.

Variety	Gypsum(kg ha^{-1})				
	0	**50**	**100**	**150**	**200**
SAMNUT 22	39.83a	37.83abc	36.83bcd	37.83abc	38.50ab
SAMNUT 23	36.17cd	36.00cd	37.83abc	35.67cd	37.50bcd
S.E ±			0.712		

Means followed by the same letters within a treatment group are not significantly different at 0.05 level of probability using DM

Table 8: Effect of gypsum and rhizobial inoculation on the dry matter accumulation (g plant^{-1}) of Groundnut varieties during the2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Dry matter accumulation(g plant^{-1})							
	SAMARU				KADAWA			
Treatments	**3WAS**	**6WAS**	**9WAS**	**12WAS**	**3WAS**	**6WAS**	**9WAS**	**12WAS**
Gypsum(kg ha^{-1})								
0	1.87ab	10.67ab	23.47	73.87	0.64	3.16	18.80	82.45
50	1.70b	10.80a	24.92	76.20	0.55	2.65	19.98	65.56
100	1.81ab	11.39a	30.03	69.75	0.55	3.24	21.68	60.00
150	1.83ab	9.15b	25.10	70.14	0.65	2.65	20.06	65.23
200	2.06a	10.25ab	25.74	71.60	0.56	2.95	21.01	76.66
SE±	0.086	0.519	2.400	3.164	0.050	0.228	1.808	8.604
Rhizobial Inoculation								
Uninoculated	1.87	10.08	26.21	73.29	0.62	2.80	20.09	63.64
Inoculated	1.84	10.82	25.49	71.33	0.57	3.06	20.52	76.32
SE±	0.055	0.328	1.515	2.001	0.031	0.144	1.144	5.441
Variety								
SAMNUT 22	1.87	10.60	27.88	75.89a	0.63	2.85	21.36	80.45a
SAMNUT 23	1.84	10.30	23.83	68.74b	0.55	3.01	19.25	59.50b
SE±	0.055	0.328	1.515	2.001	0.031	0.144	1.144	5.441
Interaction								
G*I	NS	NS	NS	NS	NS	NS	NS	NS
G*V	NS	NS	NS	NS	NS	NS	*	NS
I*V	NS	NS	NS	NS	NS	NS	*	NS
G*I*V	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. *=Significant, NS= Not Significant.

Table 9: Interaction of gypsum and variety on dry matter accumulation (g plant^{-1}) of Groundnut varieties at 9WAS during the dry season of 2012/2013 in Kadawa.

Variety	**Gypsum(kg/ha)**				
	0	**50**	**100**	**150**	**200**
SAMNUT 22	22.93a	18.07ab	19.88ab	25.31a	20.63ab
SAMNUT 23	14.68b	21.89a	23.47a	14.82b	21.40ab
SE± 2.557					

Means followed by the same letters within a treatment group are not significantly different at 0.05 level of probability using DMRT.

Table 10: Interaction of inoculation and variety on dry matter accumulation (g plant^{-1}) of Groundnut varieties at 9WAS during the 2012/2013 dry season in Kadawa

Rhizobial Inoculation	**Variety**	
	SAMNUT 22	**SAMNUT 23**
Uninoculated	19.18ab	23.54a
Inoculated	21.01a	17.49b
S.E± 1.617		

Means followed by the same letters within a treatment group are not significantly different at 0.05 level of probability using DMRT.

4.8 Crop Growth Rate ($gm^{-2}wk^{-1}$)

Table 11 shows the effects of gypsum rates, inoculation and variety on the crop growth rate during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa. Gypsum rates did not have significant effect on the crop growth rates across all the sampling periods in both locations except at 6WAS in Samaru, where 50 kg ha^{-1} and 100 kg ha^{-1} recorded a higher crop growth rates than 150 kg ha^{-1} but was at par with 0 kg ha^{-1} and 200 kg ha^{-1}.

Inoculation did not affect the crop growth rates across the all the sampling periods in both locations and the varieties used showed no difference across all the sampling periods in both locations except at 12WAS in Kadawa where SAMNUT 22 gave a higher crop growth rate.

There was significant interaction between gypsum and variety (Table 12) and between inoculation and variety (Table 13) in Kadawa.

Varying the gypsum rates from 0-200 kg ha^{-1}, the result showed no significant influence on the crop growth rate on SAMNUT 22 whereas in SAMNUT 23, increase in gypsum rate from 0 kg ha^{-1} to 50 kg ha^{-1} increased crop growth rate, while further increase to 100 kg ha^{-1} did not influence it. However, a further increase to 150 kg ha^{-1} decreased the crop growth rate which was similar with 200 kg ha^{-1}. SAMNUT 22 resulted in higher crop growth rate only at the control and applied 150 kg ha^{-1}.

SAMNUT 22 and SAMNUT 23 were both similar when they were both inoculated and not inoculated, however, SAMNUT 23 recorded a higher crop growth rate when not inoculated than when it was inoculated.

4.9 Relative Growth Rate ($gg^{-1}wk^{-1}$)

The effect of gypsum rates, inoculation and variety on the relative growth rate during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa are shown in Table 14.

Table 11: Effect of gypsum and rhizobial inoculation on the crop growth rates ($gm^{-2}wk^{-2}$) of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Crop growth rate ($gm^{-2}wk^{-1}$)					
	SAMARU			KADAWA		
Treatments	**3-6WAS**	**6-9WAS**	**9-12WAS**	**3-6WAS**	**6-9WAS**	**9-12WAS**
Gypsum(kg ha^{-1})						
0	2.93ab	4.27	16.80	0.84	5.21	21.22
50	3.03a	4.71	17.09	0.70	5.78	15.19
100	3.19a	6.21	13.24	0.89	6.15	12.78
150	2.44b	5.32	15.01	0.67	5.80	15.05
200	2.73ab	5.16	15.29	0.80	6.02	18.55
SE±	0.170	0.778	1.260	0.079	0.624	2.770
Rhizobial Inoculation						
Uninoculated	2.74	5.38	15.69	0.73	5.77	14.51
Inoculated	2.99	4.89	15.28	0.83	5.82	18.60
SE±	0.108	0.492	0.797	0.050	0.394	1.752
Variety						
SAMNUT 22	2.91	5.76	16.00	0.74	6.17	19.69a
SAMNUT 23	2.82	4.51	14.97	0.82	5.41	13.41b
SE±	0.108	0.492	0.797	0.050	0.394	1.752
Interaction						
G*I	NS	NS	NS	NS	NS	NS
G*V	NS	NS	NS	NS	*	NS
I*V	NS	NS	NS	NS	*	NS
G*I*V	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. *=Significant, NS= Not Significant.

Table 12: Interaction of gypsum and variety on crop growth rate ($gm^{-2}wk^{-1}$) of Groundnut varieties at 6-9WAS during the dry season of 2012/2013 in Kadawa.

Variety	Gypsum(kg ha^{-1})				
	0	**50**	**100**	**150**	**200**
SAMNUT 22	6.63a	5.15abc	5.68abc	7.58a	5.81abc
SAMNUT 23	3.79c	6.40ab	6.61a	4.03bc	6.23abc
SE±			0.882		

Means followed by the same letters within a treatment group are not significantly different at 0.05 level of probability using DMRT.

Table 13: Interaction of inoculation and variety on crop growth rate ($gm^{-2}wk^{-1}$) of Groundnut varieties at 6-9WAS during the 2012/2013 dry season in Kadawa.

Rhizobial Inoculation	Variety	
	SAMNUT 22	**SAMNUT 23**
Uninoculated	5.48ab	6.86a
Inoculated	6.05ab	4.78b
S.E±	0.558	

Means followed by the same letters within a treatment group are not significantly different at 0.05 level of probability using DMRT.

Table 14: Effect of gypsum and rhizobial inoculation on the relative growth rates ($gg^{-1}wk^{-1}$) of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Relative growth rate ($gg^{-1}wk^{-1}$)					
	SAMARU			KADAWA		
Treatments	**3-6 WAS**	**6-9WAS**	**9-12WAS**	**3-6WAS**	**6-9WAS**	**9-12WAS**
Gypsum(kg ha^{-1})						
0	0.58ab	0.25	0.39	0.53	0.58	0.46a
50	0.61a	0.27	0.39	0.52	0.67	0.38ab
100	0.61a	0.31	0.30	0.58	0.63	0.31b
150	0.53b	0.34	0.35	0.46	0.66	0.38ab
200	0.53b	0.30	0.35	0.55	0.65	0.41ab
SE±	0.020	0.033	0.034	0.040	0.043	0.044
Rhizobial Inoculation						
Uninoculated	0.56	0.31	0.36	0.50	0.65	0.38
Inoculated	0.59	0.28	0.35	0.56	0.63	0.41
SE±	0.013	0.021	0.021	0.025	0.028	0.027
Variety						
SAMNUT 22	0.58	0.32	0.34	0.50	0.66	0.42
SAMNUT 23	0.57	0.27	0.36	0.56	0.61	0.36
SE±	0.013	0.021	0.021	0.025	0.028	0.027
Interaction						
G*I	NS	NS	NS	NS	NS	NS
G*V	NS	NS	NS	NS	NS	NS
I*V	NS	NS	NS	NS	NS	NS
G*I*V	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. NS= Not Significant.

Gypsum rates did not affect the relative growth rates across all the sampling periods in both locations except at 6WAS in Samaru where 50 kg ha^{-1} and 100 kg ha^{-1} gave a higher relative growth rate than 150 kg ha^{-1} and 200 kg ha $^{-1}$ but similar to 0 kg ha^{-1} and at 12WAS in Kadawa where 0 kg ha^{-1} gave a higher relative growth rate than 100 kg ha^{-1} but at par with the other rates. Inoculation and variety did not influence relative growth rate across all the sampling periods in both locations and there was no significant interaction among the treatments.

4.10 Number of Nodules Plant^{-1}

Table 15 shows the effect of gypsum, inoculation and variety on the number of nodules per plant during the 2012 rainy season and 2012/2013 dry season in Samaru and Kadawa respectively.

Gypsum rates did not influence the number of nodules in both locations. However, inoculated treatment gave more number of nodules than the uninoculated in Samaru and had no significant influence in Kadawa. SAMNUT 22 had more number of nodules than SAMNUT 23 in both locations.

There was no significant interaction among the treatments on the number of nodules in both locations.

4.11 Weight of Nodules Plant^{-1} (mg)

Table 16 shows the effect of gypsum rates, inoculation and variety on the weight of nodules during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

The weight of the nodules was not influenced by gypsum fertilization in both locations. Inoculated treatment gave more nodule weight than the uninoculated in both locations and SAMNUT 22 had a higher nodule weight than SAMNUT 23 in both locations. There was significant interaction between inoculation and variety on the weight of nodules plant^{-1} in Samaru (Table 17).

Table 15: Effect of gypsum and rhizobial inoculation on the number of nodules plant^{-1} of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Number of nodules plant^{-1}	
Treatment	**Samaru**	**Kadawa**
Gypsum(kg ha^{-1})		
0	88.25	90.47
50	71.33	80.58
100	87.58	95.13
150	82.17	82.38
200	99.92	106.71
SE±	14.310	17.232
Rhizobial Inoculation		
Uninoculated	70.67b	75.95
Inoculated	101.03a	106.15
SE±	9.050	10.898
Variety		
SAMNUT 22	104.47a	111.10a
SAMNUT 23	67.23b	71.00b
SE±	9.050	10.898
Interaction		
G*I	NS	NS
G*V	NS	NS
I*V	NS	NS
G*I*V	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. NS= Not Significant.

Table 16: Effect of gypsum and rhizobial inoculation on the weight of nodules plant^{-1} (mg) of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Weight of nodules plant^{-1}(mg)	
Treatment	**Samaru**	**Kadawa**
Gypsum(kg ha^{-1})		
0	332.78	311.25
50	224.35	254.58
100	275.14	295.83
150	308.04	322.08
200	287.75	313.75
SE±	54.396	61.136
Rhizobial Inoculation		
Uninoculated	221.95b	241.17b
Inoculated	349.27a	357.83a
SE±	34.403	38.666
Variety		
SAMNUT 22	366.21a	378.83a
SAMNUT 23	205.02b	220.17b
SE±	34.403	38.666
Interaction		
G*I	NS	NS
G*V	NS	NS
I*V	*	NS
G*I*V	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. NS= Not Significant.

Table 17: Interaction of inoculation and variety on the weight of nodules plant^{-1} (mg) during the 2012 rainy season in Samaru

Rhizobial Inoculation	**Variety**	
	SAMNUT 22	**SAMNUT 23**
Uninoculated	243.67b	200.24b
Inoculated	488.74a	209.80b
S.E±	1.469	

Means followed by the same letters within a treatment group are not significantly different at 0.05 level of probability using DMRT.

SAMNUT 22 produced a higher nodule weight when it was inoculated and there was no significant difference on the weight of nodules in SAMNUT 23 when it was both uninoculated and inoculated.

4.12 Number of Mature and Immature Pods Plant^{-1}

The effect of gypsum rates, inoculation and variety on the number of mature and immature pods per plant during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa are shown in Table 18.

All the treatments had no significant effect on the number of mature and immature pods in both locations and there was significant interaction between inoculation and variety on the number of mature pods in Samaru (Table 19).

SAMNUT 22 had more number of mature pods when it was inoculated and there was no significant difference on the number of mature pods in SAMNUT 23 when it was both inoculated and not inoculated.

4.13 Pod Yield Plant^{-1} (g)

Table 20 shows the effect of gypsum, inoculation and variety on the pod yield plant^{-1} during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

Gypsum rates and inoculation had no significant effect on the pod yield plant^{-1} in both locations. However, SAMNUT 22 gave a higher pod yield than SAMNUT 23 in Samaru and no significant difference was observed in Kadawa. The interaction among the treatments on the pod yield plant^{-1} was not significant in both locations.

Table 18: Effect of gypsum and rhizobial inoculation on the number of mature and immature pods plant^{-1} of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	SAMARU		KADAWA	
Treatments	**Number of mature pods**	**Number of immature pods**	**Number of mature pods**	**Number of immature pods**
Gypsum(kg ha^{-1})				
0	19.50	13.00	75.25	13.50
50	21.33	15.42	67.00	11.50
100	21.58	16.42	75.08	15.00
150	18.42	14.75	89.08	15.42
200	21.33	15.92	71.58	13.83
SE±	1.642	1.280	9.667	2.926
Rhizobial Inoculation				
Uninoculated	19.27	15.83	76.03	13.43
Inoculated	21.60	14.37	75.17	14.27
SE±	1.038	0.809	6.113	1.850
Variety				
SAMNUT 22	19.33	14.70	78.27	15.17
SAMNUT 23	20.93	15.50	72.93	12.53
SE±	1.038	0.809	6.113	1.850
Interaction				
G*I	NS	NS	NS	NS
G*V	NS	NS	NS	NS
I*V	*	NS	NS	NS
G*I*V	NS	NS	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. NS= Not Significant.

Table 19: Interaction of inoculation and variety on the number of mature pods plant^{-1} during the 2012 rainy season in Samaru

Rhizobial Inoculation	**Variety**	
	SAMNUT 22	**SAMNUT 23**
Uninoculated	17.27b	21.27ab
Inoculated	22.60a	20.60ab
S.E±	1.469	

Means followed by the same letters within a treatment group are not significantly different at 0.05 level of probability using DMRT.

Table 20: Effect of gypsum and rhizobial inoculation on the pod yield plant^{-1} (g)of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Pod yield plant^{-1}(g)	
Treatment	**Samaru**	**Kadawa**
Gypsum(kg ha^{-1})		
0	30.50	39.15
50	29.92	33.47
100	32.20	38.87
150	27.99	42.56
200	28.97	40.21
SE±	2.062	5.203
Rhizobial Inoculation		
Uninoculated	31.21	38.51
Inoculated	28.61	39.19
SE±	1.304	3.291
Variety		
SAMNUT 22	32.25a	38.32
SAMNUT 23	27.57b	39.38
SE±	1.304	3.291
Interaction		
G*I	NS	NS
G*V	NS	NS
I*V	NS	NS
G*I*V	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. NS= Not Significant.

4.14. Kernel Yield Plant^{-1} (g)

Table 21 shows the effect of gypsum, inoculation and variety on the kernel yield plant^{-1} at Samaru and Kadawa during the 2012 rainy and 2012/2013 dry seasons respectively.

In both locations, rates of gypsum, inoculation and variety had no significant effect on the kernel yield plant^{-1} and there was no significant interaction among the treatments at both locations.

4.15. Shelling Percentage (%)

The effect of gypsum, inoculation and variety on the shelling percentage during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa are shown in Table 22.

In Samaru, gypsum fertilization at the rate of 100 kg ha^{-1} gave a higher shelling percentage only when compared with 150 kg ha^{-1} while in Kadawa, 200 kg ha^{-1} of gypsum had the highest shelling percentage only when 150 kg ha^{-1}was applied. Inoculation had no significant effect on the shelling percentage in both locations, however, SAMNUT 22 had a higher shelling percentage than SAMNUT 23 in Samaru and no significant difference was observed in Kadawa. There was no significant interaction among the treatments on the shelling percentage in both locations.

4.16. 100 Kernel Weight (g)

Table 23 shows the effect of gypsum, inoculation and variety on the 100 kernel weight during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

Gypsum rates and inoculation had no significant effect on the 100 kernel weight in both locations. However, SAMNUT 22 gave a higher 100 kernel weight than SAMNUT 23 in Samaru and no significant difference was observed in Kadawa. There was significant interaction between gypsum and inoculation in Kadawa (Table 24). Varying the gypsum rates, the result showed that when not inoculated, increase in gypsum rate from 0 kg ha^{-1} to 50 kg ha^{-1} led to a decrease in 100

Table 21: Effect of gypsum and rhizobial inoculation on the kernel yield plant^{-1}(g) of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Kernel yield plant^{-1}(g)	
Treatment	**Samaru**	**Kadawa**
Gypsum(kg ha^{-1})		
0	16.32	24.69
50	16.09	19.07
100	17.74	24.62
150	14.34	21.63
200	14.99	27.55
SE±	1.179	3.422
Rhizobial Inoculation		
Uninoculated	16.59	24.13
Inoculated	15.20	22.89
SE±	0.746	2.164
Variety		
SAMNUT 22	16.03	23.69
SAMNUT 23	15.76	23.33
SE±	0.746	2.164
Interaction		
G*I	NS	NS
G*V	NS	NS
I*V	NS	NS
G*I*V	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. NS= Not Significant.

Table 22: Effect of gypsum and rhizobial inoculation on the shelling percentage (%) of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Shelling percentage (%)	
Treatment	**Samaru**	**Kadawa**
Gypsum(kg ha^{-1})		
0	54.04ab	63.78ab
50	53.84ab	58.90ab
100	55.28a	64.42ab
150	51.39b	53.89b
200	51.91ab	68.64a
SE±	1.174	4.241
Rhizobial Inoculation		
Uninoculated	53.49	65.02
Inoculated	53.09	58.83
SE±	0.742	2.682
Variety		
SAMNUT 22	58.13a	63.18
SAMNUT 23	48.45b	60.67
SE±	0.742	2.682
Interaction		
G*I	NS	NS
G*V	NS	NS
I*V	NS	NS
G*I*V	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. NS= Not Significant.

Table 23: Effect of gypsum and rhizobial inoculation on the 100 kernel weight (g) of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	100 kernel weight(g)	
Treatment	**Samaru**	**Kadawa**
Gypsum(kg ha^{-1})		
0	36.70	46.37
50	37.05	42.93
100	35.12	44.18
150	34.20	43.47
200	36.17	44.76
SE±	1.010	1.246
Rhizobial Inoculation		
Uninoculated	36.13	44.05
Inoculated	35.57	44.63
SE±	0.639	0.788
Variety		
SAMNUT 22	38.27a	44.99
SAMNUT 23	33.42b	43.69
SE±	0.639	0.788
Interaction		
G*I	NS	*
G*V	NS	NS
I*V	NS	NS
G*I*V	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. *=Significant, NS= Not Significant.

kernel weight. However, further increase did not influence 100 kernel weight. When inoculated, gypsum had no significant effect on 100 kernel weight. However, with the control gypsum rates, uninoculated recorded heavier 100 kernel weight while at 50 kg ha^{-1}, the inoculated had higher 100 kernel weight.

4.17. Pod Yield (kg ha^{-1})

Table 25 shows the effect of gypsum, inoculation and variety on pod yield during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

In Samaru, 0 kg ha^{-1} of gypsum gave a higher pod yield only when compared with applied 100 kg ha^{-1} and 200 kg ha^{-1} while gypsum fertilization had no influence on pod yield in Kadawa.

Inoculation and variety had no significant effect on pod yield in both locations and there was significant interaction between gypsum and variety on pod yield in Samaru (Table 26).

At the various gypsum rates, SAMNUT 22 produced the highest pod yield at 150 kg ha^{-1}.Likewise, at each of the varieties, application of 150 kg ha^{-1} and the control resulted in higher pod yield when compared with all other rates with SAMNUT 22 and 23 respectively.

4.18. Haulm Yield (kg ha^{-1})

The effects of gypsum rates, inoculation and variety on the haulm yield during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa are shown in Table 27.

Gypsum rates and inoculation did not have any significant effect on the haulm yield in both locations while the varietal effect indicated that SAMNUT 22 gave a higher haulm yield than SAMNUT 23 in both locations. There was a significant interaction between inoculation and variety on the haulm yield in Samaru (Table 28).

SAMNUT 22 gave higher haulm yield than SAMNUT 23 when it was both inoculated and not inoculated.

Table 24: Interaction of gypsum and inoculation on the 100 kernel weight (g) of Groundnut varieties during the dry season of 2012/2013 in Kadawa.

Rhizobial Inoculation	**Gypsum(kg ha^{-1})**				
	0	**50**	**100**	**150**	**200**
Uninoculated	48.92a	39.32c	44.25abc	43.88bc	43.87bc
Inoculated	43.82bc	46.55ab	44.10abc	43.05bc	45.65ab
SE±			1.762		

Means followed by the same letters within a treatment group are not significantly different at 0.05 level of probability using DMRT.

Table 25: Effect of gypsum and rhizobial inoculation on pod yield (kg ha^{-1}) of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Pod yield (kg ha^{-1})	
Treatment	**Samaru**	**Kadawa**
Gypsum(kg ha^{-1})		
0	871a	1647
50	724ab	1518
100	686b	1481
150	776ab	1571
200	690b	1716
SE±	52.8	151.8
Rhizobial Inoculation		
Uninoculated	726	1604
Inoculated	773	1569
SE±	33.4	96.0
Variety		
SAMNUT 22	760	1521
SAMNUT 23	738	1652
SE±	33.4	96.0
Interaction		
G*I	NS	NS
G*V	*	NS
I*V	NS	NS
G*I*V	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. *= Significant; NS= Not Significant.

Table 26: Interaction of gypsum and variety on pod yield (kg ha^{-1}) of Groundnut varieties during the rainy season of 2012 in Samaru.

Variety	**Gypsum(kg ha^{-1})**				
	0	**50**	**100**	**150**	**200**
SAMNUT 22	772bc	734cd	661cd	1000a	635cd
SAMNUT 23	971ab	713cd	711cd	553d	745bc
SE±			74.7		

Means followed by the same letters within a treatment group are not significantly different at 0.05 level of probability using DMRT.

Table 27: Effect of gypsum and rhizobial inoculation on the haulm yield (kg ha^{-1}) of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Haulm yield (kg ha^{-1})	
Treatment	**Samaru**	**Kadawa**
Gypsum(kg ha^{-1})		
0	1538.90	5576.40
50	1608.30	5083.30
100	1513.90	5333.30
150	1622.20	5368.10
200	1444.40	4555.60
SE±	95.399	429.044
Rhizobial Inoculation		
Uninoculated	1595.56	5183.30
Inoculated	1495.56	5183.30
SE±	60.336	271.351
Variety		
SAMNUT 22	1887.78a	6438.90a
SAMNUT 23	1203.33b	3927.80b
SE±	60.336	271.351
Interaction		
G*I	NS	NS
G*V	NS	NS
I*V	*	NS
G*I*V	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. *=Significant, NS= Not Significant.

Table 28: Interaction of inoculation and variety on the haulm yield (kg ha^{-1}) of Groundnut varieties during the 2012 rainy season in Samaru.

Rhizobial Inoculation	**Variety**	
	SAMNUT 22	**SAMNUT 23**
Uninoculated	2040.00a	1151.11c
Inoculated	1735.56b	1255.56c
SE±	85.327	

Means followed by the same letters within a treatment group are not significantly different at 0.05 level of probability using DMRT.

4.19. Harvest Index

Table 29 shows the effect of gypsum, inoculation and variety on the harvest index during the 2012 rainy season and 2012/2013 dry season in Samaru and Kadawa respectively.

Gypsum rates had no significant effect on the harvest index in both locations while inoculation effect indicated that the uninoculated treatment gave a higher harvest index than the inoculated treatment in both locations. SAMNUT 22 resulted in a higher harvest index in Kadawa and showed no significant difference in Samaru. There was no significant interaction among the treatments on the harvest index in both locations.

4.20. Protein and Oil Contents(%)

Table 30 shows the effect of gypsum, inoculation and variety on the protein and oil content during the 2012 rainy season and 2012/2013 dry season in Samaru and Kadawa respectively.

In Samaru, all the treatments did not influence both the protein and oil content while in Kadawa, 0 kg ha $^{-1}$ of gypsum had the highest protein content and the least was obtained at 150 kg ha^{-1}, while other rates had statistically similar protein content that was higher than the least. With regards to oil content, 150 kg ha^{-1} of gypsum produced the highest oil content although at par with 100 kg ha $^{-1}$ while 50 kg ha $^{-1}$ produced the least oil content.

In Kadawa, the uninoculated produced more protein and oil contents than the inoculated. SAMNUT 22 produced higher protein content than SAMNUT 23 whereas SAMNUT 23 produced more oil than SAMNUT 22. There was significant interaction among the treatments on the protein and oil content both at Samaru and Kadawa.

Table 29: Effect of gypsum and rhizobial inoculation on the harvest index (%) of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Harvest Index (%)	
Treatment	**Samaru**	**Kadawa**
Gypsum(kg ha^{-1})		
0	16.56	15.18
50	16.57	14.82
100	17.35	15.90
150	15.04	14.47
200	15.31	17.49
SE±	0.903	1.562
Rhizobial Inoculation		
Uninoculated	17.14a	17.15a
Inoculated	15.19b	13.10b
SE±	0.571	0.988
Variety		
SAMNUT 22	15.72	17.69a
SAMNUT 23	16.60	13.46b
SE±	0.571	0.988
Interaction		
G*I	NS	NS
G*V	NS	NS
I*V	NS	NS
G*I*V	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. NS= Not Significant.

Table 30: Effect of gypsum and rhizobial inoculation on the protein and oil contents (%) of Groundnut varieties during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa.

	Samaru		**Kadawa**	
Treatments	**Protein(%)**	**Oil(%)**	**Protein(%)**	**Oil(%)**
Gypsum(kg ha^{-1})				
0	23.93	43.99	24.23a	44.02c
50	23.73	44.07	22.96b	43.59d
100	23.73	43.79	23.73b	44.41ab
150	23.73	43.94	22.74c	44.65a
200	23.87	44.15	23.88b	44.17bc
SE±	0.083	0.227	0.093	0.093
Rhizobial Inoculation				
Uninoculated	23.84	43.92	23.77a	44.35a
Inoculated	23.75	44.06	23.24b	43.98b
SE±	0.052	0.143	0.059	0.058
Variety				
SAMNUT 22	23.76	44.02	23.89a	43.79b
SAMNUT 23	23.83	43.95	23.42b	44.54a
SE±	0.052	0.143	0.059	0.058
Interaction				
G*I	*	NS	NS	NS
G*V	NS	NS	*	*
I*V	NS	NS	NS	NS
G*I*V	NS	NS	NS	NS

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT. *=Significant; NS= Not Significant.

Interaction between gypsum and inoculation on the protein content in Samaru is presented in Table 31. Varying gypsum rates, the result showed that increase in gypsum rate from 0 kg ha^{-1} to 50 kg ha^{-1} decreased the protein content, thereafter it remained constant through up to the highest rate for the uninoculated treatment. However, for the inoculated treatment, protein content was significantly lower at 0 and 100 kg ha^{-1} of gypsum compared only with 200 kg ha^{-1}. At each of the gypsum rates, the uninoculated recorded higher protein content only with the control.

Interaction between gypsum and variety on the protein content in Kadawa is presented in Table 32.Varying the gypsum rates, the result shows that for SAMNUT 22, successive increase in gypsum rates up to 100 kg ha^{-1} decreased the protein content. However, with increase up to 200 kg ha^{-1}, the protein content increased which was at par with 50 kg ha^{-1} and 150 kg ha^{-1}. For SAMNUT 23, increase in gypsum rate from 0 kg ha^{-1} to 50 kg ha^{-1} decreased the protein content which was similar with 150 kg ha^{-1}. Further increase to 200 kg ha^{-1} increased the protein content which was similar with 100 kg ha^{-1}. At each of the gypsum rates, SAMNUT 22 recorded higher protein content except only at 100 kg ha^{-1} where the reverse was the case.

Interaction between gypsum and variety on the oil content in Kadawa is shown in Table 33.

While holding variety constant and varying gypsum rates, the result shows that increase in gypsum rates from 0 kg ha^{-1} to 100 kg ha^{-1} led to an increase in oil content which was similar to 200 kg ha^{-1} for SAMNUT 22. For SAMNUT 23, increase in gypsum rate from 0 kg ha^{-1} to 150 kg ha^{-1} led to an increase in the oil content, although further increase to 200 kg ha^{-1} led to a decrease in the oil content. At each of the gypsum rates, SAMNUT 23 produced more oil only at the control, 100 kg ha^{-1} and 150 kg ha^{-1}.

Table 31: Interaction of gypsum and inoculation on the protein content (%) of groundnut varieties during the 2012 rainy season in Samaru.

Rhizobial Inoculation	**Gypsum(kg ha^{-1})**				
	0	**50**	**100**	**150**	**200**
Uninoculated	24.26a	23.69bc	23.84bc	23.62bc	23.79bc
Inoculated	23.61c	23.77bc	23.61c	23.83bc	23.95ab
S.E±			0.117		

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT.

Table 32: Interaction of gypsum and variety on the protein content (%) of Groundnut varieties during the 2012/2013 dry season in Kadawa.

Variety	**Gypsum(kg ha^{-1})**				
	0	**50**	**100**	**150**	**200**
SAMNUT 22	24.86a	23.86bc	23.32d	23.59cd	23.81bc
SAMNUT 23	23.59cd	22.06e	24.14b	21.90e	23.95bc
S.E±			0.132		

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT.

Table 33: Interaction of gypsum and variety on the oil content (%) of Groundnut varieties during the 2012/2013 dry season in Kadawa.

Variety	**Gypsum(kg ha^{-1})**				
	0	**50**	**100**	**150**	**200**
SAMNUT 22	43.42f	43.50ef	44.18cd	43.35f	44.53bc
SAMNUT 23	44.63b	43.69ef	44.64b	45.94a	43.82de
S.E±			0.131		

Means followed by the same letter within a treatment group are not significantly different at 0.05 level of probability using DMRT.

4.21. Correlation Analysis

The correlation among some groundnut parameters measured during the 2012 rainy season in Samaru and 2012/2013 dry season in Kadawa are shown in Tables 34 and 35.

In Samaru, there was positive and significant correlation between yield and haulm yield ha^{-1} and positive and highly significant correlation between yield and crop growth rate and oil. There was positive and highly significant correlation between plant height with number of leaves, pod yield $plant^{-1}$ and kernel yield $plant^{-1}$ and there was also positive and highly significant correlation between number of leaves and haulm yield ha^{-1}.

Positive and highly significant correlation was observed between dry matter accumulation and crop growth rate and positive and significant correlation between dry matter accumulation and haulm yield ha^{-1} was also observed. There was positive and significant correlation between haulm weight plant-^{1} and haulm yield ha^{-1}.

In Kadawa, there was positive and significant correlation between yield and plant height, dry matter accumulation, crop growth rate and haulm weight $plant^{-1}$. Positive and highly significant correlation was observed between yield and pod yield $plant^{-1}$ and kernel yield $plant^{-1}$. Plant height was positive and significantly correlated with oil and highly significantly correlated with number of leaves, dry matter accumulation, crop growth rate, pod yield $plant^{-1}$, kernel yield $plant^{-1}$, haulm weight $plant^{-1}$ and haulm yield ha^{-1}. There was also positive and significant correlation between number of leaves and crop growth rate and kernel yield $plant^{-1}$ and highly significantly correlated with dry matter accumulation, pod yield $plant^{-1}$ and haulm weight $plant^{-1}$.

Dry matter accumulation was positively and significantly correlated with haulm yield ha^{-1} and highly significantly correlated with crop growth rate, pod yield $plant^{-1}$, kernel yield $plant^{-1}$ and haulm weight plant^{-1}. Percentage oil was negatively but significantly correlated with dry matter accumulation.

Crop growth rate was positive and significantly correlated with haulm yield ha^{-1} and highly significantly correlated with pod yield plant^{-1}, kernel yield plant^{-1} and haulm yield plant^{-1}.

There was positive and highly significant correlation between pod yield plant^{-1} with kernel yield plant^{-1} and haulm weight plant^{-1}. Haulm weight plant^{-1} was positive and highly significantly correlated with kernel weight plant^{-1} and haulm yield ha^{-1}.

Table 34: Correlation matrix between yield and some growth and yield parameters in the 2012 rainy season in Samaru.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	1.000	0.234^{NS}	0.001^{NS}	0.222^{NS}	0.360**	0.187^{NS}	0.183^{NS}	0.050^{NS}	0.317*	0.473**
2		1.000	0.427**	0.145^{NS}	0.228^{NS}	0.430**	0.464**	0.118^{NS}	0.143^{NS}	0.200^{NS}
3			1.000	0.193^{NS}	0.076^{NS}	0.057^{NS}	0.086^{NS}	0.106^{NS}	0.422**	0.133^{NS}
4				1.000	0.807**	0.069^{NS}	0.124^{NS}	-0.001^{NS}	0.322*	-0.001^{NS}
5					1.000	0.154^{NS}	0.189^{NS}	-0.055^{NS}	0.173^{NS}	-0.110^{NS}
6						1.000	0.900**	0.049^{NS}	-0.238^{NS}	0.082^{NS}
7							1.000	0.153^{NS}	-0.028^{NS}	0.007^{NS}
8								1.000	0266*	0.073^{NS}
9									1.000	0.195^{NS}
10										1.000

Keys
1=Yield (kgha^{-1})
2= Plant height (cm)
3= Number of leaves
4= Dry matter accumulation (g)
5= Crop Growth Rate (g.m^{-2}wk^{-2})
6= Pod yield plt^{-1}(g)
7= Kernel yield plt^{-1} (g)
8= Haulm weight plt^{-1}
9= Haulm yield ha^{-1}
10= Oil (%)
NS= non-significant
**= significant @ 1%
*= significant @ 5%

Table 35: Correlation matrix between yield and some growth and yield parameters in the 2012 rainy season in Kadawa.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	1.000	0.305*	0.159NS	0.306*	0.273*	0.342**	0.332**	0.283*	0.129NS	-0.057NS
2		1.000	0.744**	0.540**	0.500**	0.396**	0.338**	0.449**	0.387**	-0.295*
3			1.000	0.366**	0.317*	0.355**	0.286*	0.531**	0.252NS	-0.160NS
4				1.000	0.982**	0.551**	0.551**	0.552**	0.301*	-0.255*
5					1.000	0.503**	0.513**	0.507**	0.259*	-0.208NS
6						1.000	0.896**	0.537**	0.142NS	0.040NS
7							1.000	0.490**	0.120NS	0.050NS
8								1.000	0.520**	-0.253NS
9									1.000	-0.481**
10										1.000

Keys

1=Yield ($kgha^{-1}$)
2= Plant height (cm)
3= Number of leaves
4= Dry matter accumulation (g)
5= Crop Growth Rate ($g.m^{-2}wk^{-2}$)
6= Pod yield plt^{-1}(g)
7= Kernel yield plt^{-1} (g)
8= Haulm weight plt^{-1}
9= Haulm yield ha^{-1}
10= Oil (%)
NS= non-significant
**= significant @ 1%
*= significant @ 5%

CHAPTER FIVE

5.0. DISCUSSION

5.1 Response to Gypsum Fertilization

The results of this study have shown that most of the growth and yield parameters of the two groundnut varieties did not respond significantly to gypsum in the two locations. The non significant response of most of the parameters to the application of gypsum could be attributed to the high soil calcium (6.0 cmolkg^{-1} and 5.3 cmolkg^{-1} in Samaru and Kadawa respectively) as indicated in Table 1, and as such, the addition of extra calcium may have not been necessary. This is in line with the proposition of Robert (2011) who noted that soil calcium is an important factor when evaluating the need for calcium fertilization, as additions of lime and gypsum do not show improvements in yield or seed quality when the soil has adequate calcium. In addition to this, gypsum application may have risen the pH of the soil above the requirement of groundnut as the pH of the soils in both locations were within the pH range for groundnut production before gypsum application.

Application of 100 kg ha^{-1} and 150 kg ha^{-1} of gypsum which led to higher oil content than the rest of the rates in Kadawa could be due to the sulphur element in gypsum which increased the oil content in groundnut as sulphur is directly involved in oil synthesis (Rao *et al*., 2013).

5.2 Response to Rhizobial Inoculation

The lack of response of some of growth and yield parameters of the two groundnut varieties to inoculation in this research may be due to several factors which include; adequate nodulation by indigenous rhizobia, unfavorable conditions for survival of introduced rhizobia strains and inability of inoculant strains to compete with indigenous strains for nodule sites, the use of the strains of bacteria that are incompatible with groundnut or even the high nitrogen content of the soils in both locations (4.00g kg^{-1} in Samaru and 6.30 g kg^{-1} in Kadawa).

5.3 Varietal Response

The varieties used in this experiment exhibited significant differences in their growth and yield characters such as plant height, number of branches, number of leaves, dry matter accumulation, crop growth rate, shelling percentage, 100 kernel weight, haulm yield, harvest index, number and weight of nodules and protein content. This could be attributed to differences in their genetic composition and also their interaction with the environment. Patel *et al*. (1998) in Mukhtar (2009) observed that varieties of groundnut differed in their potential productivity.

SAMNUT 22, a Virginia bunch is morphologically classified as semi- spreading whose branches trail partially on the surface of the soil. They are usually heavier yielding and later maturing than the bunch varieties (Jasani, 2009). SAMNUT 23, genetically a Spanish type is morphologically classified as erect bunch with few branches that gives it an open appearance (Mukhtar, 2009).

Flowering was delayed in SAMNUT 22, where SAMNUT 23 flowered earlier. This is related to its earlier maturity period. SAMNUT 23 had more oil content than SAMNUT 22. This can be due to the interaction between genotype and environment. Similar findings were reported by Mukhtar (2009) where SAMNUT 23 produced more oil than the rest of the varieties used in her studies.

5.4 Effect of Location

The result from the experiment shows that the crop performed better in Kadawa than in Samaru. This is shown through the higher values for plant height, number of leaves, number of branches, number of mature pods $plant^{-1}$, pod yield $plant^{-1}$, kernel yield $plant^{-1}$, shelling percentage, 100 kernel weight, pod yield ha^{-1} , haulm yield ha^{-1} , number of nodules $plant^{-1}$. This could be due to the constant supply of water at regular intervals and the appropriate weather condition compared to Samaru, although germination and initial growth of the groundnut were slow in Kadawa.

5.5 Interactions

The interactions among the parameters revealed that there were significant interactions between gypsum levels× inoculation on 100 kernel weight and protein content. Significant interactions were also observed between gypsum levels× variety with respect to days to 50% flowering, dry matter accumulation, crop growth rate, pod yield ha^{-1}, protein and oil content. There was also significant interactions between inoculation× variety with respect to dry matter accumulation, crop growth rate, weight of nodules $plant^{-1}$, number of mature pods $plant^{-1}$ and haulm yield $ha^{-1.}$ This could be as a result of the presence of favorable conditions that facilitated the performance of the varieties.

5.6 Correlation

In the two locations where the trials were conducted, positive and significant correlation was observed between pod yield and growth characters such as plant height, number of leaves, dry matter accumulation and crop growth rate. This indicates the importance of good vegetative development necessary for high yields. This is in line with the work of Wright and Bell (1992) in Mukhtar (2008) who noted a highly significant positive correlation between pod yield and vegetative dry matter.

The positive and highly significant correlation between pod yield and yield characters like pod syield $plant^{-1}$ and kernel yield $plant^{-1}$ imply that the more the pods and kernel on the plant, the more the yield. A positive and highly significant correlation between plant height and number of leaves to haulm yield shows that the vegetative development of a groundnut plant translates to high haulm yield.

CHAPTER SIX

6.0 SUMMARY AND CONCLUSION

Field trials were conducted in two locations; the Institute for Agricultural Research(IAR) farm at Samaru (lat 11^0 $11^{'}$N; long 7^0 38' E and 686m above sea level) and the Irrigation Research Sub-station of the Institute for Agricultural Research, Kadawa(lat 11^0 $39^{'}$ N; long 08^0 27' E, 500m above sea level) in the 2012 rainy and dry seasons respectively to determine the growth and yield of two groundnut varieties as well as the protein and oil content as affected by gypsum fertilization and rhizobial inoculation. The treatments evaluated consisted of two groundnut varieties (SAMNUT 22 and SAMNUT 23), five gypsum rates (0, 50, 100, 150 and 200 kg ha^{-1}) and two rhizobial inoculation levels (uninoculated and inoculated) which were factorially combined and laid out in a randomized complete block design (RCBD), replicated three times. The results of the experiment from the two locations showed that the application of gypsum rates and rhizobial inoculation had no effect on most of the parameters. Significant interactions between gypsum rates and inoculation on 100 kernel weight and protein content were observed. Significant interactions were also observed between gypsum rates and variety on days to 50 % flowering, dry matter accumulation, crop growth rate, pod yield ha^{-1}, protein and oil content. Significant interaction between inoculation and variety was also observed with respect to dry matter accumulation, crop growth rate, weight of nodules $plant^{-1}$, number of mature pods and haulm yield ha^{-1}.

SAMNUT 22 exhibited better growth than SAMNUT 23 in both locations by having higher values for plant height, number of branches, number of leaves, dry matter accumulation, crop growth rate, pod yield $plant^{-1}$, shelling percentage, 100 kernel weight, haulm yield, harvest index, number and weight of nodules, and protein content, although SAMNUT 23 had a higher oil content in Kadawa.

Positive correlations were observed on plant height, number of leaves, dry matter accumulation, crop growth rate, haulm yield, pod yield $plant^{-1}$ and kernel yield $plant^{-1}$ and oil with yield.

Based on the results obtained from the two locations, there was no significant response from gypsum fertilization on most of the parameters and rhizobial inoculation influenced only the number of nodules in Samaru and the weight of nodules in both loactions, while SAMNUT 22 performed better than SAMNUT 23 both in the rainy and dry seasons except in Kadawa where SAMNUT 23 had higher oil content than SAMNUT 22.

In conclusion, application of gypsum may not be necessary on soils high in calcium, further inoculation studies should be carried out on groundnut with the right strains of bacteria and SAMNUT 22 produced good yield both in the rainy and dry seasons although SAMNUT 23 had a higher oil potential.

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Appendix I: Meteorological data showing mean rainfall amount, minimum and maximum temperatures, relative humidity and sunshine hours during the 2012 rainy season at Samaru.

		Air temperature (^{0}C)		Relative Humidity (%)		Sunshine
Month	Rainfall (mm)	Min.	Max.	Min.	Max.	Hours
April	7.3	23.1	39.0	27.7	52.0	7.2
May	263.4	21.2	33.8	53.9	68.3	5.9
June	120.7	22.0	31.5	63.6	76.1	6.7
July	165.3	20.1	30.3	67.7	82.6	5.3
August	426.7	19.5	29.1	74.0	82.3	4.5
September	270.3	19.8	30.4	73.8	77.2	5.0
October	79.6	20.8	33.8	55.3	70.2	7.3
November	NA	17.4	34.3	28.2	32.9	8.6
December	NA	16.5	32.3	15.6	20.3	8.6

Source: Institute for Agricultural Research Meteorological Unit, Samaru
NA- Not applicable

Appendix II: Meteorological data showing mean minimum and maximum temperatures, relative humidity and solar radiation during the 2012/2013 dry season at Kadawa.

		Air temperature (^{0}C)		Relative Humidity (%)		Solar Radiation (Ly)	
Month	Rainfall (mm)	Min.	Max.	Min.	Max.	Min.	Max.
January	NA	16.4	36.9	22.1	28.7	5.6	21.9
February	NA	14.9	32.8	10.6	21.3	4.2	22.9
March	NA	19.2	38.2	12.7	37.3	5.6	25.3
April	NA	25.1	36.9	24.5	47.1	8.2	25.5
May	10.9	25.4	39.8	23.7	42.2	6.7	23.3
June	14.2	22.3	35.1	35.4	49.9	5.4	23.5

Source: National Institute for Horticultural Research Meteorological Unit, Bagauda
1 Langley (Ly) = 41840 Jm^{-2}
NA- Not applicable

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