RESPONSE OF GROUNDNUT (*Arachis hypogaea* L.) VARIETIES TO RATE AND METHOD OF GYPSUM APPLICATION IN SUDAN SAVANNA OF NIGERIA.

BY

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A DISSERTATION SUBMITTED TO THE DEPARTMENT OF AGRONOMY, BAYERO UNIVERSITY KANO, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRONOMY (CROPS AND CROPPING SYSTEMS IN THE DRYLANDS).

JULY, 2021

DECLARATION

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

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CERTIFICATION

This is to certify that the research work for this dissertation and subsequent write-up by DJENAISSEM ALFRED (SPS/18/MAG/00008) were carried out under our supervision.

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PROF. I. B. MOHAMMED (Head of Department)	Date

APPROVAL

This dissertation titled "Response of Groundnut (*Arachis hypogeae* L.) Varieties to Rate and Method of Gypsum Application in Sudan Savanna of Nigeria" by DJENAISSEM ALFRED (SPS/18/MAG/00008) has been examined and approved for the award of Master of Science Degree in Agronomy (Crops and Cropping Systems in the Drylands).

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DEDICATION

This research work is dedicated to my beloved wife MELOM Onesime, my daughter MAOUNDONODJI Dignity and my entire family for their love and support during the period of study.

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

A field trial was conducted during the 2020 rainy season at the Teaching Research Farm of the Centre for Dryland Agriculture (CDA), Bayero University, Kano, Nigeria (Latitude 11^{o}58´N and Longitude 8^{o}26´E) and at Institute for Agricultural Research, Sub Station at Minijibir (Latitude 12^{o}17´N and Longitude 8^{o}65´E). The research determined the effects of gypsum rates and methods of application on the growth, yield and oil content of groundnut varieties. The treatments consisted of four gypsum rates (0, 125, 250 and 500 kg ha^{-1}), two methods of gypsum application (foliar and soil application) and four varieties (SAMNUT 23, SAMNUT 24, SAMNUT 25 and SAMNUT 26) and laid out in a Randomized Complete Block Design with three replications. Data collected on growth, yield characters, yields and oil content were subjected to analysis of variance using JMP Pro15th. The control treatment gave the highest canopy height (50.60 cm) and oil content (59.90 %) at Minjibir only. Soil application of gypsum gave heavier 100-kernel weight, 40.37 g and 47.60 g over the foliar application at BUK and Minjibir, respectively. SAMNUT 23 had the highest number of branches per plant ($p<0.05$), 100-kernel weight and oil content than all the other varieties at both locations. SAMNUT 26 recorded the highest canopy (49.96 cm) at BUK. While SAMNUT 24 (63.40 cm) had it at Minjibir. SAMNUT 24 gave the highest number of pods plant^{-1} (18) at both experimental sites. SAMNUT 24 produced significantly ($p<0.021$) higher pod yield (1415.50 kg ha^{-1}) and kernel yield (1058.50 kg ha^{-1}) which was statistically at par with SAMNUT 26 in pod yield (1330.70 kg ha^{-1}) and kernel yield (933.00 kg ha^{-1}) at Minjibir only. It is recommended that SAMNUT 24 and SAMNUT 26 can be promoted for the production of pod and kernel yield in the Sudan savanna ecological zone of Nigeria.

CHAPTER ONE

1.0. INTRODUCTION

1.1. BACKGROUND INFORMATION

Groundnut (*Arachis hypogaea* L.) belongs to the family of *Fabaceae*, a leading oilseed crop grown in many tropical and sub-tropical countries of the world. The cultivated groundnut or peanut is of South America origin. The term *Arachis* is derived from the Greek word "arachos", meaning a weed, and *hypogaea*, meaning underground chamber, that is a weed with fruits produced below the soil surface (Holbrook and Stalker, 2003). Groundnut is a self-pollinated plant whereby flowers are produced above ground and, after fertilization, pegs move towards the soil, and seed-containing pods are formed and developed underneath the soil (Holbrook and Stalker, 2003). According to Varaprasad *et al.*, (2011) the genus *Arachis* is morphologically well defined and distinguished from other genera by having a peg and geocarpic reproductive growth. The genus *Arachis* has more than 70 wild species, of which only *A. hypogaea* is domesticated and commonly cultivated.

Groundnut is grown in Asia, North America, South America, Europe and Africa. In Africa, groundnut is grown mainly in Nigeria, Sudan, Senegal, Chad, Ghana, Congo, and Niger (Hedge, 2014). The major groundnut producing states in Nigeria are Kano, Katsina, Kaduna, Jigawa, Sokoto, Zamfara and Kebbi in the Northwest, Adamawa, Bauchi, Yobe and Borno in the Northeast and Benue, Plateau, Taraba, Nasrawa, FCT Abuja, Kogi, Niger and Kwara in the Central Zone (Ajeibe *et al.,* 2008). Food and Agricultural Organization Statistic; FAOSTAT (2017) reported that Nigeria is the largest groundnut producing country in West Africa, accounting for 51% of production and contributes 10% of total global production in the world. World Agricultural Production; (WAP, 2020) stated that the world production of groundnut was 46.07 million metric tons from 27.33 million hectares with an average yield of 1690 kg ha^{-1}. In the same year the Nigerian production was 4.42 million metric tons from 2.82 million hectares with an average yield 1570 kg ha^{-1}.

Groundnut being a leguminous crop is capable of fixing atmospheric nitrogen (Veeramani *et al*., 2011). The groundnut enriches the soil with nitrogen without draining nonrenewable energies or upsetting the agro-ecological balance (Khan, Faridullah and Uddin, 2009). Ajeigbe *et al.* (2008) reported also that groundnut improves soil fertility through nitrogen fixation, thereby increasing the productivity of other crops when used in rotation or in a cereal cropping system.

According to Fekria (2009) groundnut is valued for its high oil content which ranges between 44 to 56% thus averaging about 50% of the kernel. The protein content in groundnut kernel ranges from 16 to 36%. Groundnut contains primary elements such as calcium, magnesium, potassium, sodium, iron and certain trace elements such as manganese, copper zinc and boron. It is also a source of certain vitamins, especially vitamins B, E and K. It is mainly used as a source of food (edible oil, vegetable protein, boiled or roasted directly or mixed in confectionary products). Groundnut haulms are in high demand for fodder, and the groundnut cake after the extraction of the oil is also mixed in animal feeds or organic fertilizers (Acharya, 1990). Groundnut oil is the most important product of the crop, which is used for both domestic and industrial purposes. The tender leaves are also used in certain parts of West Africa as a vegetable in soups (Khan *et al*., 2009). Of all these importance, groundnut cultivation contributes to the sustainability of mixed crop-livestock production system of the semi- arid areas (FAO, 2019).

According to Ajeigbe *et al*. (2008) before 1992, twenty groundnut varieties had been officially released in Nigeria. Most of these are medium- to late-maturing varieties, requiring more than four months to mature. The growing season in the savanna zone is shorter (90-100 days) and requires short–duration varieties. According to International Crops Research Institute for the Semi-Arid Tropics; ICRISAT (2019) the improved dual purpose groundnut varieties in Nigeria are SAMNUT 21 (released in 2000), SAMNUT 22 (released in 2000), and SAMNUT 23 (released in 2000), SAMNUT 24 (released in 2011), SAMNUT 25 (released in 2013), SAMNUT 26 (released in 2013), SAMNUT 27 (released in 2018), SAMNUT 28 (released in 2018), and SAMNUT 29 (released in 2018),

Groundnut can be grown in a wide range of temperate and tropical regions, but maximum production comes from the semiarid tropics. The crop requires about 500-600 mm of rainfall per annum which should be well distributed and optimum temperature ranges from 28 to 30 ºC. Groundnut produces good yields in soils with pH of 6.0- 6.5. About 90% of the total groundnut production is in the rainy season. In West Africa it is grown in the rainy season either as a sole crop or mixed with sorghum or millets (Sivakumar and Virmani, 1986).

Nutrient requirements for groundnuts are lower than for most other crops, like corn or Soybean for example. In parts of Africa and Asia where most of the crop is used for local consumption, fertilizer application is not a common practice. However, the crop responds rather well to fertilizers. In general, groundnut requires about 20 kg N ha^{-1}, 50-80 kg P_2O_5 ha^{-1}, and 30-40 kg K_2O ha^{-1} (Thilakarathna and Kirthisinghe, 2014). Gypsum is widely used as a source of Ca for groundnut worldwide. This is done by dusting the plant at early flowering. The response of groundnut to gypsum, as with any other fertilizer, depends on the fertility status of the soil. The dissolution of gypsum is fairly rapid and therefore readily adds Ca to the podding zone. However, the major disadvantage of gypsum is its vulnerability to leaching especially on light textured soils (Mupangwa and Tagwira, 2005). The application of gypsum at a rate of 250 kg ha^{-1} increased the mean pod dry weight per plant of groundnut by 39% (from 618 to 865 g) and quality of the kernels when grown in acidic soils (Chapman *et al*., 1993). According to Echekwu (1994) gypsum also provides sulphur to crops. Groundnut pod development takes 20-80 days following the entrance of the peg into the soil and that about 92% of its calcium needs is absorbed within this period while about 69% was found to be absorbed within 20-30 days of its development. Gypsum, being a slowly soluble material, if applied at blooming stage, can continually release calcium for up to 45-60 days. Thilakarathna and Kirthisinghe (2014) showed that the application of 250 kg ha^{-1} of gypsum changed the soil pH from 4.1 to 5.0.

Mupangwa and Tagwira (2005) reported that gypsum application at rate of 100, 200 and 400 kg ha^{-1} increased yields by 50, 58 and 90% over the control treatment. Calcium application at flowering does not only ensure high seed yield, but also an increase in oil content (Gashti *et al.*, 2012). Mbonwa (2013) reported that oil content was significantly increased by calcium application at flowering with 27.28% compared to 20.7% without calcium.

1.2. PROBLEM STATEMENT

In Nigeria, one of the reasons for the failure of agricultural plans is underestimating the importance of soil status and, therefore, mismanagement of the nation's soil (FAO, 2015). A survey conducted by Shehu, Jibrin and Samndi (2015) in the Sudan Savanna Biome of Northern Nigeria revealed that Calcium contents in all the surveyed fields in both surface and subsurface soils were in moderate (2.0-5.0 cmol (+) kg^{-1}) fertility status. According to ICRISAT (1992) the groundnut crop is predominantly grown in low input production systems in developing countries in Asia and Africa. Lack of calcium leads to unfilled pods (also termed as pops), small Pods, and high incidence of pod rot. In addition, plants deficient in Ca will also have poor growth and development.

According to WAP (2020) the total world production of groundnut was 46.78 million metric tons from 27.14 million hectares with an average grain production of 1720 kg ha^{-1} in 2017/18, while Nigeria groundnut production was estimated at 4.25 million metric tons from 2.82 million hectares with an average yield of 1510 kg ha^{-1}. The world production was 46.75 million tons from 27.84 million ha with yield of 1680 t ha^{-1} in 2018/19, while total Nigeria ground production was 4.42 million metric tons from 2.82 million ha with an average of 1570 kg ha^{-1}. It was 45.52 million metric tons from 26.51 million hectares with an average yield 1720kgha^{-1} in 2019/2020 while the Nigerian production was 3.50 million metric tons from 2.80 million hectares with an average yield 1250 kg ha^{-1}.

From 2017 to 2019, Nigeria had made efforts in groundnut production however the average yields constantly decreased: 1510 kg ha^{-1} (2017/18), 1570 kg ha^{-1} (2018/19), 1250kg ha^{-1} (2019/20) (WAP, 2019) which are far below the potential yield that ranges 2500 kg ha^{-1} to 3500 kg ha^{-1}. The decrease in groundnut yield in Nigeria compared to the potential groundnut yield may be attributed to the moderate soil status in calcium among other factors.

1.3. JUSTIFICATION FOR THE STUDY

Groundnut responds to gypsum, as with any other fertilizer by adding calcium to the pod zone (Chikowo, 1999). According to ICRISAT (1992) calcium is the most important nutrient for pod development. The crop has a very high calcium requirement;

about 90% calcium is absorbed during flowering, pod formation and development. Calcium application at flowering does not only ensure high seed yield, but also an increase in oil content (Gashti *et al.*, 2012). Mbonwa (2013) reported that oil content was significantly increased by calcium application at flowering with 27.28% compared to 20.7% without calcium.

Considering the importance of calcium in groundnut, this research aimed to contribute to the groundnut production in Sudan savanna of Nigeria through gypsum application to the four new improved groundnut (*Arachis hypogaea* L.) varieties.

1.4. OBJECTIVES OF THE STUDY

There were essentially three objectives for this research namely to:

i- determine an adequate gypsum application rate to groundnut varieties;

ii- To determine the appropriate method of gypsum application;

iii- To evaluate oil content in groundnut varieties as affected by gypsum rates and methods of gypsum application.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. CALCIUM MANAGEMENT IN GROUNDNUT

2.1.1. Importance of Determining Soil Calcium Level Before Planting

Hartzog and Adams (1973) reported the importance of the soil calcium level before planting in order to determine if calcium sources will have an effect on peanut yield and germination. Sorenson and Butts (2008) observed that the addition of calcium to low calcium soils improves yield, increases the percentage of sound mature kernels (SMK), and improves germination and vigour. The authors further observed that the amount of soil calcium required might differ among cultivars, as there may be differences in seed size, ability to accumulate seed calcium, seed germination requirements, and tolerance to low calcium soils. Florence (2011) determined that basically, calcium fertilization does not show improvements in yield or seed quality when the soil has adequate calcium. Florence (2011) reported that germination is also limited by inadequate soil calcium and that more calcium is required for maximum germination than for maximum yield and SMK. Arnold (2014) emphasized that low calcium levels in soils can reduce peanut yield, grade, and seed quality.

2. 1.2. Calcium Movement and Translocation in Groundnut Plant

Skelton and Shear (1971) suggested that replenishing pegging zone calcium is important because peanut plants do not readily translocate calcium from the roots to the developing shoot. Hence, Skelton and Shear (1971) further observed that pods must therefore acquire calcium from the surrounding soil. Summer *et al*. (1988) reported that calcium enters the seed by diffusing directly from the soil through the hull to the seed.

These researchers further attributed the lack of xylem flow into the peg to the lack of transpiration once it is underground.

2.1.3. Impact of Calcium to Potassium Ratio and Phosphorus on Calcium Uptake

Sullivan *et al*. (1974) found that potassium applications reduced yield, percentage SMK, and extra-large kernels, and slightly increased the incidence of dark plumules. Also Acording to Jakbsen (1979) an accumulation of calcium ions at root surfaces may precipitate phosphate and thereby hinder uptake of not only phosphate but also of calcium for a short time. The consequences may be very pronounced because calcium is not translocated in plants. Alva *et al*. (1989) argued that soil calcium levels are not the only factor to consider when determining whether a soil is limited by calcium. The calcium to potassium ratio is also important. The plant may be limited in its ability to absorb calcium. This is due to competition between calcium and potassium during the diffusion process into the hull. High concentrations of potassium will limit calcium diffusion conversely. Florence (2011) determined that an over-application of calcium might limit general potassium and magnesium uptake by the plant and subsequently reduce yields. Despite the favorable effect of calcium, its excess may cause P deficiency in the soil, because there is an antagonistic effect between calcium and phosphorus (Oumar, 2019)

2.1.4. Benefits of Gypsum Application in Groundnut yield and Percent in Oil Content

Williams and Rajengdrudu. (1986) reported that gypsum application was found to significantly increase yield of groundnut of groundnut genotypes, but there was no obvious response if there was no drought.

Chapman *et al*. (1993) reported that applying at early flowering by dusting on the plants, groundnut responds to gypsum, as with any other fertilizer, depending on the fertility status of the soil. The dissolution of gypsum is fairly rapid and therefore readily adds calcium to the podding zone. The application of gypsum at a rate of 250 kg ha^{-1} increased the mean pod dry weight of groundnut by 39% (from 618 to 865 g) and quality of the kernels when grown in acidic soils. Observations made by Adams *et al*. (1993) indicated that while gypsum does not increase pH as lime does, it might be more beneficial to developing pods than lime, possibily because according to Echekwu (1994) gypsum is a source of sulphur to crops.

According to FAO (2002) the major mineral that is required for the development of groundnut pod is calcium. Calcium deficiency causes groundnut pegs and pods to abort, causing decreased shelling percentages and yield. Environmental factors influencing calcium availabilty include soil calcium content and soil moisture. Genetic attributes that influence the sensitivity of groundnut cultivars to soil calcium supply includes pod size, soil volume per pod (varied by plant growth habit) and pod wall attributes. Where calcium fertilization is not possible, genetic solution to calcium deficiencies is important and breeders need information on the relative importance of these attributes. Mupangwa and Tagwira (2005) argued that gypsum is widely used as a source of calcium for groundnut worldwide.

Groundnut pod development takes 20-80 days following the entrance of the peg into the soil and that about 92% of its calcium need is absorbed within this period while about 69% was found to be absorbed within 20-30 days of its development (Echekwu, 1994). Gypsum, being a slowly soluble material, if applied at blooming stage, can continually release calcium for up to 45-60 days. Thilakarathna and Kirthisinghe (2012) showed that the application of 250 $kgha^{-1}$ of gypsum changed the soil pH from 4.1 to 5.0 and increased the mean pod dry weight from 618 to 865 g with high quality kernels (with good appearance and size).

Harris and Brolmann (1966) mentioned that gypsum applications have been shown to improve yield, grade, and germination particularly under rain fed conditions. Mbonwa (2013) reported that oil content was significantly increased by gypsum as calcium fertilizer at flowering by 7.28% over the control.

2.1.5. Disadvantage of Gypsum Application in Groundnut Production

Alva and Gascho (1991) observed that while gypsum has many benefits, there are some disadvantages *viz*.,application of gypsum may reduce the availability of potassium and magnesium in the pegging zone, which may lead to potassium and magnesium deficiencies in the seed, thereby reducing the seed quality. Florence (2011) further observed that a deficiency of these elements also affects vegetative plant growth and health because they are essential in the development of healthy leaves.

2.1.6. Effect of Rainfall on Leaching of Surface-Applied Calcium/Gypsum in Sandy Soils

Alva *et al.* (1989) reported that the leaching of gypsum from the pegging zone might occur before the end of the growing season. Because the majority of applied gypsum may leach within a month of application, it has now been established that gypsum should conventionally be applied 40 days after planting or at early bloom. The authors further reported that gypsum is present during pegging, as well as when pods are developing. Applying gypsum at early bloom does not ensure that gypsum will supply sufficient calcium for the rest of the growing season.

Florence (2011) indicated that if applied calcium leaches from the pegging zone prior to harvest, the pods that develop later in the season may be limited by calcium. Rate of leaching is dependent on the amount of gypsum applied, soil texture, and rainfall pattern. High rainfall events may remove gypsum from the pegging zone and create deficiencies in peanuts developing later in the season. However, the major disadvantage of gypsum is its vulnerability to leaching especially on light textured soils (Mupangwa and Tagwira, 2005). According to Florence (2011) gypsum is also subjected to leaching from the pegging zone and deficiency is created in the developing peanuts.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. DESCRIPTION OF THE STUDY AREAS

A field trial was conducted during the 2020 rainy season at Research Farm of the Centre for Dryland Agriculture, Bayero University, Kano, Nigeria (Latitude 11^{o}58´N and Longitude 8^{o}26´E) and at Institute for Agricultural Research, Sub Station at Minijibir (Latitude 12^{o}17´N and Longitude 8^{o}65´E). Both were within Sudan savanna of Nigeria. The locations are characterized by wet and dry seasons. The wet season starts from May to October, sometimes to the beginning of November and the dry season from November to April.

3.2. TREATMENTS AND EXPERIMENTAL DESIGN

3.2.1. Detail on Treatments

The experiment consisted of three factors: Gypsum fertilizer with four levels (0, 125, 250 and 500 kg ha^{-1}), Method of gypsum fertilizer application with two levels (foliar application and soil application) and groundnut varieties with four varieties (SAMNUT 23, SAMNUT 24, SAMNUT 25 and SAMNUT 26).

According to ICRISAT (2019) the four groundnut varieties are characterized as follow:

- SAMNUT 23: Early-maturing (90 -100 days), pod yield ranges 2.0 - 2.5 t ha^{-1}, haulm yield estimated at (2.0 t ha^{-1}), oil content estimated at 56%, resistant to Early and Late Leaf Spots and kernel color is deep red .

- SAMNUT 24: Extra early maturity (80 - 90 days), escapes end of dry season drought, pod yield ranges 2.0 - 2.5 t ha^{-1}, haulm yield estimated at 2.5 - 3.0 t ha^{-1}, oil content estimated at 48%, moderately resistant to Early and Late Leaf Spots, Resistant to rosette Disease and kernel color is Tan .

- SAMNUT 25: Early-maturity (90 - 95 days), escapes end of dry season drought, pod yield ranges 2.5 - 3.0 t ha^{-1}, haulm yield estimated at 2.5 - 3.0 t ha^{-1} and oil content estimated (46%), moderately resistant to Early and Late Leaf Spots, Resistant to rosette Disease and Kernel color is Tan .

- SAMNUT 26: Early-maturing (90 - 95 days), escapes end of dry season drought, pod yield ranges 2.0 -2.5 t ha^{-1}, haulm yield estimated at 2.5 - 3.0 t ha^{-1} and oil content estimated (49%), moderately resistant to Early and Late Leaf Spots, Resistant to Rosette Disease and Kernel color is Tan.

3.3.3. Experimental Design

The levels of factors were combined giving 32 treatments combination and laid out in Randomized complete Block Design (RCBD) and replicated three times. Each plot had six ridges and each ridge was 5 m long. The spacing between ridges was 0.75 m. Each gross size was 6 x 0.75 m x 5 m = 22.5 m^2. Net plot was 0.75 m x 2 x 4 m = 6 m^2. Total area for each experimental site was 2,880.00 m^2.

3.4 CULTURAL PRACTICES

3.4.1. Land Preparation

The land was cleared before the establishment of rainfall. Harrowing and ridging were done using a tractor New holland. The distance between furrows was 0.75 m as recommended in groundnut production in Sudan savanna of Nigeria.

3.4.2. Seed Treatment and Sowing

The seed was obtained from Center for Dryland Agriculture and treated with Dress Seed (powder for seed treatment, Insecticide/Fungicide) 45 WS at recommended rate of 10 g of formula to 4 kg seed before sowing**.**

The fields were sown when the rain was well established. The trial at Minijibir was established on 2nd July 2020 and 8th July 2020 at Kano.

Inter-row spacing was 75 cm and marked out along the 4.5 m length (6 rows). The intra-row was 25 cm. The number of stands was 25 per ridge. Sowing was carried out manually by hand with two seeds making a density of 106,666 plants ha^{-1} (Ajeigbe *et al*., 2008).

3.4.2. Fertilizer Application

Cow dung was applied at 5 t ha^{-1} during the land preparation as recommended by the manual of Fertilizer Use and Management Practices for Crops in Nigeria. The quantity for each gross plot (22.5 m^2) was11.25 kg. It was divided into 6 rows giving 1.87 kg and applied after making a hole on top of ridge then closed.

The fields were fertilized by applying 20:54:20 kg ha^{-1} (N, P_2O_5 and K2O) at 15 Days After Sowing (DAS) (Romain, 2001). For that, four types of fertilizers were used NPK (15 15 15): 225 g, Urea (46% N): 24.46 g, SSP (20% P_2O_5): 337.50 g and KCl (60% K_2O): 10.74 g. The quantities were mixed and applied on each gross plot (22.5 m^2). The method of application was side dressing when the soil was lightly moistured. Gypsum was applied at the rate of 0, 125, 250 and 500 kg ha^{-1} as detected by the various treatments five weeks after sowing (WAS). For the foliar application, gypsum was dusted on top of leaves. For the soil application, side dressing was applied.

3.4.3. Weed and water erosion Control

The weed control was done manually by hoe weeding. First at 2 WAS, second at 5 WAS and hand pulling of weeds was done 8 WAS. At 7 WAS, ridging was done to control the water erosion caused by the heavy rain.

3.4.4. Harvesting

Harvesting was done at maturity stage when color of the inner shell turn to brown (Anonymous, 2020). SAMNUT 24, SAMNUT 25 and SAMNUT 26 were harvested on the 5^{th} and 13^{th} of October at Minjibir and BUK followed by SAMNUT 23 on the 16^{th} and 23^{rd} of October, respectively. Three stands (along with 50 cm as discard) at the ends of two middle rows were taken as sample for the measurement of canopy height, number of branches and number of nodules. Harvesting for the assessment of pods and fodder yield was done from the net plot ($6m^2$).

3.5. DATA COLLECTION

3.5.1. Meteorological Data

The weather data were collected from the Department of Geography, Bayero Kano and International Institute for Tropical Agriculture(IITA), Kano station for the Research Farm of the Centre for Dryland Agriculture (CDA), Bayero University Kano, Nigeria (Latitude $11^o58'$N and Longitude $8^o26'$E) and at Institute of Agricultural Research, Sub Station at Minijibir (Latitude $12^o17'$N and Longitude $8^o65'$E) respectively.

3.5.2. Soil Sampling and Analysis

Soil samples from the two locations were collected before sowing at 0-30 cm depth. Composite soil samples were made for each location and was air dried. Soil samples were taken to the Laboratory at Centre for Dryland Agriculture for physical and chemical properties analyses using standard procedures. The pH was determined by glass electrode pH metre; particle size by Bouyocous (1951) hydrometer method; organic carbon by oxydation (Black, 1965). Available phosphorus as described by Troug (1930); total nitrogen content by Macro-Kjedhal method (Bremner and Mulvaney, 1982); exchangeable bases (Ca, Mg, K and Na) using 1M ammonium acetate solution (Anderson and Ingram, 1993); exchangeable acidity by potassium chloride extraction method (Peech *et al*., 1962) and Cation exchange capacity (estimated by summation of exchangeable bases and exchangeable acidity).

3.5.3. Growth Characters

Canopy height (cm)

Four plants were randomly selected at harvest from each plot, their heights were measured with a tape from the ground to the tip of the uppermost leaf and the mean was recorded.

Number of branches plant^{-1}

Four plants was randomly selected at harvest and number of branches per plant was counted and the mean was determined and recorded.

Number of nodules plant^{-1}

The number of nodules were counted from four plants at harvest and the mean was recorded.

Leaf area index at 9 weeks after sowing

It is the ratio of the total area of the leaves to the area of ground occupied by the crop. The leaf area was determined using leaf area meter and multiplied by the correction of factor 0.821. The total leaf area was done obtained by multiplying the surface of one leaf area by the total number of leave. The leaf area index was determined using the following formula proposed by Watson (1952).

$LAI = \frac{LA}{GA}$; where LA= Leaf Area and GA= Ground Area.

Chlorophyll content (µmol m^{-2})

This was determined using a chlorophyll meter (Model- CCM-200 Plus) at 9 WAS. Sample were taken to the Laboratory at old agriculture, BUK. Readings were obtained from three leaves (from upper, middle and base of each plant) four plants were selected randomly by inserting each leaf let under the probe. Values were taken from each leaf let were multiplied by four to obtain the chlorophyll content for a full leaf. Those values were summed up and divided by 3 to obtain an average leaf chlorophyll content and the mean values were recorded from four plant.

Crop growth rate (g g^{-1} week^{-1})

The crop growth rate was taken from 6- 9 WAS. Four plants per plot were randomly selected at 6 and 9 WAS. The plants were removed, freed from soil and dried in an oven at 65^{o}C to a constant weight and dry matter was determined and the mean values were recorded. The crop growth rate was computed using the equation as proposed by Happer (1999).

$CGR = \frac{W2-W1}{T2-T1}$**(g g^{-1} week^{-1})**

Where w_2 and w_1 are the total dry weight in plant and T_2 and T_1 are weeks.

Relative growth rate (g g^{-1} week^{-1})

It is the cumulative dry matter increment per unit per unit time. It was calculated at 6-9 WAS as described by Radford (1967).

$$RGR = \frac{\text{Log W2} - \text{LogW1}}{\text{T2} - \text{T1}}$$ **(g g^{-1} week^{-1})**

Where W_2 and W_1 are the total dry weight in plant and T_2 and T_1 are weeks.

Net assimilation rate (g cm^{-2} week^{-1})

The mean Net Assimilation Rate (NAR) is the increase in dry weight per unit leaf area per unit time (g cm^{-2} week^{-1}). It was calculated from 6-9 WAS using the formula below proposed by Watson (1952).

$$NAR = \frac{W2 - W1}{A2 - A1} x \frac{LogeA2 - LogeA1}{T2 - T1}$$ **(g cm^{-2} week^{-1})**

Where W_2 and W_1, A_2 and A_1 are dry weights and Leaf area at times T_2 and T_1 respectively.

3.5.4. Yield Characters

Number of pods plant^{-1}

Number of pods plant^{-1} was counted by dividing the total number pods from net plot (6 m^2) by stand count at harvest from net plot(6 m^2).

100-Kernels weight (g)

One hundred (100) kernels were randomly selected from the net plot and weighed in grams using precision balance (OHAUS. PIONNER) at CDA.

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

At maturity the groundnuts were uplifted from the ground and the pods were removed from the soil and air dried then weighed using precision balance (OHAUS. PIONNER) at CDA to obtain the pod yield per net plots. Net plot yield was extrapolated to ha^{-1} basis. This pod yield was calculated using the equation below.

$$\text{Pod yield ha}^{-1} = \frac{pod\ yield|net\ plot(kg)}{6\text{m}^2} x 10{,}000\ m^2$$

Kernel yield (kg ha^{-1})

The kernels were weighed using precision balance (OHAUS. PIONNER) at CDA. Net plot kernel yield was extrapolated to ha^{-1} basis using the equation below.

Kernel yield $ha^{-1} = \frac{kernel\ yield|net\ plot(kg)}{6\mathrm{m}^2} x10{,}000\ m^2$

Stand count at harvest in percentage

Stand count at harvest was taken from the net plot 6 m^2 and will be extrapolated to ha^{-1} basis.

Haulm yield (kg ha^{-1})

After removing the pods, the biomass was dried under shade and weighed. This haulm yield was extrapolated to the ha^{-1} basis. It was calculated by the following formula.

Haulm yield $ha^{-1} = \frac{haulm\ yield|\ net\ plot(kg)}{6m^2} x10{,}000\ m^2$

Harvest index

It was computed as the ratio of kernel weight to the haulm yield of groundnut and pod yield (Chandra *et al.*, 1996). It was calculated by the following formula.

$$\mathrm{HI} = \frac{kernel\ yield}{haulm\ yield + pod\ \ yield}$$

3.5.6. Oil content

Oil content was determined by hydrotec 8000 TM and Soxtec 8000 TM Extraction System at the laboratory of CDA. According to manual: Dedicated Analytical Solutions-Foss, the groundnut kernel sample was hydrolyzed by hydrotec 8000 TM then the oil extraction was done using Soxtec 8000 TM.

3.6. DATA ANALYSIS

Data generated from the experiment were subjected to analysis of variance (ANOVA) using JMP 2019. SAS Institute Inc.15th Edition. https://www.jmp.com and the difference between the means was compared using SNK at 5% level of probability. Pearl's correlation between some growth, yield characters and yield was done to determine their relationship.

CHAPTER FOUR

4.0. RESULTS AND DISCUSSION

4.1. RESULTS

4.1.1. Soil Analysis

The result of soil analysis for the experimental sites is presented in Table 1. The result indicated that the soil was sandy loam BUK while it was sandy clay at Minjibir. The pH was slightly acidic at BUK, while it was acidic at Minjibir. The Organic Carbon (OC), total N available P and CEC were relatively low at both locations. Calcium (Ca) content was low at BUK, while it was medium at Minjibir, magnesium (Mg) content and sodium (Na) content were medium at both sites. Potassium content (K) was medium at BUK, however, it was high at Minjibir.

4.1.2. Meteorological Data

Appendix I shows the weather data during the 2020 rainy season at both locations. It was observed that the rain started at both locations in May and reached the highest amount in July at BUK and August at Minjibir then ended in October at both sites. The total amount of rainfall were 989.8 mm within 43 days and 690.4 mm within 59 days at BUK and Minjibir respectively. The mean maximum monthly temperature of BUK (40 ^{o}C) and Minjibir (30.9 ^{o}C) were recorded in May. The mean minimum monthly temperature for BUK (22 ^{o}C) was recorded in August while for Minjibir (21.3^{o}C) was in May.

Table 1.Physical and Chemical Properties of the Soil of the Experimental Sites During the 2020 Rainy Season.

Soil Properties	BUK	Minjibir
Physical		
Sand (g kg^{-1})	642.20	506.90
Silt (g kg^{-1})	213.90	233.00
Clay (g kg^{-1})	144.00	260.02
Textural Class	Sandy loam	Sandy Clay
Chemical		
pH (1:1)	6.37	5.47
OC (g kg^{-1})	5.00	6.50
N (g kg^{-1})	0.40	0.50
P (mg kg^{-1})	4.87	2.40
Exchangeable base		
Ca (cmol (+)/kg)	1.76	2.44
Mg (cmol (+)/kg)	0.44	0.58
K (cmol (+)/kg)	0.19	0.44
Na (cmol (+)/kg)	0.12	0.10
EA (cmol (+)/kg)	0.25	0.56
ECEC (cmol (+)/kg)	2.75	4.13

Source: Soil Science Laboratory Centre for Dryland Agriculture (CDA) Bayero University, Kano.

4.1.3. Leaf Area Index at 9 Weeks After Sowing Canopy Height, Number of Branches plant^{-1} and Number of Pods plant^{-1} of Groundnut Varieties at BUK and Minjibir

The effect of Gypsum Rates, Methods of Gypsum Application and difference among Varieties on leaf area index(LAI), canopy height (CH), number of branches plant^{-1}(NBP) and number of pods plant^{-1}(NPP) at BUK and Minijibir during the 2020 rainy season is shown Table 2. The result of the study indicated that gypsum rates did not affect LAI, NBP, and NPP at both locations. CH was not affected by gypsum rates at BUK, however, a significant (p=0.036) effect of gypsum rate on canopy height was observed at Minjibir. The rate of 0 kg ha^{-1} recorded the highest CH (50.60 cm) which was statistically similar with the rate of 125 kg ha^{-1} that gave 49.90 cm. The methods of gypsum application was not effective on LAI, NBP and NPP at both location. CH was significantly (p=0.001) affected by methods of gypsum application at BUK. Soil application recorded the higher CH (45.05 cm) than foliar application which had 44.16 cm, but there was no significant difference observed at Minjibir. Groundnut varieties differed significantly (p=0.027) in LAI at BUK. SAMNUT-25 recoded the highest LAI (0.61) which was statistically at par with SAMNUT 23 (0.47) and SAMNUT 26 (0.47), but there were no significant differences observed at Minjibir.

There were significant differences among varieties in CH, NBP and NPP at both locations. SAMNUT 26 had the highest CH (49.96 cm) and the lowest was recorded from SAMNUT 23(40.63 cm) at BUK. SAMNUT 24 and SAMNUT 26 were statistically similar at Minjibir and they recorded 63.40 cm and 59.40 cm, respectively. SAMNUT 23 recorder the highest NBP (9) and SAMNUT 24 had the lowest NBP (6) at both locations.

Table 2. Leaf Area Index (LAI) at 9 Weeks After Sowing, Canopy Height (CH), Number of Branches Plant^{-1}(NBP), Number of Pods Plant^{-1}(NPP) of Groundnut Varieties at BUK and Minijibir During the 2020 Rainy Season.

Treatments			BUK				Minjibir	
	LAI	CH (cm)	NBP	NPP	LAI	CH (cm)	NBP	NPP
Gypsum rates (GR) Kg ha^{-1}								
0	0.44	46.0	8	15	0.3	50.6^{a}	9	16
125	0.50	44.8	8	15	0.3	49.9^{ab}	8	16
250	0.46	43.0	7	13	0.3	48.6^{b}	7	15
500	0.43	44.6	7	14	0.3	47.8^{b}	8	15
p-value	0.813	0.100	0.940	0.712	0.993	0.036	0.393	0.416
SE±	0.07	4.99	0.70	2.00	0.05	2.66	0.68	2.00
Method of application(MA)								
Foliar	0.48	44.16^{b}	6	14	0.3	49.17	7	15
Soil	0.44	45.04^{a}	7	14	0.3	49.37	7	15
p-value	0.791	0.001	0.543	0.543	0.237	0.567	0.492	0.151
SE±	0.06	4.72	1.00	2.00	0.05	2.66	0.68	2.00
Varieties(V)								
SAMNUT 23	0.47^{ab}	40.6^{c}	9^{a}	7^{b}	0.3	42.9^{b}	9^{a}	10^{b}
SAMNUT 24	0.34^{b}	43.4^{bc}	6^{b}	18^{a}	0.2	63.4^{a}	6^{b}	18^{a}
SAMNUT 25	0.61^{a}	44.1^{ab}	8^{ab}	16^{a}	0.30	43.0^{b}	6^{b}	17^{ab}
SAMNUT 26	0.47^{ab}	49.9^{a}	7^{ab}	15^{a}	0.28	59.4^{a}	7^{ab}	15^{ab}
p-value	0.027	0.023	0.032	0.005	0.066	<.0001	0.011	0.555
SE±	0.06	4.72	1.00	2.00	0.05	2.7	1.00	2.00
Interations								
GRxMA	0.731	0.005	0.591	0.827	0.486	0.019	0.384	0.308
GRxV	0.011	0.168	0.892	0.512	0.211	<.0001	0.252	0.453
MAxV	0.296	0.009	0.446	0.971	0.519	<.0001	0.384	0.724
GRxMAxV	0.189	0.101	0.907	0.361	0.191	<.0001	0.387	0.500

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.

LAI = Leaf Area Index, CH = Canopy Height, NBP = Number of Branches per plant^{-1}, NPP = Number of Pod plant^{-1}.

However, SAMNUT 24 recorded the highest NPP (18) and lowest NPP (7) was recorded from SAMNUT 23, 7 at BUK and NPP (10) at Minjibir.

The interaction between gypsum rates and varieties on leaf area index at BUK is presented in Table 3. When 250 kg ha^{-1} was applied, SAMNUT 24 recoded the highest LAI (0.54). However, the lowest (0.34) was recorded from the control treatment. Similarly, with SAMNUT 26, the highest leaf area index was recorded from 250 kg ha^{-1} of gypsum among all the rates of gypsum. With SAMNUT 25, it was the control treatment that recorded the highest (0.62) leaf area index.

The interaction between gypsum rates and methods of gypsum application on CH at BUK is presented in Table 4. The interaction between gypsum rates and method of gypsum application on CH at BUK showed that application of gypsum through the soil significantly reduced the CH. When gypsum was applied through the foliage, only the application of 500 kg ha^{-1} significantly reduced r the CH (28.50 cm).

The interaction between gypsum rates and methods of gypsum application on CH at BUK and Minjibir are presented in Table 5. With foliar application, 500 kg ha^{-1} recorded the slowest canopy height (33.2 cm). Inversely, when gypsum was applied into soil, application of 500 kg ha^{-1} was only significantly higher CH (44. 95 cm) than the rate of 125 kg ha^{-1} which recorded 36. 75 cm.

Table 6 shows the interaction between method of gypsum application and varieties on CH at BUK. It was observed that foliar and soil application did not affect CH with AMNUT 24, SAMNUT 25 and SAMNUT 26. However, with SAMNUT 23, Soil application recorded higher CH (58.55 cm) than foliar application which had 34.22 cm.

Table 3. Interaction Between Gypsum Rates and Groundnut Varieties on Leaf Area Index of Groundnut Varieties at 9 Weeks After Sowing at BUK During the 2020 Rainy Season.

Gypsum rates (kg ha^{-1})	Varieties			
	SAMNUT 23	SAMNUT 24	SAMNUT 25	SAMNUT 26
0	0.47^{bcd}	0.34^{d}	0.62^{ab}	0.47^{bcd}
125	0.50^{bcd}	0.39^{cd}	0.48^{bcd}	0.76^{a}
250	0.49^{bcd}	0.54^{bc}	0.43^{cd}	0.52^{bcd}
500	0.41^{cd}	0.4^{cd}	0.38^{cd}	0.41^{cd}
SE±	0.06			

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.

Table 4. Interaction Between Gypsum Rates and Methods of Gypsum Application on Canopy Height (cm) of Groundnut Varieties at BUK During the 2020 Rainy Season.

Gypsum Rates (kg ha^{-1})	Methods of application	
	Foliar	Soil
0	34.2^{bc}	58.5^{a}
125	41.6^{bc}	36.9^{bc}
250	45.6^{ab}	38.4^{bc}
500	28.5^{c}	37.1^{bc}
SE±	4.7	

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.

Table 5. Interaction Between Gypsum Rates and Methods of Gypsum Application on Canopy Height of Groundnut Varieties at Minjibir During the 2020 Rainy Season.

Gypsum Rates (kg ha^{-1})	Methods of Gypsum Application	
	Foliar	Soil
0	43.0^{ab}	40.8^{ab}
125	38.7^{abc}	36.7^{bc}
250	42.9^{ab}	39.4^{abc}
500	33.2^{c}	44.9^{a}
SE± 2.3		

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.

Table 6. Interaction Between Methods of Gypsum Application and Groundnut Varieties on Canopy Height of Groundnut Varieties at BUK the During 2020 Rainy Season.

Methods of gypsum application	Varieties		
	SAMNUT 23	SAMNUT 24	SAMI
Foliar	34.2^{c}	39.4b^{c}	49.6^{ab}
Soil	58.5^{a}	34.81^{c}	45.83
SE± 4.7			

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.

CH as affected by the interaction between methods of gypsum application and varieties at Minjibir is presented in Table 7. Foliar and soil application did not affect CH with SAMNUT 23. Soil application recorded higher CH with SAMNUT 24 (63.41 cm) and SAMNUT 26 (59.44 cm) than foliar application. Inversely, foliar application had higher CH than soil application with SAMNUT 25(51.33 cm). Table 8 shows the interaction between gypsum rates and varieties on canopy height at Minjibir. With SAMNUT 23, the control treatment had the highest canopy height (43.03 cm), while the lowest (32.20 cm) was recorded from 500 kg ha^{-1}. With SAMNUT 24, the highest (63.40 cm) canopy height was recorded from the control treatment. When 250 kg ha-1 of gypsum was applied, SAMNUT 25 had the highest (51.80 cm) canopy height, but the lowest (42.90 cm) was recorded from the control treatment. Table 9 shows the interaction between gypsum rates, methods of gypsum application and varieties on canopy height at Minjibir during the 2020 rainy season. When 500 kg ha^{-1} was applied through foliar application with SAMNUT 23 had the highest CH (44.90 cm). However, the lowest CH (33.20 cm) was recorded from the rate of 500 kg ha-1 through soil application. The rate of gypsum application through foliar application with SAMNU 24 recorded the lowest CH (42.20 cm). The rate of gypsum application with 500 kg ha^{-1} through foliar application with SAMNUT 26, had the lowest CH (47.50 cm).

4. 1.4. Chlorophyll Content at 9 Weeks After Sowing, Number of Nodules $plant^{-1}$ and Stand Count at Harvest of Groundnut Varieties at BUK and Minjibir

Chlorophyll content (CC) at 9 WAS, number of nodules (NN) and stand count at harvest (SCH) as affected by gypsum rates, methods of gypsum application and difference among varieties during the 2020 rainy season is shown in Table 10. It was observed that gypsum rates, methods of gypsum application did not affect CC, NN, and SCH at harvest

Table 7. Interaction Between Methods of Gypsum Application and Groundnut Varieties on Canopy Height of Groundnut Varieties at Minjibir During the 2020 Rainy Season.

	Varieties			
Methods of gypsum application	SAMNUT 23	SAMNUT 24	SAMNUT 25	SAMNUT 26
Foliar	40.87^e	54.7^bc	51.3^c	49.8^cd
Soil	43d^e	63.4^a	42.9^de	59.4^ab
SE± 2.70				

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.

Table 8. Interaction Between Methods of Gypsum Rates and Groundnut Varieties on Canopy Height (cm) of Groundnut Varieties at Minjibir the During the 2020 Rainy Season.

	Varieties(V)			
Gypsum rates(GR) kg ha^{-1}	SAMNUT 23	SAMNUT 24	SAMNUT 25	SAMNUT 26
0	43.03^ef	63.4^a	42.9^fg	59.43^ab
125	38.7^gh	42.2^fg	49.6d^ef	53.93^bc-e
250	42.9^fg	48^ef	51.8^cde	58.6^ab
500	33.2^h	50.63^ef	48.5^ef	56.4^ab-d
SE±	2.7			

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK

Table 9. Interaction Between, Gypsum Rates Methods of Gypsum Application and Groundnut Varieties on Canopy Height of Groundnut Varieties at Minjibir the During the 2020 Rainy Season.

		Varieties			
Gypsum rates (kg ha^{-1})	Methods of gypsum application	SAMNUT 23	SAMNUT 24	SAMNUT 25	SAMNUT 26
0	Foliar	40.87^mn-o	54.7^bc-g	51.3^de-i	49.83^ef-j
	Soil	43.03^jk-o	63.40^a	42.92^kl-o	59.43^abc
125	Foliar	36.67^op	61.1^ab	55.30^bc-f	58.23^ab-d
	Soil	38.7^nop	42.20^lm-o	49.61lm^-o	53.93^bc-g
250	Foliar	39.4^nop	45.92^hi-n	50.5^ef-j	52.1^cd-i
	Soil	42.90^klo	48^fg-m	51.8^de-i	58.61^ab-d
500	Foliar	44.90^ij-n	48.71^fg-l	52.9^cd-h	47.50^fg-m
	Soil	33.20^p	50.62^ef-i	48.51^fg-l	56.42^ab-i
SE±	2.6				

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.

Table 10. Chlorophyll Content at 9 Weeks After Sowing, Number of Nodules plant^{-1} and Stand Count at Harvest of Groundnut Varieties at BUK and Minjibir During the 2020 Rainy Season.

Treatments		Kano			Minjibir	
	CC	NN	SCH	CC	NN	SCH
Gypsum rates(GR) kg ha-1						
0	137.51	72	75250	486.28	78	97000
125	140.73	74	69667	478.70	77	10043
250	138.51	65	71167	465.46	70	102000
500	137.49	69	72348	482.44	72	97083
p-value	0.915	0.184	0.723	0.789	0.250	0.456
SE±	5.36	12.00	9140.00	42.51	10.00	1179.00
Method of application(MA)						
Foliar	138.50	74	70851	487.44	78	101298
Soil	138.64	66	73333	469.18	71	102208
p-value	0.213	0.592	0.358	0.895	0.259	0.205
SE±	5.08	12.00	8654.04	42.51	10.00	1079.00
Varieties(V)						
SAMNUT 23	139.51	66	80348	492.64	74	103783
SAMNUT 24	136.86	75	65583	473.33	76	90833
SAMNUT 25	139.42	67	68833	478.30	72	101333
SAMNUT 26	138.52	72	74000	469.19	74	104292
p-value	5.079	0.452	0.509	0.965	0.803	0.363
SE±	0.65	12.00	8654.04	42.51	10.00	1079.00
Interations						
GRxMA	0.265	0.156	0.399	0.361	0.085	0.130
GRxV	0.732	0.240	0.365	0.841	0.436	0.359
MAxV	0.459	0.293	0.979	0.758	0.300	0.306
GRxMAxV	0.659	0.300	0.152	0.797	0.261	0.584

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.
CC = Chlorophyll Content, NN = Number of Nodules, SCH = Stand Count at Harvest.

at both locations. The interactions between gypsum rates and methods of gypsum application, gypsum rates and varieties, methods of gypsum application as well as the interaction between gypsum rates, methods of gypsum application and varieties were significant at 5% level of probability on CC, NN and SCH at both locations.

4. 1.5. Crop Growth Rate, Relative Growth Rate and Net Assimilation Rate of Groundnut Varieties From 6-9 Weeks After Sowing at BUK and Minjibir

Table 11 shows crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) as affected by gypsum rates, methods of gypsum application and difference among varieties at BUK and Minjibir during the 2020 rainy season. It was found that gypsum rates and methods of gypsum application did not significantly affect CGR, RGR and NAR at both locations. Groundnut varieties, differed highly significantly (p=0.004) among them in CGR at BUK. SAMNUT 26 had the highest CGR (7.11 g g^{-1} $week^{-1}$) and the lowest was from SAMNUT 25 (5.38 g g^{-1} $week^{-1}$). The differences among varieties was similarly significant (p=0.049) in RGR at BUK with SAMNUT 26 recording the highest RGR (0.19 g g^{-1} $week^{-1}$) while the lowest was from SAMNUT 24(0.13 g g^{-1} $week^{-1}$). Similarly, SAMNUT 26 recoded the highest NAR (0.93 g cm^{-2} $week^{-1}$) and the lowest was SAMNUT 24 (0.65 g cm^{-2} $week^{-1}$) at BUK, while varieties did not differ significantly at Minijibir in 2020 rainy season.

There was no significant interaction between gypsum rates and methods of gypsum application on CGR, RGR and NAR at both locations. The combination of gypsum rates and varieties was effective on CGR (Table 12) and NAR (Table 13) from 6-9 WAS at BUK, but not at Minjibir. At BUK, when 250 kg $ha^{-1}$of gypsum was applied, SAMNUT 23 and SAMNUT-25 recorded the highest CGR (7. 77 g g^{-1} $week^{-1}$) and CGR (7. 17 g g^{-1} $week^{-1}$). While the interaction of gypsum rate of 500 kg ha^{-1} with SAMNUT 23 resulted in

Table 11. Crop Growth Rate, Ralative Growth Rate and Net Assimilation Rate of Groundnut Varieties From 6-9 Weeks After Sowing at BUK and Minijibir During 2020 Rainy Season.

Treatments		BUK			Minjibir	
	CGR	RGR	NAR	CGR	RGR	NAR
(GR) kg ha^{-1}						
0	6.71	0.89	0.89	4.64	0.12	0.60
125	4.94	0.64	0.64	4.61	0.11	0.61
250	6.32	0.82	0.82	4.26	0.11	0.57
500	4.82	0.64	0.64	4.75	0.12	0.63
p-value	0.122	0.115	0.101	0.812	0.778	0.755
SE±	1.46	0.19	0.19	1.46	0.03	0.18
Methods of application(MA)						
Foliar	6.00	0.78	0.78	4.38	0.11	0.57
Soil	5.41	0.72	0.72	4.74	0.12	0.63
p-value	0.211	0.176	0.212	0.190	0.114	0.123
SE±	1.39	0.12	0.19	1.39	0.03	0.18
Varieties(V)						
SAMNUT 23	5.30^{ab}	0.14^{ab}	0.69^{b}	4.37	0.12	0.58
SAMNUT 24	5.00^{ab}	0.15^{ab}	0.71^{bc}	4.65	0.12	0.64
SAMNUT 25	5.38^{c}	0.13^{b}	0.65^{c}	4.51	0.12	0.57
SAMNUT 26	7.11^{a}	0.19^{a}	0.93^{a}	4.71	0.11	0.62
p-value	0.004	0.050	0.002	0.845	0.488	0.853
SE±	1.386	0.030	0.176	1.389	0.034	0.182
Interations						
GRxMA	0.496	0.329	0.525	0.560	0.394	0.543
GRxV	0.023	0.201	0.009	0.771	0.883	0.701
MAxV	0.229	0.189	0.225	0.911	0.677	0.792
GRxMAxV	0.361	0.074	0.307	0.619	0.497	0.571

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.

CGR = Crop Growth Rate ($g.g^{-1}$ $week^{-1}$), RGR = Relative Growth Rate ($g.g^{-1}$ $week^{-1}$)
NAR = Net Assimilation Rate (g cm^{-2} $week^{-1}$)

Table 12. Interaction Between Gypsum Rates and Groundnut Varieties on Crop Growth Rate of Groundnut Varieties at BUK During the 2020 Rainy Season.

	Varieties			
Gypsum Rates (kg ha^{-1})	SAMNUT 23	SAMNUT 24	SAMNUT 25	SAMNUT 26
0	5.38^{bcd}	6.81^{abc}	2.84^{d}	10.16^{a}
125	5.38^{bcd}	6.81^{abc}	2.84^{d}	10.16^{a}
250	7.77^{ab}	3.52^{cd}	7.17^{abc}	7.06^{abc}
500	2.41^{d}	6.64^{ab-d}	6.32^{ab-d}	7.13^{abc}
SE±	1.39			

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.

Table 13. Interaction Between Gypsum Rates and Groundnut Varieties on Net assimilation Rate of Groundnut Varieties at BUK During the 2020 Rainy Season.

	Varieties			
Gypsum Rates kg ha^{-1}	SAMNUT 23	SAMNUT 24	SAMNUT 25	SAMNUT 26
0	0.69^{bc-d}	0.87^{bcd}	0.36^{e}	1.36^{a}
125	0.67^{bc-d}	0.65^{bc-e}	0.77^{bc-e}	0.61^{bc-e}
250	1.03^{ab}	0.46^{cde}	0.92^{abc}	0.87^{bcd}
500	0.33^{de}	0.93^{abc}	0.83^{bc-e}	0.9^{abc}
SE±	0.18			

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.

the lowest CGR (2.41 g g^{-1} $week^{-1}$). However the interaction of o and 125 kg ha^{-1} of gypsum with SAMNUT 26 gave highest CGR (10.16 g g^{-1} $week^{-1}$) respectively. Net assimilation as affected by the interaction between gypsum rates and varieties is presented in Table 13. SAMNUT 23 had the highest NAR (1.03 g cm^{-2} $week^{-1}$) with the application of 250 kg ha^{-1} and the lowest (0.33 g cm^{-2} $week^{-1}$) was obtained when 500 kg ha^{-1} was applied. Similarly, SAMNUT 25 recorded the highest NAR (0.92 g cm^{-2} $week^{-1}$) with the application of 250 kg ha^{-1} of gypsum. Meanwhile, SAMNUT 26 recorded the highest NAR (1.36 g cm^{-2} $week^{-1}$) with the control treatment. Trend of gypsum rates was observed with SAMNUT 24. There were not interaction between methods of gypsum application, gypsum rates, method of gypsum application and varieties on CGR, RGR and NAR from 6-9 WAS at both locations.

4.1.6. Hundred Kernels Weight Percent Oil Content of Groundnut Varieties at BUK and Minijibir

Effect of Gypsum Rates, Methods of Gypsum Application and difference among Varieties on 100 kernel weight (100-KW) and percent oil content OC (%) at BUK and Minijibir in 2020 rainy season is shown in Table 14. The result showed that gypsum rates did not affect 100- KW at both locations and OC (%) at BUK in 2020 rainy season. Oil content was significantly (p=0.047) affected by gypsum rates at Minjibir Site. The control recorded the highest OC (%) (59.90%) while the lowest was recorded with the application of 125 kg ha^{-1} (51.20%). It was also found that methods of gypsum application highly significantly affected 100-KW at both locations in 2020 rainy season. Soil application had higher 100-KW than foliar application at BUK (40.37g) and Minjibir (47.60 g), respectively. Methods of gypsum application did not influence oil content at both location. There were however

Table 14. Hundred Kernels Weight (100-KW) and Percent Oil Content OC (%) of Groundnut Varieties at BUK and Minijibir During the 2020 Rainy Season.

Treatment	BUK		Minjibir	
	100-KW(g)	OC (%)	100 –KW(g)	OC (%)
GR(kg ha^{-1})				
0	34.17	50.26	40.09	59.90[a]
125	37.90	50.10	40.29	51.20[b]
250	37.50	50.40	39.00	54.80[ab]
500	33.55	49.57	38.82	54.30[ab]
p-value	0.870	0.792	0.476	0.036
SE±	1.70	0.61	1.32	0.047
Method of application(MA)				
Foliar	34.17[b]	49.80	43.13[b]	50.99
Soil	40.37[a]	50.30	47.60[a]	50.90
p-value	0.007	0.567	0.024	0.632
SE±	1.60	0.438	1.32	0.14
Varieties(V)				
SAMNUT 23	34.17[a]	52.34[a]	45.05[a]	59.90[a]
SAMNUT 24	24.73[b]	49.51[bc]	36.65[b]	48.70[b]
SAMNUT 25	26.70[b]	48.06[b]	36.8[b]	47.61[b]
SAMNUT 26	29.17[b]	50.41[ab]	39.8[a]	50.92[b]
p-value	<0.001	<0.001	<0.001	0.0002
SE±	1.60	0.61	1.32	0.20
Interations				
GRxMA	0.082	0.999	0.023	0.871
GRxV	0.769	0.319	0.341	0.279
MAxV	0.08	0.776	0.211	0.908
GRxMAxV	0.736	0.573	0.131	0.99

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.

100-kW = 100 kernel weight. OC = oil content.

Significant ($p<0.001$) varietal differences among groundnut on 100-KW at both experimental sites. SAMNUT 23 recorded the highest 100-KW (34.17 g) at BUK. Similarly, SAMNUT-23 had the highest 100-KW (45.05 g) at Minjibir which was statistically at par with SAMNUT 26 that recorded 39.80 g. significant ($p<0.001$) differences were observed among varieties in oil content at both locations. SAMNUT 23 having the highest oil content (52.34%) and (59.90%) in both locations respectively; that was however with oil content of (50.41%) for SAMNUT 26 at BUK during the 2020 rainy season.

The interaction between gypsum rates and methods of gypsum application was not significant on 100-KW and oil content at BUK as well on oil content at Minjibir. There was a significant ($p=0.023$) interaction between gypsum rates and methods of gypsum application on 100-KW at Minjibir (Table 15). When 125 kg ha^{-1} and 500 kg ha^{-1} rates were applied, methods of gypsum application did not differ. Soil application recorded the lower kernel yield with 250 kg ha^{-1}compared to foliar application in 2002 rainy season.

4.1.7. Pod Yield and Kernel Yield of Groundnut Varieties at BUK and Minijibir

Pod yield (PY) and kernel yield (KY) as affected by gypsum rates methods of gypsum application and differences among varieties is shown in Table 16 during the 2020 rainy season at BUK and Minjibir. The result of the study revealed that, gypsum rates and methods of gypsum application did not affect PY and KY at both experiment sites. Varieties did not differently affected PY and KY at BUK, but at Minjibir in 2020 rainy season.

Table 15. Interaction Between Gypsum rates and Methods of Gypsum Application on 100-kernels weight of Groundnut Varieties at Minjibir During 2020 rainy Season.

	Method of application(MA)	
Gypsum rates kg ha^{-1}	Foliar	Soil
0	43.13^{bc}	47.6^{a}
125	45.8^{abc}	46.3^{ab}
250	45.75^{ab}	41.85^{c}
500	44.53^{ab}	45.75^{ab}
SE±	1.32	

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.

Table 16. Pod Yield and Kernel Yield of Groundnut Varieties at BUK and Minjibir During the 2020 Rainy Season.

Treatments	BUK		Minjibir	
	PY(kg ha^{-1})	KY(kg ha^{-1})	PY(kg ha^{-1})	KY(kg ha^{-1})
Gypsum rates(GR) kg ha^{-1}				
0	604.43	407.40	1221.28	819.82
125	563.02	376.92	1253.84	837.90
250	524.52	344.28	1125.60	826.29
500	555.43	382.50	1211.78	773.03
p-value	0.490	0.767	0.162	0.396
SE±	76.90	56.50	152.53	103.27
Method of application(MA)				
Foliar	531.06	354.29	1174.20	793.91
Soil	592.13	400.68	1231.59	834.53
p-value	0.273	0.349	0.416	0.922
SE±	72.77	53.57	144.41	103.27
Varieties(V)				
SAMNUT 23	580.77	370.60	1104.30^{b}	714.53^{b}
SAMNUT 24	528.69	367.41	1415.50^{a}	1058.50^{a}
SAMNUT 25	528.32	356.14	1017.60^{b}	692.47^{b}
SAMNUT 26	610.68	415.86	1330.70^{ab}	933.00^{ab}
p-value	0.62	0.63	0.021	0.041
SE±	72.77	53.57	144.41	103.27
Interations				
GRxMA	0.602	0.982	0.161	0.730
GRxV	0.087	0.613	0.160	0.113
MAxV	0.633	0.599	0.137	0.080
GRxMAxV	0.059	0.429	0.140	0.090

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.
PY = Pod Yield, KY = Kernel Yield

SAMNUT 24 recorded the highest PY (1415.50 kg ha^{-1}) which was statistically similar with SAMNUT 26(1330.70 kg ha^{-1}), while SAMNUT 24 had the highest KY

(1058.50 kg ha^{-1}) which was statistically at par with SAMNUT 26 (933.00 kg ha^{-1}). The interactions between gypsum rates and methods of gypsum application, gypsum rates and varieties, methods of gypsum application and varieties as well as gypsum rates and methods of gypsum application of varieties were not significant on PY and KY at both locations during the study period.

4.1.8. Haulm Yield and Harvest Index of Groundnut Varieties at BUK and Minijibir

Haulm yield (HY) and harvest index (HI) as affected by gypsum rates, methods of gypsum application and difference among varieties is shown in Table 17.The result of the study revealed that, gypsum rates and methods of gypsum application did not affect HY, and HI at both experimental sites during the period of study. Varieties were not different in their effect on HY, and HI at BUK, however, however significantly differs in their effect on HI at Minjibir site. SAMNUT 24 had the highest HI (0, 26) which was statistically at par with SAMNUT 26 (0.21) during the study period.

The interactions between gypsum rates and methods of gypsum application, gypsum rates and varieties, methods of gypsum application and varieties as well as gypsum rates and methods of gypsum application of varieties were not significant on HY and HI at both locations in 2020 rainy season.

4.1. 9. Correlation Analysis

Table 18 shows the result of simple correlation analysis among some growth and yield characters respectively at BUK during the 2020 rainy season. Crop growth rate was

Table 17. Haulm Yield and Harvest Index of Groundnut Varieties at BUK and Minijibir During the 2020 Rainy Season.

Treatments	BUK		Minjibir	
	HY(Kg ha^{-1})	HI	HY(Kg ha^{-1})	HI
Gypsum rates(GR) kg ha^{-1}				
0	1608.33	0.18	2653.17	0.21
125	1520.83	0.18	2939.13	0.20
250	1470.83	0.17	3002.08	0.20
500	1541.30	0.18	2700.42	0.20
p-value	0.181	0.215	0.782	0.584
SE±	191.47	0.03	313.41	0.02
Method of application(MA)				
Foliar	1477.66	0.18	2749.29	0.20
Soil	1591.67	0.18	2897.23	0.21
p-value	0.796	0.569	0.386	0.555
SE±	181.28	0.02	313.41	0.02
Varieties(V)				
SAMNUT 23	1445.65	0.18	3092.61	0.18^{b}
SAMNUT 24	1291.67	0.20	2484.33	0.26^{a}
SAMNUT 25	1537.50	0.18	2665.08	0.20^{b}
SAMNUT 26	1862.50	0.17	3059.17	0.21^{ab}
p-value	0.103	0.463	0.554	0.033
SE±	181.30	0.02	313.41	0.02
Interations				
GRxMA	0.062	0.204	0.549	0.968
GRxV	0.905	0.236	0.856	0.270
MAxV	0.971	0.614	0.405	0.067
GRxMAxV	0.703	0.674	0.929	0.136

Means followed by same letter(s) in a column within a treatment group are not significantly different at 5% level of probability using SNK.

HY = Haulm Yield, HI = Harvest Index.

positively highly ($p<0.001$) correlated with relative growth rate. Similarly crop growth rate had a highly positive correlation with net assimilation rate. It was found that pod yield was positively and highly ($p<0.001$) correlated with kernel yield, harvest index. The correlation between pod yield, number of pod plant^{-1} was positive and significant ($p=0.0201$). The correlation between kernel yield and harvest index was positive and highly significant ($p<0.001$). Number of pod plant^{-1} had a highly negative correlation with leaf area index at 9 WAS and number of branches. The result of simple correlation analysis among some growth and yield characters at Minjibir is presented in Table 19. The result revealed that crop growth rate correlated highly ($p=0.001$) positively with relative growth rate and net assimilation rate. Similarly, pod yield and number of pods plant^{-1} had a highly ($p<0.001$) positive correlation between them. Harvest index correlated highly positively with kernel yield and canopy height. However, the correlation between number of branches plant^{-1} with harvest index and number of pod plant^{-1} were strongly ($p<0.001$) negative. It was found that harvest index had a highly significant ($p=0.0025$) negative correlation with leaf area index. The correlation was negative and significant ($P=0.0326$) between leaf area index and number of pod plant^{-1} during the 2020 rainy season.

4.2. DISCUSSION

4.2.1. Soil Analysis

The result revealed that the soil was sandy clay at Minjibir while it was sandy loam at BUK during the 2020 rainy season. The clay soil texture could have a positive influence on water retention as well as nutrient adsorption and hence contributed to acceptable crop yield at Minjibir. The Organic Carbon (OC) content, total N and available P and CEC were low across the two locations. This agreed with Hussaini (2019) stated that the low status in

Table 18: Matrix of Simple Correlation analysis of Some Growth and Yield Characters of Groundnut Varieties Related to Pod and Kernel Yield at BUK During the 2020 Rainy Season.

	CGR	CH	HI	KY	LAI	NAR	NBP	NPP	PY	RGR
CGR										
CH	0.099									
HI	-0.112	0.095								
KY	0.1	0.211*	0.563**							
LAI9	-0.148	0.072	-0.161	-0.205*						
NAR	0.981**	0.122	-0.1	0.1	-0.181					
NBP	0.05	0.091	-0.177	-0.12	0.399**	0.046				
NPP	0.083	0.077	0.307**	0.32**	-0.351**	0.086	-0.409**			
PY	0.151	0.125	0.459**	0.915**	-0.196	0.15	0.004	0.237*		
RGR	0.872**	0.119	-0.136	0.081	-0.05	0.853**	0.033	0.029	0.106	

CGR= Crop Growth Rate from 6-9 WAS, RGR= Relative Growth Rate from 6-9 WAS, NAR= Net Assimilation Rate from 6-9 WAS, CH= Canopy Height, LAI9= Leaf Area Index at 9 WAS, Number of Branches plant^{-1} Number of Pod Plant^{-1}, PY= pod yield, KY= kernel Yield, HI= Harvest Index.

Table 19: Matrix of Simple Correlation analysis of Some Growth and Yield Characters of Groundnut Varieties Related to Pod and Kernel Yield at Minjbir During the 2020 Rainy Season.

	CGR	CH	HI	KY	LAI	NAR	NBP	NPP	PY	RGR
CGR										
CH	0.157									
HI	-0.033	0.41**								
KY	0.041	0.425**	0.706**							
LAI9	-0.003	-0.189	-0.305**	-0.159						
NAR	0.976**	0.148	-0.023	0.032	-0.013					
NBP	0.072	-0.06	-0.366**	-0.185	0.162	0.027				
NPP	0.053	0.396**	0.627**	0.44**	-0.218*	0.047	-0.442**			
PY	0.018	0.257*	0.522**	0.909**	-0.03	0.003	-0.096	0.305**		
RGR	0.926**	0.077	-0.032	-0.031	0.002	0.934**	0.066	-0.005	-0.038	

CGR= Crop Growth Rate from 6-9 WAS, RGR= Relative Growth Rate from 6-9 WAS, NAR= Net Assimilation Rate from 6-9 WAS, CH= Canopy Height, LAI9= Leaf Area Index at 9 WAS, Number of Branches plant^{-1} Number of Pod Plant^{-1}, PY= pod yield, KY= kernel Yield, HI= Harvest soil fertility is one of the characteristics of dryland area. The exchangeable base Ca was medium at Minjibir, this agrees with the report of Shehu, Jibrin and Samndi (2015) that Calcium (Ca) contents in both surface and subsurface soils were moderate (2.0-5.0 cmol (+) kg^{-1}) in the Sudan Savanna Biome of Northern Nigeria, however it was found that the calcium content was low at BUK. The potassium content was medium at BUK, but high at Minjibir during the study period. The magnesium and sodium content were medium at both locations. The soil was acidic (pH=5.47) at Minjibir while it was slightly acidic (pH=6.37) at BUK. Nevertheless the pH at Minjibir was a bit little far from the requirement according to the report of Sivakumar and Virmani (1986) who stated that the optimum pH in groundnut production ranges between 6.0 - 6.5.

4.2.2. Meteorological Data

It was found that the rainfall during the 2020 raining season was enough for groundnut production. The rain started at both locations in May and reached the highest amount in July at BUK and August at Minjibir then ended in October at both sites. The total amount of rainfall were 989.8 mm within 43 days and 690.4 mm within 59 days at BUK and Minjibir respectively. This agreed with Sivakumar and Virmani (1986) who reported that the groundnut crop requires about 500-600 mm of well distributed rainfall in dryland area. However the amount of rain was a bit higher at BUK than Minjibir.

The establishment and the variability in the amount of rainfall between the two locations were with the respect to their latitudes. Examining the average of rainfall per day across the two locations BUK, recorded the higher distribution than Minjibir. That was the consequences in flooding at BUK at 6 WAS after sowing. That flooding affected seriously groundnut crop and leading to the lower pod and kernel yield at BUK than Minjibir site.

The average minimum temperature was 23.2 ^{o}C and 21.5 ^{o}C at Kano and Minjibir, respectively. Similarly, the maximum temperature was 34.2 ^{o}C and - 34.3 ^{o}C at BUK and Minjibir, respectively. These average temperature across two location were close to the optimum temperature in groundnut production according Sivakumar and Virmani (1986) who reported that the optimum temperature for groundnut production ranges between 28 to 30 ^{o}C.

4.2.3.Effect of Gypsum Rate on Growth , Yield Characters and Yiel of Groundnut Varieties

The control treatment gave the highest canopy height (50.60 cm) and oil content (59.90%) at Minjibir. However, the effect of gypsum was observed not at BUK. That could be due to the water logging that might have affected the rates of gypsum leading to the non-significant difference observed during the period of the experiment. The result about the oil content was contrary to Mbonwa (2013) who reported that oil content was significantly increased by calcium application at flowering with 27.28% compared to 20.7% without Ca. Pod and kernel yields were not affected by gypsum rates and methods of gypsum application at both locations during the 2020 rainy season. This is not in line with with Gashi *et al.,* (2012) who reported that calcium application at flowering stage increases the kernel yield. This might be due to the Single Superphosphate (SSP) (20% P, 18% Ca, 11% S) which was used to balance the phosphorus requirement 54 ($P_2$05), applied at 15 DAS. According to the result of soil analysis, calcium content was medium at Minjibir and low at BUK. The added calcium through SSP at 15DAS might be already enough for the varieties tested. This is in line with Florence (2011) who determined that basically, calcium fertilization does not show improvements in yield when the soil has adequate calcium.

4.2.4. Effect of Methods of Gypsum Application on Growth Yield Characters and Yield of Groundnut Varieties

Soil application gave heavier 100 kernel weight, 40.37g and 47.60 g over the foliar application at BUK and Minjibir respectively. This shows gypsum was absorbed more through soil application than the foliar application.

4.2.5. Differece Among Groundnut Varieties in Growth , Yield Characters and Yield

Groundnut varieties differed significantly in some growth and yield characters. This could be due to their genetic constitution and the weather conditions. SAMNUT 26 had the higher CGR, RGR and NAR which was statistically similar with SAMNUT 24 However there was no significant difference among varieties in CGR, RGR and NAR at Minjibir site. The significant difference observed at BUK for these characters could be due to the weather conditions that depressed significantly other varieties tested than SAMNUT 26 and SAMNUT 24. At harvest, SAMNUT 24 had canopy height which was statistically at par with SAMNU 26 and the lowest was SAMNU 23 at Minjibir. However SAMNUT 26 recorded the highest canopy height which was statistically similar with SAMNUT 25. The difference between SAMNUT 25 and SAMNUT 24 across the two locations could be related to the weather conditions. It could be due to effect of sun shine that could be higher at Minjibr with respect of it higher latitude location. The poor growth of SAMNUT 24 might be due to the waterlogging at BUK site during the 2020 rainy season. SAMNUT 23 differed from all the varieties tested and had the highest number of branches plant^{-1}, 100 kernel weight at both locations. It had the highest oil content among all the varieties.

This agreed with Asibuo, *et al.* (2008) who stated that oil content differed significantly among groundnut varieties.

SAMNUT 24 and SAMNUT 26 differed from the rest of varieties giving the higher number of pods plant^{-1} across the two locations. Therefore, SAMNUT 24 gave the highest pod and kernel yield as well as harvest index which were at par with SAMNUT 26 at Minjibir. SAMNUT 26 gave higher pod and kernel yield at BUK, but the difference was not significant. Although pod and kernel yield were lower at BUK than Minjibir due to the low population density as a result of waterlogging. This is in agreement with Parent *et al* (2008) who stated that waterlogging leads groundnut and many upland crops to low crop yield.

4.2.6. Interaction Between Gypsum Rates and Methods of Gypsum Application

The interaction between gypsum rates and method of gypsum application on canopy height at BUK show that application of gypsum through the foliage significantly reduced the canopy height. When gypsum was applied through the foliage, only the application of 500 kg ha^{-1} significantly reduced the canopy height (28.50 cm). This indicated that the application of more gypsum through foliage stunt the growth of groundnut crop. That could have affected the stomata activity then altering the metabolism activity. When gypsum was applied into soil at Minjibir, the application of 500 kg ha^{-1} only recorded higher canopy height (44. 95 cm) than the rate of 125 kg ha^{-1} which recorded 36. 75 cm.

4.2.7. Interaction Between Gypsum Rates and Groundnut Varieties

When the rate 250 kg ha^{-1}of gypsum was applied at BUK, SAMNUT 23 recorded higher CGR (7.77g g^{-1} week^{-1}) and the lower (2.41 g g^{-1} week^{-1}) was from 500 kg ha^{-1}. SAMNUT 25 recorded the highest CGR (7.17 g g^{-1} week^{-1}) with application of 250 kg ha^{-1} of gypsum which was statistically similar with 500 kg ha^{-1}. Still at BUK, SAMNUT 23 had the highest NAR (1.03 g cm^{-2} week^{-1}) with the application of 250 kg ha^{-1} and the lowest

(0.33 g cm^{-2} wk) was obtained when 500 kg ha-1 was applied. Similarly, SAMNUT 25 recorded the highest NAR (0.92 g cm^{-2} $week^{-1}$) with the application of 250 kg ha^{-1} of gypsum. Meanwhile, SAMNUT 26 recorded the highest NAR (1.36 g $cm^{-2}week^{-1}$) with the control treatment. Trend of gypsum rates 250 kg ha^{-1} performance was observed with SAMNUT 24. This is an obvious advantage of the rate of 250 kg ha^{-1} of gypsum on SAMNUT 23 and SAMNUT 25 at 9 WAS. However, SAMNUT 24 did not show significant effect on growth characters at 9 WAS when gypsum was applied. Inversely, SAMNUT 26 performed significantly with the control treatment. This shows the growth in groundnut crop is not only controlled by the amount of gypsum but also by the genetic performance of varities and the effect of the environment. At Minjibir, the interactions on CGR and NAR were absent at 9 WAS. This could be explained that varieties did not differ in accumulating dry matter from 6 to 9 WAS due to the weather conditions, moderate calcium content at Minjibir could have significantly improved all the varieties before the application of gypsum.

4.2.8. Interaction Between Methods of gypsum Application and Groundnut Varieties

With SAMNUT 23, Soil application recorded higher canopy height (58.55 cm) than foliar application which had 34.22 cm at BUK. This indicated the advantage of soil application of gypsum on the growth of groundnut crop, thus resulting on heavier 100 kernel yield that was recorded from soil application at both locations. Therefore, soil application can be adopted in this area of study. However, the rest of the varieties tested did not show a significant interaction on canopy height.

4.2.9. Correlation Analysis

It was found that pod yield and kernel yield were correlated positively with number of pod plant^{-1} and harvest index at both locations. However, number of branches and leaf area correlated negatively with number of pods plant^{-1}, pod and kernel yield. This was observed with SAMNUT 23 which had more number of branches and more number of leave, but produced less number of pods plant^{-1} and therefore less pod and kernel yield.

CHAPTER FIVE

5.0. SUMMARY, CONCLUSION AND RECOMMANDATIONS

5.1. SUMMARY

A trial was conducted during the 2020 rainy season at Research Farm of the Center for Dry land Agriculture (CDA), Bayero University, Kano, Nigeria (Latitude 11^{o}58'N and Longitude 8^{o}26´E) and at Institute for Agricultural Research, Sub Station at Minijibir (Latitude 12^{o}17´N and Longitude 8^{o}65´E). Both locations were within Sudan savanna of Nigeria. The objectives of the research were to determine an adequate gypsum application rate to groundnut varieties, to determine the appropriate method of gypsum application and evaluate oil content in groundnut varieties as affected by rates and methods of gypsum application.

The treatments consisted of three factors: Gypsum fertilizer with four levels (0, 125, 250 and 500 kg ha^{-1}), Method of gypsum fertilizer application with two levels (foliar application and soil application) and groundnut varieties with four varieties (SAMNUT 23, SAMNUT 24, SAMNUT 25 and SAMNUT 26 .The treatments were laid out in Randomized complete Block Design (RCBD) and were replicated three times. Each plot had 6 ridges and each ridge 5 m. The interrow spacing was 0.75 cm and intrarow spacing was 0.25 cm. Each gross size was 6 x 0.75 m x 5 m (22.5 m^2) and net plot 0.75 m x 2 x 4 m (6 m^2). All the cultural practices were carried out as per requirement of the treatments.

BUK site was affected by waterlogging at 6 WAS. The soil remained very wet till 8 WAS. That caused the groundnut plants to become yellow and visibly stunted.

The total amount of rainfall were 989.8 mm within 43 days and 690.4 mm within 59 days BUK and Minjibir, respectively. The average minimum and maximum temperature ranges between 23.2 -34.2 ^{o}C and 21.5- 34.3 ^{o}C at Kano and Minjibir respectively.The calcium content was medium at Minjibir. While it was low at BUK. The total availability of N, P, OC and CEC were low at both locations.

Data collected were subjected to analysis of variance using JMP 2019.SAS Institute Inc.15th Edition. https://www.jmp.com. Correlation between growth, yield characters and yield was done to determine their relationship. Gypsum rates and application methods did not significantly affect number of branches per plant at both locations. The control treatment gave the highest canopy height (50.60 cm) and highest oil content (59.90 %) at Minjbir. But no significant differences were observed at BUK. Soil application gave heavier 100 kernel weight, 40.37g and 47.60 g over the foliar application at BUK and Minjibir, respectively.

SAMNUT 23 had the highest number of branches plant^{-1} ($p<0.05$), 100 kernel weight and oil content than all the other varieties at both locations. At Minjibir, both gypsum rates and methods did not significantly affect the crop growth rate, relative growth rate at both locations. Varieties differed significantly ($p<0.05$) in crop growth rate, relative growth rate and net assimilation rate at BUK. SAMNUT 26 had the highest crop growth rate, relative growth rate and net assimilation rate than all the other varieties. These differences were not observed at Minjibir site. Varieties were significantly different in canopy height, number of pods plant^{-1} at both locations. SAMNUT 26 recorded the highest canopy height at BUK. While SAMNUT 24 had it at Minjibir. SAMNUT 24 gave the highest number of pod plant^{-1} at both experiment sites. SAMNUT 24 produced significantly ($p<0.021$) higher pod yield (1415.50 kg ha^{-1}) and kernel yield (1058.50 kg ha^{-1}) which was statistically at par with SAMNUT 26 in pod yield(1330.70 kg ha-1) and kernel yield (933.00 kg ha^{-1}) at Minjibir. Varieties did not differ significantly at BUK. Pod yield correlated strongly and positively with kernel yield number of pods plant-1 and harvest index at both locations during the period of study.

5.2. CONCLUSION

According to the result of study, it can be concluded that SAMNUT 24 and SAMNUT 26 performed well at both locations in growth and yield characters leading to the production of high pod and kernel yield at Minjibir. SAMNUT 24 recorded the highest pod yield (1415.50 kg ha^{-1}) and kernel yield (1058.50 kg ha^{-1}) which was statistically similar with SAMNUT 26 at Minjibir in pod (1330.70 kg ha-1) and kernel yield (933.00 kg ha^{-1}). However the pod and kernel yield were lower at BUK due to low population density and waterlogging among other factors. Gypsum rates and methods of gypsum application were not effective on groundnut varieties due to the calcium that was in SSP which was applied to balance the phosphorus need at 15 days after sowing.

5.3. RECOMMANDATIONS

Based on the results obtained, it is therefore recommended that SAMNUT 24 and SAMNUT 26 can be chosen by farmers in groundnut production in Sudan savanna of Nigeria for the production of pod and kernel yield.

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APPENDICES

Appendix I. Meteorological Data of the Experimental at BUK and Minjibir.

	Temperature (ºC)				Number of days and rainfall			
	BUK		Minjibir		BUK		Minjibir	
Month	Min	Max	Min	Max	days	Rainfall(mm)	days	Rainfall (mm)
May	26.5	40.0	21.3	39.9	3	33.9	2	2.3
June	24.8	36.7	22.8	38.1	5	101.4	12	67.7
July	22.6	32.0	22.4	31.7	12	323	17	169.5
August	22.0	29.7	21.4	30.8	10	219.7	13	265.8
September	22.4	31.9	21.6	31.5	10	254.3	13	169.1
October	20.7	34.7	19.4	33.7	3	57.5	2	16
Total					43	989.8	59	690.4

Sources: Department of geography, Bayero University Kano and IITA station Kano During the 2020 raining season.

Appendix II. Critical Limits for Interpretation Level of Soil Analytical Parameters and Level of Soil pH.

Parameters	Critical Limits for Interpretation Level of Soil Analytical Parameters Rating				Critical Limits for Interpretation Levels of Soil pH	
					Soil Reaction	pH
	Low	Medium	High	Units	Ultra-acid	<3.5
					Extremely	3.5-
Ca	<2	2-5	>5	cmol(+)kg^{-1}	acid	4.4
Mg	<0.3	0.30-10	>0.30	cmol(+)kg^{-1}	Very strongly	
						4.5-
K	<0.15	0.15-0.30	>0.15	cmol(+)kg^{-1}	acid	5.0
					strongly	5.1-
Na	<0.1	0.1-0.30	>0.1	cmol(+)kg^{-1}	acid	5.4
						5.5-
CEC	<6	5-12	>12	cmol(+)kg^{-1}	Moderatly	6.0
					Slightly	6.1-
BS	<50	50-80	>50	cmol(+)kg^{-1}	acid	6.5
OC	<10	10-15	>15	g kg^{-1}		
Tatal N	<0.1	0.1-0.2	>0.1	g kg^{-1}		
Avail.P	<10	10-20	>20	mg kg^{-1}		

Source: Esu (1991)

Appendix III. Area and Groundnut Production in some Developing Countries.

Countries	years	Area(million hectares)	Production (million tons)
Burkina	2017	0.56	0.33
	2018	0.56	0.33
	2019	0.56	0.45
Cameroon			
	2017	0.43	0.6
	2018	0.43	0.6
	2019	0.43	0.6
Chad			
	2017	0.7	0.87
	2018	0.7	0.89
	2019	0.7	0.85
Ghana			
	2017	0.34	0.43
	2018	0.34	0.52
	2019	0.34	0.44
Mali			
	2017	0.39	0.3
	2018	0.38	0.49
	2019	0.34	0.43
Nigeria			
	2017	2.82	4.25
	2018	2.82	4.42
	2019	2.8	3.5
Niger			
	2017	0.92	0.46
	2018	0.93	0.59
	2019	0.9	0.5
Senegal			
	2017	1.25	1.41
	2018	1.25	1.45
	2019	1.25	1.1
Sudan			
	2017	2.22	1.65
	2018	3.07	2.88
	2019	2.3	1.8

Source: World Agricultural Production (WAP) (January, 2020)