PERFORMANCE OF GROUNDNUT *(Arachis hypogaea* L.*)* AND SORGHUM *(Sorghum bicolor* L. Moench) VARIETIES IN INTERCROPS

BY

JOSEPH IKHIDUANUMEN AKHIBI
SPS/10/MAG/00003

A DISSERTATION SUBMITTED TO THE DEPARTMENT OF AGRONOMY, BAYERO UNIVERSITY, KANO IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF SCIENCE IN AGRONOMY

FEBRUARY, 2016

DECLARATION

I hereby declare that this work is the product of my own research effort, undertaken under the supervision of Prof. S.G. Mohammed and Prof. S. Miko and has not been presented and will not be presented elsewhere for the award of a degree or certificate. All sources have been dully acknowledged.

………………………………….…… ……………………..

Joseph Ikhiduanumen Akhibi Date

The above declaration is confirmed by

……………………………………… …………………….

Prof. S.G. Mohammed Date
(Major Supervisor)

CERTIFICATION

This is to certify that the research work for this dissertation and the subsequent preparation of this dissertation by Joseph Ikhiduanumen Akhibi, (SPS/10/MAG/00003) were carried out under our supervision.

………………………………….. ……………..

Prof. S. G. Mohammed Date
(Major Supervisor)

………………………………… ……………..

Prof. S. Miko Date
(Co-Supervisor)

………………………………. ……………..

Prof. S. G. Mohammed Date
(Head of Department,)

APPROVAL

This dissertation titled "Performance of Groundnut (*Arachis hypogaea* L.) and Sorghum (*Sorghum bicolor* L. Moench) varieties in Intercrops has been examined and approved for the award of the Degree of MASTER OF SCIENCE IN AGRONOMY.

………………………………….. ……………..

Dr. B. A. Babaji Date
(External Examiner)

………………………………….. ……………..

Prof. S. G. Mohammed Date
(Major Supervisor)

………………………………….. ……………..

Dr. S. U. Yahaya Date
(Internal Examiner)

………………………………….. ……………..

Prof. S. Miko Date
(Co-supervisor)

………………………………….. ……………..

Dr. A. Mustapha Date
(PG, Board Representative)

………………………………….. ……………..

Prof. S. G. Mohammed Date
(Head of Department)

ACKNOWLEDGEMENTS

I wish to thank Prof. S.G. Mohammed, Prof. S. Miko, Dr. I. B. Mohammed, A.A. Adnan, Isah Danja, Ibrahim Maina and others for their support and encouragement at various levels during the research work and the preparation of dissertation.

I wish to express my gratitude to the Department of Agronomy, Bayero University, Kano and the Agricultural Research Station (ARS), Minjibir for allowing me use their facilities for my experiments.

I also wish to recognize all the assistance received from my wife Mrs. Comfort Akhibi and indeed all my friends that stood solidly behind me to make this work possible.

DEDICATION

I dedicate this work to my parents Mr. Wilfred Iyoha Akhibi and Mrs. Mary Akhibi for sponsoring my education up to university level. I also dedicate it to my darling wife, Mrs. Comfort Akhibi who occupies a special place in my heart, for her patience and encouragement.

TABLE OF CONTENTS

Page

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

LIST OF TABLES

LIST OF APPENDIX

ABSTRACT

An investigation was carried out to determine the performance of groundnut/sorghum varieties as influenced by varieties and crop arrangement. Field trials were varied out during the 2012 net season at Bayero University Farm Site, Kano and Agricultural Resource Station (ARS), Minjibir, Kano. Both locations are in Sudan savannah ecological zone of Nigeria. In the growing season, rainfalls were below normal while temperatures were normal. The treatments were two sorghum varieties (Farafara and ICSV400) and four groundnut varieties (Samnut 21, Samnut 22, Samnut 23 and Kampala). The experiment was laid out in a split plot design which was replicated three times. At BUK and Minjibir, ICSV400 grown in combination with Samnut 22 at 1:1 crop arrangement, produced higher sorghum grain yield than Farafara. At Minjibir, Samnut 22 planted in combination with ICSV400 at 1:2 crop arrangements had significantly highest kernel yield than Samnut 21, Samnut 23 and Kampala. However, Samnut 22 grown in combination with Farafara at 2:4 crop arrangements was observed to have the highest kernel yield at BUK. For land equivalent ratio, Farafara/Samnut 23 at 1:2 crop arrangements had the highest LER at BUK while Farafara/Kampala at 1:2 crop arrangements had the highest LER at Minjibir. Farmers could be advice to plant based on the combination and crop arrangements that had the highest yield.

CHAPTER ONE

1.0 INTRODUCTION

Intercropping is a popular farming system among small-scale farmers in the tropics (Ruthenerg, 1980; Vandemer, 1992). It is a form of multiple cropping where two or more different crops are grown on the same farm at the same time. There are two types of intercropping: mixed intercropping and strip intercropping. Mixed intercropping is the growing of two or more crops simultaneously with no distinct row arrangement. Strip intercropping is the growing of two or more crops simultaneously in different strips in the alternate arrangement, which are wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically. Intercropping sorghum and groundnut may increase, decrease or not affect yields of sorghum and groundnut depending on the spatial arrangement of the intercrops (Okiror *et al*., 1997). Sorghum is one of the major cereal crops where as groundnut is one of the most important legumes grown in Nigeria savanna. Most of the production of cereals come in mixture of two or more of the cereals and legumes (Odion, *et al.,* 1990; Olufajo, 1990; Olabanji, 1997).

Sorghum (*Sorghum bicolor* L. Moench) is a cereal in the family of Poaceae. Within the group are a number of species and varieties deferring in structure and chemical composition. Various terms are used to refer to sorghum according to the local names or places of cultivation. Other common names for sorghum include great millet, guinea corn, Durra in the Sudan, Jowal, jola and cholam in India, Milo and Sorgo in the USA and Kaoliang in China. The area under cultivation and the production data are only estimates since sorghum production is concentrated on small subsistence farms where the grains are largely consumed by the producers. Groundnut or peanut (*Arachis hypogaea* L.) belongs to the family fabaceae. According to Tura *et al,* (2008), Groundnut is grown as an annual crop on about 19 million hectares in tropical and subtropical regions and the warm areas of temperate regions of the world, principally for its edible oil and protein rich kernels or seeds, borne in pods, which develop and mature below the soil surface. In their report, groundnut is one of the most important sources of vegetable oil in the world. In the developing countries, where about 80 percent of the crop is produced, the average yields are around 1 tonne/hectare. In India, the world's largest producer, the average yields is about 900kg/hectare. They further identified the other major world producers of groundnut to include China, USA, Nigeria, Senegal and Brazil. According to them, the USA is the largest exporter of groundnut. In Nigeria, the leading production states are Niger, Kano, Jigawa, Zamfara, Kebbi, Sokoto, Katsina, Kaduna, Adamawa, Yobe, Borno, Taraba, Plateau, Nassarawa, Bauchi and Gombe (Taru *et al.,* 2008). Nigeria ranks fourth country, among the major producers in 1995 (Nwokolo, 1996). Annual world output of unshelled nuts in 2010 in the northern parts was about 36.5 metric tones (FAO, 2011).

1.1 Uses of Sorghum and Groundnut

Sorghum constitutes a major source of energy and protein for millions of people in Asia and Africa. Sorghum is believed to have the greatest potential among food crops for attaining technological breakthroughs that will improve food production in any region. In West Africa, sorghum is used to prepare many foods, of which the most popular are "tuwo, akamu, kunu and koko". Sorghum flour when mixed with cassava or sweet potato flour form a very palatable food. Sorghum beer is also popular and may be drunk as burukutu.

Groundnut provides an inexpensive source of high quality dietary protein and oil. It supplies about 5.6 calories per grain when consumed raw and 5.8 calories per grain when consumed roasted. It is a rich source of essential amino acids, minerals and vitamins. The testa is composed of carbohydrates, cellulose, protein and phenolic compounds while cotyledons have mainly oil and protein (Abdel Rahman, 1982). Crops residues from cereals and oil seed crops after harvesting form the staple feed for ruminant livestock. However, the nutritive value of sorghum crop residues is very poor. Even ruminants, despite their unique and highly efficient digestive systems, are not able to extract sufficient energy from low quality, highly lignified crop residues to grow or produce milk.

1.2 Statement of Problem

Intercrop productivity depends on the genetic constitution of component crops, growth environment and manipulations of micro-environments. Although groundnut production has picked up again in Nigeria, use of improper crop combination and crop arrangement which cause competition for resources such as light (shading) and nutrient, limit growth and yield of groundnut are still widely practiced. Another limiting factor is the use of local varieties of groundnut in sorghum intercrop resulting in low yield.

1.3 Justification for the Study

There is need to step up the production of groundnut in Nigeria in view of its importance as staple food to man, source of vegetable oil and as animal feed. Considering also the daily increase in population and increase in the demand of groundnut for both domestic and industrial uses, there is need to increase its production in Nigeria. New groundnut varieties with different responses to cropping systems and environmental adaptation are continuously being developed and released by research institute to the farming communities, but these varieties are mostly evaluated under systems of mono-cropping, thus, this may not be sufficient to identify suitable genotype for intercropping (Smith, 2002). The resultant of faulty intercropping system, such as defective planting geometry, use of low yielding varieties, inappropriate sowing dates and other undesirable operations, together with various crop stress factors (both biotic and a biotic), greatly reduces the efficacy of the system and causes considerable reduction in output (Singh and Ajeigbe, 2002). Agriculture researcher originally focused on sole cropping and ignored the potentiality of intercropping. Intercropping has been shown to produce higher and more stable yield in a wide range of crop combinations, while the system is characterized by minimal use of inputs and in the context of environmentally sound production (Van Bueren *et el;* 2002). It is therefore essential to support researches to develop efficient and sustainable systems in order to guarantee improvements in food productivity

However, the current low yields of the crop characterized by use of local crop varieties and inappropriate cropping systems could be enhanced using improved varieties of groundnut in appropriate crop arrangement. Furthermore there is need to develop an improved cropping system to replace the traditional system usually associated with excessive shading of plants. Improved groundnut varieties (Samnut 21, 22 and 23) are currently being intercropped by farmers. For this reason, it is necessary to determine the best row arrangement of groundnut with sorghum for better results. Crop row arrangement of intercropping systems manipulates the crop micro climates such as modification of radiation, temperature, moisture and wind which is likely to improve the productively of the whole intercrop.

1.4 Objectives of the Study

i. To determine the performance of some selected groundnut and sorghum varieties at BUK and Minjibir.

ii. To determine the performance of either crop in presence of the other companion crop.

iii. To come up with the best arrangement for groundnut and sorghum.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Cereals/Legumes intercrops

Intercropping according to the definition of Sullivan (2003), "is the growing of two or more crops in proximity to promote interaction between them." It is popular in rain-fed agriculture, with limited resources, because one crop can exploit a resource that the other is not exploiting fully. This is especially important in the semi- arid tropics, where the growing season is short and soil moisture and fertility are the main constraints (Marshal, 1983). Farmers practice different cropping systems to increase productivity and sustainability (Hauggaard-Nieson . 2001).

Intercropping is the simultaneous growing of two or more crops in the same field (Takim, 2012) and is a cropping system that has long been used for a long-time in tropical areas. It increases total productivity per unit area through maximum utilization of land, labour and growth resources (Marshal, 1983; Craufard; 2000). Yields of intercropping are often higher than in sole cropping systems (Lithourgidis, 2006) mainly due to resources such as water, light and nutrients that can be utilised more effectively than in sole cropping systems (Li *et al.,*2006). Cereal-legume intercropping plays an important role in subsistence food production in both developed and developing countries, especially in situations of limited water resources (Dahmardeh *et al.,* 2010).

Intercropping of cereal and legume crops helps maintain and improve soil fertility (Tsubo *et al.,* 2005) and plays an important role in subsistence food production.In developing countries (Dahmardeh *et al.,* 2010).Most farmers cannot afford inorganic fertilizers. Legumes fix atmospheric nitrogen, which may be utilized by the host plant or may be excreted from the nodules into the soil and be used by other plants growing nearby (Andrews, 1979). Legumes can also transfer fixed N to intercropped cereals during their joint growing period and this N is an important resource for the cereals (Shen and Chu, 2004). The use of intercropping by smallholder farmers is a common practice (Ofuso-Amin, 2007) that dates back to ancient time (Dahmardeh *et al.,* 2009) in the tropics(Banik, 2000) and rain-fed areas worldwide(Dhima *et al.,* 2007). Intercropping legumes with non-legume in Nigeria can be a principal means of intensifying crop production both spatially and temporally to improve crop yields for smallholder farmers. Legume intercrops are a potential source of plant nutrients that compliment/supplement inorganic fertilizers (Jeranyama, 2000). Legume intercrops have several socioeconomic (Ofori and Stern, 1987), and biological and ecological (Van Rheenen;1981, Aggarwal; 1992, Exner; 1993, Giller; 1995; Chemeda, 1996) advantages compared to sole cropping for small-holder farmers (Chemeda, 1997). The main reason for growing two or more plant species together is the increase in productivity per unit of land. Several authors have shown that over time, average dry matter (DM) yields are higher with intercropping than when each of the plant species in the mixture is grown as a monoculture (Vandermeer, 1989). When legumes are included in a crop mixture, an extra benefit is improved soil fertility due to the legume species' fixation of biological nitrogen (N), and increased protein content of the cereal component.

In recent years, research has provided increasing evidence that substantial yield advantages can be achieved from intercropping compared to sole cropping. The beneficial interaction that is most widely applicable in intercropping systems is the better use of environmental resources. This is often attributed to the fact that different crops can complement each other and achieve an improved yield stability (Sinoquet and Crux, 1995). The mechanisms through which yield stability is achieved are threefold: Two such mechanisms are better control of pests and the greater relative advantages under stress; where these occur, they can provide a useful buffer against low yields in adverse years. A third mechanism, and perhaps the most universally applicable one, is that if one crop fails or grows poorly, the other can compensate; such compensation clearly cannot occur if crops are grown separately (Willey *et al.,* 1979).

Intercropping conserves soil water by means of reduction of the evaporation losses and increases the organic matter in the soil, which in turn improves soil structure, infiltration and water retention and helps prevent soil erosion. Through biological decomposition and mineralization, the organic matter also can increase the level of soil nutrients available for plant production Malithano *et al.* (1980) and Nadar (1980).

Additional advantages are that intercropping patterns will reduce labor peaks, suppress weeds, reduce risks of pests and diseases Alemseged (1991), stabilize crop yields and returns and optimize the use of natural resources Rahman *et al.*(1982) and Sullivian (2003). Soil fertility determines the ability of soils to produce food for man and animal. Declining fertility of lands and sandy soils is a fundamental impediment to crop production and a major reason for low crop yields. In addition, they are heavily leached and some nutrients are removed by erosion and surface run off, due to their sloping nature, while some nutrients are carried along with the crops after harvest. The continuous cropping of the same smallholdings with the same crops (mostly cereals), without rotations or fertilizer application, besides the poor land management, have also contributed to degradation and exhaustion of the valuable agricultural lands.

2.2 Effects of row arrangement on groundnut and sorghum productivity

The main intercropping systems in Nigeria are cereals/legumes, root and tuber crops/cereals and legumes/ tuber crop. The cropping systems are used to maximize production and diversify crops from parcel of land either in time or space than would be obtained by one crop. Intercropping is the growing of two or more crop species simultaneously on the same piece of land during the growing season. The main types of intercropping systems include strip, row, relay and mixed.

However, spatial arrangements of crops is another form of intercropping when two or more crops are grown in separate rows or alternating rows on the same piece of land. In spatial arrangements, the crops involved compete for growth resources such as light, water, carbon dioxide and nutrients. Differences in the canopies of crops appear to provide more efficient light use by spatial arrangements than by sole cropping.

Competition is one of the factors that can have a significant impact on yield of mixtures compared with pure stands. Higher yields have been reported when competition between two species of the mixtures have lower competition than within the same species (Vandermer, 1992). Competition can also have a significant impact on the growth rate of the different species used in spatial arrangements.

A number of advantages have been advanced for the use of spatial arrangements in place of sole cropping. According to Steiner (1982), spatial arrangements bridge the gap between planting and new harvest "the hungry season" where early maturity crops are planted at the beginning of the rainy season. According to Andrews and Kassam (1972), intercropping reduces the damage caused by pest and diseases and ensures greater yield stability by producing from the same field even if some of the crop fails.

Intercropping reduces soil temperature and moisture loss, which favours multiplication and growth of some soil micro-organisms. Intercropping systems in mechanization is difficult, management requirements are higher and overall cost per unit production may be higher due to reduced efficiency in planting, weeding and harvesting.

2.3 Performance of groundnut in intercrops

Cereal-legume mixture is the common form of intercropping practiced by most small scale farmers in the tropics and subtropics. In the developing world, groundnuts are commonly grown in intercropping systems, especially by small farmers who use traditional combinations often involving up to 5-6 crops. Detailed statistics of farming practice are difficult to obtain, but it has been estimated that 95% of the groundnuts in Nigeria and 56% in Uganda are grown as mixtures with other crops (Okigbo and Greenland 1976). They also reported that in the Northern Guinea Savanna Zone of Nigeria, only about 16% of the total area under groundnut was in sole cropping while about 70% was in 2-4 crop mixtures.

In Nigeria, groundnut is grown by farm families on small scale, both in pure stands and in crop mixtures, especially with cereals. Yields obtained from the crop are traditionally low due to a combination of factors including unreliable rains, little technology available to small-scale farmers, pest and disease occurrences, poor seed technology and agronomic practices, as well as increased cultivation on marginal lands. Despite the numerous problems facing groundnut cultivation, it ranks as the number one grain legume grown in the Guinea savanna zone of Ghana. Groundnut production in Nigeria started around 1912 in response to the high world prices. In the fifties and sixties, Nigeria was among the leading exporter of groundnut. Nigeria reached a peak production of 1.5million metric tons in 1973 but later fell drastically due to pests and diseases attack, the coincidence of oil boom in Nigeria about the same time, poor farming techniques and management, inadequate land available for farming and the shifting of government attention from agriculture to oil industry. The dismantling of marketing board including that of groundnut as a result of SAP, caused a lot of farmers who could not cope, to shift from groundnut to other crops (Ilu and Damisa, 2002). Groundnut is grown in 26.4 million hectares across the globe with a total production of 37.1 million metric tons with average production of 1.4 metric t/ha (FAO, 2006). Leading producing states in

Nigeria are Kano, Jigawa, Zamfara, Kebbi, Sokoto (Taru *et al.* 2008). The multiple uses of groundnut plant make it excellent as crop and for foreign trade in the world (Ahmad *et al.,* 2007). The main reason for using a multiple cropping system is the fact that it involves integrating crops using space and labor more efficiently (Baldy and stigter, 1997). Cereal and legume intercropping is recognized as a common cropping system throughout tropical developing countries (Ofori and Sterm, 1987).

Incidentally, sorghum is one of the most important and widely cultivated cereal in Nigerian savannahs. However, competition between the two crops for limited land holdings by farm families who need to produce both the sorghum to feed the family and groundnut for income to cater for the health, education and other needs of the family is intense. To enable the farm family meet its household food needs and cash requirements, many subsistence farmers therefore practice intercropping in which groundnut frequently forms an important part of the system. Groundnut-sorghum mixture is practiced in Nigeria and elsewhere (Siddig et al., 2013). In most of these reports, groundnut-sorghum intercropping achieved land equivalent ratios (LER) greater than 1 and gave higher economic returns. The yields obtained from the intercrops were found to relate directly to their population densities (Langat et al., 2006), giving an indication that the overall plant population can be skewed to favour one crop over the other in the intercrop depending on the farmer's priority or individual crop profitability.

2.4 Performance of sorghum in intercrops

Intercropping is a popular farming system among small-scale farmers in the tropics (Ruthenerg, 1980; Vandemer, 1992). It is a form of multiple cropping where two or more different crops are grown on the same farm at the same time. There are two types of intercropping: mixed intercropping and strip intercropping. Mixed intercropping is the growing of two or more crops simultaneously with no distinct row arrangement. Strip intercropping is the growing of two or more crops simultaneously in different strips in the alternate arrangement, which are wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically. Intercropping sorghum and groundnut may increase, decrease or not affect yields of sorghum and groundnut depending on the spatial arrangement of the intercrops (Okiror *et al*., 1997). Sorghum is one of the major cereal crops where as groundnut is one of the most important legumes grown in Nigeria savanna. Most of the production of cereals come in mixture of two or more of the cereals and legumes (Odion, *et al.,* 1990; Olufajo, 1990; Olabanji, 1997)

Savanna zone is the most ideal of the climatic zones in Nigeria that best supports cereal and legume production (Kowal and Kassam, 1978; Ayoade, 2002). Sudan savanna with mean annual rainfall of 600-900mm and growing seasons of 90-140days (Ker, 1995) has the potential of supporting cereal and legume crops. Sorghum is one of most important world cereal following wheat, rice and maize. It is a staple food in the drier parts of tropical Africa, India and China. Pop sorghums are prepared in a similar way to popcorn, and are used in India. Some sorghum varieties with sweet grains are eaten like sweet corn. Sorghum is used for brewing beer particularly in Africa. In developed countries, it is used as food for livestock. In underdeveloped countries it is still valuable as human food to be used for this purpose.

Sorghum is drought resistance. It grows well in dry regions and areas with unreliable rainfall. It will also stand temporary water logging. The drought resistance of sorghum is due to the following morphological and properties; (a) the plant above ground grows slowly until the root system has become well established (b) produces many secondary roots (c) Silica deposits in the endodermis of the roots prevent collapse during drought stresses (d) the leaf area is small (e) the leaves have a waxy coating that reduces evaporation (f) it requires little water to produce substantial amount of dry matter (g) it can compete well with weeds once it has become well established (h) the plant can remain dormant during periods of drought and resume growth when conditions become favorable thereby permitting the production of grain under conditions of limited or uncertain rainfall.

Sorghum is very susceptible to storage pests, which take a very heavy toll on stored sorghum. For grains storage, the grain should be as dry as possible, with moisture content of not more than 10-11 percent. Birds also cause serious damage to sorghum. Statistics of farming practice estimated that 95% of the groundnuts in Nigeria are grown as mixtures with other crops (Okigbo and Greenland, 1976).

Mohammed *et al* (2008) found that when local sorghum was intercropped with legume, the grain and stover yields of the local sorghum were 1303kgha^{-1} and 6467kgha respectively. They also revealed the panicle length, 1000 seed weight and threshing % of the local sorghum to be 30.4cm, 39.13g and 67% respectively. In a study by Ajeigbe *et al.* (2010) in Kano State, they found that the mean grain yields of sorghum in 2004 and 2005 under traditional system were found to be 250kgha^{-1} and 239 kgha^{-1} with corresponding stover yields of 3695kgha^{-1} and 2366kgha^{-1} respectively.

On the world scene sorghum which is also produced in intercrop with legume crops such as groundnut is produced primarily in Africa, Asia, America and Australia. Foremost producers in Africa include Nigeria, Ethiopia, Sudan, Burkina Faso, Cameroon, Chad, Mali and Rwanda. Nigeria ranks first in Africa and the third largest worlds producers after the United States and India in area and production (FAOSTAT, 2012). They further stated that Nigeria being the largest producer of sorghum in West Africa prdocues 71% of the total regional sorghum output and about 35% of the African production.

In Nigeria, sorghum is the third most important cereal in terms of production after rice and maize with more than 4.5 million tonnes harvested in 2010 representing 25% of the total cereal production (FAOSTAT, 2012). Sorghum cultivation in Nigeria is confined to the semi-arid zones of the country. Kebbi, Sokoto, Zamfara, Kastina, Kano and Jigawa are regarded as the foremost sorghum produceing states. Sorghum is adapted to a wide range of environmental conditions but grows well on deep, fertile and well-drained loamy soils (USAID, 2013). In Nigeria, these soils are common in the Northern Gunea Savannahs and in the Sudan Savannah of Nigeria (Ogbonna, 2011).

2.5 Groundnut varietal performance

Development of photoperiod-insensitive groundnut cultivars with improved plant types and a shorter time to maturity have gave researchers the opportunity to improve groundnut performance in cereal intercrops. Andrews (1974), studying the response of sorghum varieties to intercropping, concluded that the practice of intercropping could be made more advantageous by the use of improved crop varieties.

Therefore, competitive relations in mixture may be manipulated by choice of variety (Andrews 1974) and by the time of planting. Tefera, T. and Tana (2002) reported the performance of sorghum and groundnut cultivars that was studied in sale cropping and intercropping systems at Babile in the semiarid area of eastern Ethiopia in 1996, 1997 and 1999. In their findings, late-maturing cultivars of groundnut and sorghum gave higher dry pod yield and grain yield on the average, respectively, when intercropped with early-maturing cultivars of the associated crops. Furthermore, they stated that the significant varieties among groundnut cultivars in yield and yield revealed that sole cropping may not provide the appropriate environment for selecting varieties intended for use in intercropping. The scientists reported that the productivity of intercropping by total land equivalent ratios

(LER), was higher than sole cropping, indicating the presences of temporal complementarily in the use of growth resources.

2.6 Sorghum varietal performance

Aggarwal *et al* (1992) reported that the yield advantage of any intercrop is attributed to below-and above-ground plant interactions which are likely to vary depending upon the temporal and spatial differences in resource use by component crops. Thus, a fundamental understanding of how intercrops capture and use resources would provide a scientific basis of recommending appropriate crop combinations and spatial arrangements at different locations. Willey (1979b) reported that intercrop performance can be improved with respect to temporal and spatial complementarities by improving the compatibility of genotypes used as components of the mixture. Staggering the relative planting time of the crops would be an example to account for temporal differences in resource use by the crops. Therefore, selection of varieties for use in intercrop should be done with caution to ensure that cultivar growth habit fits in to the intercrop pattern for increase production per unit area and time and also improve the resource use efficiency

Andrew (1974) reported that in a study conducted where tall local sorghum and new dwarf varieties were compared, both as sole crops and when intercropped with an early cereal, in a replicated experiment, and at five sites in observation plots. Dwarf varieties were superior both as intercrops and as sole crops, and intercropping was better than sole cropping for all varieties. In the experiment 27 per cent more total grain yield (sorghum + early cereal) was obtained when dwarf varieties were used instead of tall. When the sorghum was intercropped, increased yields per plant came largely because there were more grains per head.

2.7 Groundnut and sorghum intercrops

In an intercrops experiment consisting of one row of sorghum between two rows of groundnut (1:2), along with sole crops of the components at the same intra and inter row spacing during the wet and dry seasons, intercropped sorghum produced more yields than would be expected under sole, while intercropped groundnut produced less than would be expected if intercropping had no effect (Harris *et al.,* 1987). Sorghum was able to compete more successfully for soil water with groundnut in the intercrop when water was limited than with itself sole crop. In a field crops research, two rows of groundnut (Kadiri 3) alternating with one row of sorghum (hybrid CSH-8), increases in grain and filled pod weight per plant due to intercropping were large, especially in droughted stand. There were large differences in plant temperature and water status between "wet and dry" stands throughout the post-rainy season, but mean difference between sole crops and intercrops within each water regime were small. According to Harris *et al.,* (1987) shading of groundnut by sorghum in the intercrop ameliorated to some extent the effects of high temperature and water stress, especially in the droughted stands. This resulted to less flower damage and more pegs forming pods, leading to high yield. Natarajan *et al., (*1986) reported an experiment in which a line source irrigation system was used to study the effects of a range of moisture regimes in order of increasing stress due to insufficient of moisture on sole crops of sorghum and intercrops of 1 row sorghum 2 rows groundnut. In his findings the dry matter yield advantages of intercropping compared with sole cropping ranged from 0 to 19%. For intercropping treatments, the plant population of each crop was only a proportion of that of its sole crop and total population was equivalent to that in either of the sole crops. It is then suggested that if total population in the intercrops are higher than in the sole crops then, under stress conditions, intercropping yields could well be less than sole crop yields because of increased competition for moisture.

According to the report of Matthew *et al.(*1991) in an experiment, one row of sorghum was intercropped with three rows of groundnut and sole crops of the two species were equally grown with limited water supply. Two patterns of response were evident in the intercropped groundnut. Those involving resource use (light and water) and dry matter production were lowest in the outer two rows and highest in the centre row, while those involving development (e.g. pod numbers) increased from the least shaded row to the most shaded. Competition for water by the more aggressive sorghum was thought to be responsible for the first response and temperature and water potential gradients caused by differing degrees of shading for the second. The availability of environmental resources to each of the component crops is important in determining combined intercrop productivity. In an experiment reported by Fuka *et al.,* (1993) which examined how intercrop productivity is determined, the analysis was based on capture of environmental resources and efficiency of conversion of captured resources into growth of harvested organs of the component crops. It is emphasized that the competitive abilities of component crops which determine their biomass production and often yields, vary greatly according to growth environment, and hence cultural manipulation can adjust the balance of their yields. Fukai *et al.* (1993) reported that intercrops are productive when their component crops differ greatly in growth duration so that their maximum requirements for growth resources occur at different times. According to their findings, for high intercrop productivity, plants of the early maturity component should grow with little interference from the late maturity crop. The latter may be affected somewhat by the associated crop, but a long time period for further growth after the harvest of the first crop should ensure good recovery and full use of available resources. According to them, the reduced size of non-harvested organs of the late-maturing crop can result in improved assimilate partitioning to the harvested organ during the latter part of the growth period and consequently a higher harvest index. He further stated that when growth durations of component crops are similar the crops compete more intensely for available resources. Their relative performances can then be greatly affected by small changes in growth environment. According to him, where a dominant crop uses available resources excessively and inefficiently, agronomic manipulation in favour of the usually suppressed component seems most likely to improve the productivity of the whole intercrop. In their conclusion, intercrop productivity depends on the genetic constitutions of component crops, growth environment (atmosphere and soil) and agronomic manipulations of micro environment. Keating *et al.,* (1993) in his findings on resource capture and use in intercropping advanced a more efficient use of resources as a major reason for the advantage of intercropping over alternative cropping system. He stated that intercropping either increase the interception solar radiation and/or has greater radiation use efficiency by minimizing the proportion of radiant energy reaching the ground. There is also improved utilization of radiant energy, once intercropped either by more efficiency production of biomass or increased proportion of biomass partitioned to yield. Morris *et al.,* (1993) compared the capture and utilization of water by sole and intercrops by decomposing crop production/unit area into uptake/unit are (captured) and production unit uptake (utilization efficiency). They further stated water capture by intercrops differs from water capture by sole crops only slightly (usually between 6 and +7%). Water utilization efficiency by intercrops, however greatly exceeds water utilization efficiency by sole crops, often by more than 18% and by as much as 99%. Variations in plant density often affect water utilization efficiency.

2.8 Productivity of groundnut in sorghum intercrop

Canopy structures and roots systems of cereal crops are generally different from those of legume crops. The formative rate is comparatively greater in cereal than in legume crops. In cereal-legume intercropping, cereal crops form relatively higher canopy structures than legume crops and indicates that the components crops probably have different spatial and temporal use of environmental resources such as radiation, water and nutrients (Willey, 1990). Therefore, combination of crops may help improve productivity of low external inputs farming, which depends largely on natural resources such as rainfall and soil fertility. In India and Africa, groundnut is very commonly intercropped with sorghum. Some reports have emphasized that significant yield reductions of groundnuts have been obtained when they were intercropped with sorghum. John *et al.,* (1943) reported that sorghum depressed the yield of groundnut by about 50%.

Despite reductions in groundnut yields, there are many reports of overall benefits when the yields of both crops are considered. Lingegouda *et al., (*1972) reported that three rows of groundnut and one row of sorghum was more profitable than pure sorghum or pure groundnut. A positive benefit was shown in almost all experimental combinations of groundnuts with sorghum in East Africa (Evans, 1960). Experiments conducted at ICRISAT with this combination have given yield advantages as high as 38% (Rao and Willey, 1980).

In the study of Groundnut and Genotypes of Groundnut/Cereal intercropping, Reddy *et al.* (1980) reported that as in sole cropping, it seems likely that groundnut performance in intercropping could be improved by identification of suitable genotypes. According to him, it can indeed be argued that the potential for genotype improvement could be greater in intercropping because of possible interactions with the associated cereal crops. Willey (1981) emphasized that for crops growing with a more dominant associated crop, there may be particular need for identification and selection of genotypes within the actual intercrop situation because genotype performance in intercropping may not be very closely related to genotype performance in sole cropping. Crop row arrangement of intercropping systems manipulates the crop microclimates such as modification of radiation, temperature, moisture and wind. In assessments of crop productivity of sole cropping systems, a useful expression is mass yield (mass per unit area). However, in intercropping systems, direct expression is difficult because products are different for the different plant species growing on one piece of land (Beets, 1982). In this case, crop productivity should be evaluated using a common unit. A widely used method is the land equipment ratio (LER) (Beets, 1982; Willey, 1985) which is defined as the total land area required under mono-culture cropping to give the yields obtained in the polycultrue cropping system. Total LER (LER_T), can be calculated as follows:

$LER_T = LER_S + LER_G = Y_{IS}/Y_{SS} + Y_{IG} / Y_{SG}$ where

LER_T is the total and equivalent ratio,

LER_S is the land equivalent ratio for sorghum

LER_G is the land equivalent ratio for groundnut

Y_{IS} is the yield of sorghum intercropping

Y_{SS} is the yield of sorghum sole

Y_{IG} is the yield of groundnut intercropped

Y_{SG} is the yield of groundnut sole

If the total land equivalent ratio is greater than one (LER> I), intercropping has a yield advantage while there is yield disadvantage from intercropping if it is less than one (LER_T<I). (Beets, 1982; Willey, 1985). Mukhala (1998) reported that field experiments were conducted at the experimental sites of the Department of Soil, Crop and Climate Sciences, University of the Free State, during three summer growing seasons 1996/1997, 1998/1999 and 2000/2001, with variables in row orientation. In all cases, intercropping groundnut had growth advantages. Good crop growth results in high crop yield. Many authors have reported

that cereal-legume intercropping systems have higher productivity than sole cropping systems in various regions of Africa, including African semi-arid regions such as East Africa (Fisher, 1977a, b; 1979; Pilbeams *et al.* 1994; Alemseged *et al.*1996a:b)

In dry land crop production, the most limiting factor is water (rainfall and irrigation) availability and it is thus necessary to improve crop water-use efficiency. The key solution can be found in reduced soil temperature and retained soil moisture. The solution may then lie in traditional cropping techniques, such as intercropping and mulching (Wilken, 1972; Baldy and Sigter, 1997). Intercropping is one of the types of mulching, often referred to as live mulching.

Net radiation (overall incoming and outgoing radiant energy at a surface) is the major contributor to energy balance. Within plant canopies, net radiation is of importance in describing the fundamental quality of energy available for plant growth; that is, net radiation drives the processes of photosynthesis, evaporation, transpiration, and air and soil heating (Rosenberg *et al.,* 1983). Net radiation comprises net short-wave solar radiation, which is utilized for assimilating carbon dioxide (CO_2) and net long-wave (thermal) radiation. Net radiation primarily provides the energy needed for evapotranspiration. It is interesting that shade manipulation by associated crops in intercropping may increase crop water use of dominant crops because of a reduction in evaporation from soil (Stigter and Weiss, 1986).

An experiment was conducted at the university of zalingei demonstration farm, zalingei, west Darfur State, Sudan during 2006 and 2007 rainy seasons to evaluate the effects of three row intercropping arrangements of sorghum and groundnut plus control on crop yield. In case of groundnut, all crop mixtures showed significant difference ($P<0.01$) in total pod yield and yield components under study except 100-pod weight in the second season. The results further showed that the low yield and yield components of both intercrops in the second season were attributed to end-of-season drought due to early cease of rainfall (Saddiq *et al.,*2003). In their findings mixed cropping increased soil moisture content, which resulted in good establishment and better yield of the crops.

Longat *et al.,* (2006) reported the results of an experiment at Busia farmers' Training Centre during the short rains of 1998 and long rains of 1999, to determine the effects of intercropping groundnut with sorghum. The result showed that intercropping significantly affected the yield components of sorghum: the number of tillers and viable panicles per plant were generally higher in intercrops than in pure stands. In his findings groundnut produced an average of 17 pods per plant. The lowest pod number was in pure groundnut. The highest number of pods per plants could have been due to shading which could have affected soil moisture levels. This finding agrees with that of Reddy and Reddy (2000) that the number of pods per plant is influenced by moisture. He concluded that since the seed yield, seeds per pod, pods per plant and 100 seed weight were generally lower in the long rains compared to the short rains it seems that groundnut production is more suited for the short rains than long rains in the study area.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Sites

This study was carried out during the 2012 cropping season at research farms of the Faculty of Agriculture, Bayero University, Teaching and Research Farm, Kano (11^0 8N, 8^0 26E and 460m above sea level). Location two is the Agricultural Research Station (ARS) of the institute bfor Agricultural Research (IAR) Minjibir (Lat. 11^0 $59^{'}$N, long $8^0 34^{'}$E, Alt.486.5m), Kano State. Both locations are in Sudan savannah ecological zone of Nigeria.

3.2 Soil Sampling and Analysis

Composite soil samples for each experimental site were randomly taken from 0-15cm and 15-30cm depth by using soil auger in May 2012. The samples were air dried, sieved and used to determine the physical and chemical properties of the soil using standard procedures as described by Black, (1965).

Table 1: Physical and Chemical Properties of the Soil at BUK and MINJIBIR, 2012

Soil Properties	BUK		Minjibir	
	0-15cm	15-30cm	0-15cm	15-30cm
Physical (%)				
Sand	75	75	75	69
Clay	11	13	13	13
Silt	14	12	12	18
Textural Class	Sandy-loam	Sandy-loam	Sandy-clay loam	Sandy-clay loam
Ph(h2o)	7.10	7.30	5.4	5.6
pH in $CaCl_2$(0.01m)	6.60	6.20	5.2	5.3
Organic Carbon (%)	36	28	0.82	0.60
Available P (ppm)	10.50	8.74	13.42	13.2
Exchangeable base (g/kg)				
Ca	4.10	4.40	2.20	1.6
Mg	0.98	0.63	0.20	0.20
K	0.26	0.33	0.04	0.04
Na	0.31	0.64	0.20	0.19
CEC	5.80	6.30	2.65	2.04

3.3 Meteorological Data

Climatic records on rainfall, temperature, relative humidity, solar radiation, as well as evaporation rate were collected from the Department of Geography meteorological station, B.U.K Kano and Agricultural Research Station, Kano as indicated in appendix I.

3.4 Description of Test Crop Varieties

1. Samnut 21: It is one of the released groundnut varieties adapted to Sudan savannah. It is erect, late maturing (110 to 120 days) with multiple resistance to rosette, pest and leaf diseases and has a yield potential of 2800 to 3500kg/ha under favourable condition. The number of seeds per pod is hardly more than two.

2. Samnut 22: This groundnut variety is adapted to Sudan and Guinea savanna ecological zone of Nigeria. It has high yield of seed and forage. The pod yield potential is 2200 to 3100 kg/ha while forage or haulm yield is about 4000kg/ha. Maturation period is between 110 to 120 days after sowing. It is late maturing The skin colour of the seed is brown. The number of seeds per pod is hardly more than two.

3. Samnut 23: This groundnut variety is adapted to Sudan Savannah of Nigeria. It has pod yield of about 2000kg/ha. It has maturity period of about 90 to 100 day. It is earlt maturing. The seed colour is red with no constriction between the seeds. It is rosette resistant. The number of seeds per pod is hardly more than two.

4. Kampala: It is a local variety, susceptible to rosette disease, law yielding, and late maturing. The seed is light brown in colour.

5. Farafara: It is late maturing, usually above 120 days and low disease resistance. Yield is low compared to improved varieties. The pod yield potential is about 400 to 900kg/ha.

6. ICSV 400: The sorghum variety is medium size average in height of about 35cm, early maturing (about 90 days) and high yielding of between 2000 to 5000kg/ha under favorable conditions. It has hard grains.

3.5 Treatments and Experimental Design

The experiment consisted of 30 treatments made up of 24 sorghum/groundnut intercrop and 6 sole cropping systems of the test crops. The 24 sorghum/groundnut intercrop combinations were made up of 4 varieties of groundnut (Samnut 21, 22, 23 and Kampala) and 2 varieties of sorghum (ICSV400 and Farafara) factorialy combined with 1:1, 1:2 and 2:4 row arrangements in all possible combinations as follows:

Treatment Combination	Cropping system
ICSV 400 /Samnut 21(S_1 /G_1)	1:1
ICSV 400/Samnut 21 (S_1 /G_1)	1:2
ICSV 400/Samnut 21(S_1 /G_1)	2:4
Farfara /Samnut 21(S_2 /G_1)	1:1
Farfara /Samnut 21(S_2 /G_1)	1:2
Farfara /Samnut 21(S_2 /G_1)	2:4
ICSV 400/Samnut 22 (S_1 /G_2)	1:1
ICSV 400/Samnut 22 (S_1 /G_2)	1:2

ICSV 400/Samnut 22 (S_1/G_2)	2:4
Farfara /Samnut 22 (S_2/G_2)	1:1
Farfara /Samnut 22 (S_2/G_2)	1:2
Farfara /Samnut 22 (S_2/G_2)	2:4
ICSV 400/Samnut 23 (S_1/G_3)	1:1
ICSV 400 /Samnut 23 (S_1/G_3)	1:2
ICSV 400/Samnut 23 (S_1/G_3)	2:4
Farfara /Samnut 23 (S_2/G_3)	1:1
Farfara /Samnut 23 (S_2/G_3)	1:2
Farfara /Samnut 23 (S_2/G_3)	2:4
ICSV 400/Kampala (S_1/G_4)	1:1
ICSV 400/Kampala (S_1/G_4)	1:2
ICSV 400/Kampala (S_1/G_4)	2:4
Farfara /Kampala (S_2/G_4)	1:1
Farfara /Kampala (S_2/G_4)	1:2
Farfara /Kampala (S_2/G_4)	2:4
ICSV	Sole
Farfara	Sole
Samnut 21	Sole

Samnut 22	Sole
Samnut 23	Sole
Kampala	Sole

The experiment was laid out in a split plot design and was replicated three times. The main plot consisted of intercrop arrangement while the sub-plot consisted of sole arrangements.

1:1 Arrangement: 1 row of groundnut alternated with 1 row of sorghum. It was sown at a spacing of 75cm x 25cm. The plot was made up of six rows (3rows of sorghum, 3 rows of groundnut) in an area of (6m x 4.5) 27m^2. The final plant population was 144 plants for groundnut and 72 plants for Sorghum, which is equivalent to 66.7% groundnut and 33.3% Sorghum.

1.2 Arrangement: 2 rows of groundnut alternated with I row of sorghum. It was sown at a spacing of 25cm within ridges and 75cm between ridges (75cm x 25cm). The plot was made up of 6 rows (2rows of sorghum and 4 rows of groundnut) in an area of (6m x 4.5m) 27m^2. The final plant population was 48 plants for sorghum and 192 plants for groundnut which is equivalent to 20% of sorghum and 80% groundnut.

2:4 Arrangements: 4 rows of groundnut alternated with 2 rows of sorghum. It was sown at a spacing of 75cm x 25cm. The plot was made up of 6 rows (2 rows of sorghum and 4 rows of groundnut) in an area of (6m x 4.5m) 27m^2. The final plant population was 48 plants for sorghum and 192 plants for groundnut; which is equivalent to 20% sorghum and 80% groundnut.

Sole: Sole sorghum and sole groundnut were sown separately in different plots at a space of 6m x 4.5m (27m^2). The final plant population for sorghum plot was 144 plants while that of groundnut was 288 plants.

3.6 Cultural practices

3.6.1 Land preparation: The land was cleared, harrowed to a fine tilth, andN ridged at a spacing of 75cm apart.

3.6.2 Sowing Time: planting of sorghum and groundnut were done in June, 2012 when rain became established.

3.6.3 Spacing: Planting was done at a spacing of 75cm x 25cm for both sorghum and Groundnut. Sorghum was thinned to 1 plant per stand while groundnut was thinned to 2 plants per stand.

3.6.4 Fertilizer application: Fertilizer was applied by the side placement as per recommended rates, which is as follows: 64:32:30 N, P_2O_5, K_2O, kg/ha for sorghum and 20:40:20 N, P_2O_5, K_2O kg/ha for groundnut.

3.6.5 Weed control: This operation was done manually at 4. 7 and 10 WAS as soon as weeds started to appear. The number of times for this operation was three.

3.6.6 Harvesting: Harvesting was done when the plants reached harvest maturity. The sorghum and groundnut plants were harvested, threshed and weighed for yield determination. The pods of groundnut were shelled for yield determination while stalks and leaves (fodder) were packed in bundles and weighed.

3.7 Data collection

3.7.1 Sorghum growth parameters:

i. Plant height (cm): 5 plants from each plot were tagged upon which measurements on plant height were recorded at 4, 6, 8, 10 and 12 WAS. The mean of all measurements were determined and recorded. Plants height were measured by using a metre rule from the ground level to the tip of the longest leaf or panicle.

ii. Number of leaves per plant: The numbers of leaves from the tagged plants were counted and average values were determined and recorded at 4, 6, 8, 10 and 12 WAS.

iii. Leaf area (LA): The leaf area was calculated using leaf product method, by using the formula length x breath x correction factor (0.8)

iv. Panicle length: This was determined by using ruler to measure the panicle length of each of the tagged plants when plants attained physiological maturity. The average values were determined.

3.7.2 Yield parameters for sorghum

i. Weight of panicle/plant (g): The panicles of 5 of the tagged plants in each plot were collected and weighed. The mean were determined.

ii. 1000-seed weight (g): 100 seeds were sampled from each plot randomly and were counted and weighed. The results were extrapolated to 1000 seed weight. The mean of the results from the plots were determined.

iii. Grain yield per hectare (kg): The entire panicles in each plot were harvested, dried, threshed the grains weighed and expressed in kg/ha.

iv. Stover yield in kg per hectare: the remaining vegetative parts of the tagged plants (leaves and stalk) after removing the pods were packed after harvesting in bundles and weighed. The mean was determined and expressed in kg/ha.

v. Threshing percentage: These were obtained by dividing the weight of threshed sorghum by the weight of panicle before threshing and this was multiplied by 100.

3.7.3 Growth parameters for groundnut

(i) Number of leaves per plant: the number of leaves of the five tagged plants in each plot were determined by counting at 4, 6, 8, 10 and 12 WAS from which the mean was later determined.

(ii) Number of branches per plant: The numbers of primary branches of the five tagged plants were determined at 4, 6, 8, 10 and 12 WAS and the mean was thereafter determined.

(iii) Leaf area (LA): This was determine by measuring the length and breath of leaves of five tagged plants, and average was determined calculation using product method, by length x breath x correction factor (0.7) was used to determine the leaf area of a leaf and the value was multiplied by the number of leaves in a plant.

(iv) Plant height (cm): This was determined by using a meter ruler to measure the plant height from the ground level to the tip of highest leaf. The mean was determined.

3.7.4 Yield parameters for groundnut

(i) Number of pods per plant: The pods from the five tagged plants were collected, counted, and recorded. Mean value was thereafter determined and recorded.

(ii) Pod weight per plant (g): This was determined by using measuring scale to weigh the pods harvested from the five tagged plants. The average pod weight per plant was later determined.

(iii) Number of seeds per pod: Five pods were randomly picked from each plot, which were shelled manually and counted. The mean number of seeds/pod was determined.

(iv) Shelling percentage: This was obtained by dividing the weight of a handful pods by the weight of the same handfull pods before shelling and multiplying by 100.

(v) Grain yield (kg) per hectare: grain yield were determined by harvesting the pods in each plot which was dried and weighed using measuring scale. The yields were expressed in Kg/ha.

(vi) Haulm yield (kg/ha): The haulm of each plot i.e the stem and the leaves left behind after harvesting the pods were gathered and dried. The total weight were determined and expressed in Kg/ha.

3.8 Data analysis:

Data analysis was done using Genstat 16th edition (Gentat, 2013). ANOVA was conducted to test for significant differences between treatments and described by Snedecor and Cochran (1976). Significant means were separated using Duncan Multiple Range Test (DMRT) (Duncan, 1955).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Groundnut growth parameter at BUK and Minjibir in 2012 wet season

Plant height (cm)

Table 2 shows the plant height of four groundnut varieties and their responses to cropping pattern at 4, 6, 8 and 10 weeks after sowing at BUK. Variety of groundnut did not affect groundnut plant height at all the sampling periods. Samnut 22 and cropping system 2:4 were observed to produce the tallest plants in all the sampling periods. At 10 week, cropping pattern 1:1 produced the tallest plants but was at par with 2:4 cropping pattern. The table further revealed that interaction between groundnut and sorghum and between sorghum and cropping system were highly significant. The results of the interaction between groundnut and sorghum on groundnut plant height as presented in Table 3 showed that Samnut 22 in companion with ICSV 400 at 2:4 crop arrangements produced the tallest plants but was at parity with Samnut 23 and Kampala planted with ICSV400 at 1:1 crop arrangements. The shortest plant was produced by Samnut 21 grown with ICSV 400 at 1:2 crop arrangements.

Table 4 reveals the results of the interaction between sorghum and cropping system on plant height of groundnut varieties at BUK. From the results, groundnut planted with ICSV 400 at 1:1 crop arrangement gave the tallest plants while the shortest plants was produced by groundnut grown with Farafara at 1:2 cropping system. Samnut 22 grown in combination with ICSV400 at 2:4 crop arrangement was observed to produce the tallest plants

Table 2. Effect of crop arrangement and companion Sorghum varieties on plant height (cm) of groundnut varieties weeks after sowing at BUK

	4 WAS	6WAS	8WAS	10WAS
Groundnut variety (G)				
Samnut 21	15.47	30.88	40.74	48.18
Samnut 22	27.32	30.99	42.36	50.23
Samnut 23	16.99	31.19	40.02	48.73
Kampala	16.67	29.96	39.24	47.49
SE±	4.450	1.306	1.524	1.012
Companion sorghum variety(S)				
ICSV 400	22.20	32.72	42.06	51.72
Farafara	16.00	28.78	39.13	45.59
SE±	3.040	0.874	0.951	0.713
Cropping system (C)				
1:1	17.25	32.07a	40.56ab	51.44a
1:2	17.67	28.53b	37.55b	43.22b
2:4	22.43	3167a	43.66a	51.32a
SE±	3.730	0.070	1.165	0.874
Interaction				
G x S	NS	*	NS	**
G x C	NS	NS	**	NS
S x C	NS	*	NS	**
G x S x C	NS	*	NS	NS

Means along the same column having different letter(s) are significantly different at p≤0.05 using DMRT. NS= not significant, **=significant at p≤ 0.01 *= Significant at P ≤0.05

Table 3. Interaction between groundnut and sorghum on plant height (cm) of groundnut varieties 10 WAS at BUK

	Groundnut			
Sorghum	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	47.87bcd	53.80a	53.77a	51.47ab
Farafara	48.50bc	46.67bcd	43.69cd	43.51d
SE±		1.430		

Table 4. Interaction between sorghum and cropping system on plant height (cm) of groundnut varieties 10WAS at BUK

	Cropping System		
Sorghum	1:1	1:2	2:4
ICSV400	55.38a	43.62cd	56.18a
Farafara	47.50b	42.81d	46.47bc
SE±		1.236	

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 5 reveals the effect of crop arrangement and companion sorghum varieties on groundnut plant height at Minjibir. There was progressive increase in plant height on all the groundnut varieties at all the sampling periods. Variety did not have effect on groundnut plant height at 10 WAS. Cropping system had significant effect on groundnut plant height. Samnut 23 in combination with ICSV 400 at 2:4 cropping pattern produced the tallest plant as revealed in Table 6 but was at par with Samnut 22 in combination with Farafara at 1:2, Samnut 23/Farafara at 2:4 and Samnut 21/ICSV400 at 2:4 crop arrangement. It was also observed that Samnut 23/Farafara at 1:2 crop arrangement produced the shortest sorghum plants 10 WAS at Minjibir. The interaction between groundnut and sorghum, groundnut and cropping system, sorghum and cropping system were not significant. However, the interaction between groundnut, sorghum and cropping system was observed to be significant.

Number of leaves per plant.

Table 7 shows the results of effect of crop arrangement and companion sorghum on groundnut numbers of leaves per plant at BUK and progressive increase in number was also observed. There was a significant difference in the number of leaves among the four tested groundnut varieties throughout the sampling periods at BUK and. At 10 WAS groundnut varieties had effect on groundnut number of leaves. Cropping system equally had significant effect on groundnut number of leaves. According to the results of Table 8, Samnut 21 grown with Farafara produced the highest number of leaves in the interaction between groundnut and sorghum crops. The results of the interaction between groundnut and copy system as presented in Table 9 showed that Samnut 21 planted at 2:4 crop arrangement produced the highest number of leaves while Samnut 23 grown at 2:4 was observed to produce the lowest number of leaves. The results of the interactions between groundnut, sorghum and cropping system on groundnut number of leaves is presented in Table 10.

Table5. Effect of crop arrangement and companion Sorghum varieties on plant height (cm) of groundnut varieties weeks after sowing at Minjibir

	4 WAS	6WAS	8WAS	10WAS
Groundnut variety (G)				
Samnut 21	9.63b	16.97ab	25.47	34.62
Samnut 22	10.17b	16.98ab	26.11	34.48
Samnut 23	12.10a	19.52a	28.29	36.27
Kampala	8.23c	15.48b	26.05	35.11
SE±	0.290	0.986	1.111	1.117
Companion sorghum variety(S)				
ICSV 400	9.82	16.46	25.51	35.64
Farafara	10.25	18.02	27.45	34.60
SE±	0.224	0.547	0.764	0.798
Cropping system (C)				
1:1	9.23b	16.19b	24.84b	34.88ab
1:2	10.66a	17.03ab	25.09b	32.93b
2:4	10.22a	18.50a	29.51a	37.55a
SE±	0.275	0.670	0.935	0.977
Interaction				
G x S	**	NS	NS	NS
G x C	**	NS	NS	NS
S x C	**	NS	NS	NS
G x S x C	**	S	NS	**

Means along the same column having different letter(s) are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$

Table 6. Interaction between groundnut sorghum and cropping system on plant height of groundnut varieties (cm) 10 WAS at Minjibir

		Groundnut			
Sorghum	Cry.Sys.	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	1:1	35.20c-h	36.00c-g	32.00e-h	36.00c-g
	1:2	29.73gh	31.30e-h	34.00d-h	36.00c-g
	2:4	40.40a-d	31.00fgh	47.00a	39.00b-e
Farafara	1:1	34.20c-h	33.10d-h	34.50c-h	38.00b-f
	1:2	32.00e-h	44.10ab	28.00h	28.33gh
	2:4	36.20b-g	31.40e-h	42.10abc	33.30d-h
SE±			2.742		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 7. Effect of crop arrangement and companion sorghum varieties on number of leaves of groundnut varieties weeks after sowing at BUK

	4 WAS	6 WAS	8 WAS	10 WAS
Groundnut variety (G)				
Samnut 21	133.2a	132.9c	381.8a	480.8a
Samnut 22	116.7b	201.8b	268.1c	325.6c
Samnut 23	72.3c	234.1a	196.5d	249.0d
Kampalu	106.2b	220.5a	315.9b	374.7b
SE±	3.85	4.99	5.26	5.35
Companion sorghum variety(S)				
ICSV 400	105.8	168.2	258.4	319.9
Farafara	108.3	226.4	322.8	397.7
SE±	2.28	2.78	2.86	3.38
Cropping system (C)				
1:1	107.1	197.2b	285.8	356.5b
1:2	108.1	182.8c	278.7	340.0c
2:4	106.0	211.9a	307.3	379.8a
SE±	2.80	3.41	3.51	4.14
Interaction				
G x S	**	N5	**	**
G x C	**	**	**	**
S x C	NS	NS	NS	NS
G x S x C	**	**	**	**

Means along the same column having different letter are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$

Table 8. Interaction between groundnut and sorghum on number of leaves of groundnut varieties10WAS at BUK

	Groundnut			
Sorghum	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	460.6b	290.8e	189.8f	338.4d
Farafara	501.1a	360.4d	308.2e	421.0c
SE±		7.37		

Table 9. Interaction between groundnut and cropping system on number of leaves of groundnut varieties 10WAS at BUK

	Groundnut			
Cropping System	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	480.5b	352.5e	260.2f	333.0e
1:2	439.2c	239.3fg	260.0f	421.7c
2:4	522.8a	385.0d	226.8g	384.5d
SE±		9.02		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 10. Interaction between groundnut, sorghum and cropping system on number of leaves of groundnut varieties 10WAS at BUK

		Groundnut			
Sorghum	Crop.Sys.	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	1:1	409.0de	275.7i	244.7ij	339.0gh
	1:2	512.3b	253.0ij	139.0l	269.3i
	2:4	460.3c	343.7gh	185.7k	407.0de
Farafara	1:1	552.0a	429.3cd	275.7i	327.0h
	1:2	366.0fg	225.7j	381.0ef	574.0a
	2:4	585.3a	426.3cd	268.0i	362.0fgh
SE$\pm$			12.76		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

The results revealed that Samnut 21 grown in companion with Farafara at 2:4 cropping pattern produced the highest number of leaves while Samnut 23 in combination with ICSV400 at 2:4 crop arrangement gave the least number of leaves. However Samnut 21/Farafara at 2:4, Samnut 21/Farafara at 1:1 and Kampala/Farafara at 1:2 crop arrangements that produced tall plants were observed to be at parity.

Table 11 shows the results of the effect of crop arrangement and companion sorghum varieties on number of leaves of groundnut varieties at Minjibir. Varieties and cropping system had effects on groundnut number of leaves throughout the sampling periods. There was also interactions across the sampling periods and in all the interactions between groundnut, sorghum and cropping system which was observed to be highly significant. Table 12 shows the results of the interaction between groundnut and sorghum on groundnut number of leaves at 10 WAS. From the result Samnut 21 grown in companion with ICSV 400 produced the highest number of leaves while Samnut 23 planted in combination with ICSV 400 gave the lowest number of leaves.

The result of the interaction between groundnut and cropping system on groundnut number of leaves is presented in Table 13. Samnut 21 grown at 2:4 crop arrangement produced the highest number of leaves while Samnut 22 planted at 1-2 crop arrangement gave the least. At 10 WAS Samnut 21 grown with ICSV400 at 2:4 crop arrangement, had the highest number of leaves and was statistically significantly different from others. At the same time, Samnut 23 grown with ICSV400 at 1:1 crop arrangement produced the least number of leaves but was at par with Samnut 22/Farafara at 1:2 crop arrangement.

Number of branches

The results of the effect of cropping systems on the number of branches of groundnut varieties at BUK is presented in Table 14. Variety and cropping system affected groundnut number of branches in all the sampling periods. At 10 WAS, interaction between groundnut and sorghum, groundnut and cropping system, sorghum and cropping system and groundnut, sorghum and cropping system were observed to be highly significant. Table 15 results revealed that Samnut 21 grown at 1:2 crop arrangement produced the highest number of branches in the interaction between groundnut and cropping system while Kampala grown at 1:1 was observed to have the least number of branches.

Table11. Effect of crop arrangement companion sorghum varieties on number of leaves of groundnut varieties weeks after sowing at Minjibir

	4 WAS	6 WAS	8WAS	10 WAS
Groundnut variety (G)				
Samnut 21	56.06a	197.10a	366.40a	439.70a
Samnut 22	43.72c	127.60b	213.20c	249.60c
Samnut 23	49.61b	105.60c	180.00d	205.50d
Kampala	43.94bc	136.80b	275.80b	306.00b
SE±	1.987	4.660	4.980	8.440
Companion sorghum variety(S)				
ICSV 400	54.50	148.40	264.80	299.90
Farafara	53.17	135.10	252.90	300.60
SE±	0.954	2.660	3.240	4.630
Cropping system (C)				
1:1	47.00	122.10b	228.10c	2.90.00b
1:2	49.75	144.20ab	284.40a	297.8ab
2:4	48.25	148.0a	264.10b	312.8a
SE±	1.169	3.260	3.970	8.440
Interaction				
G x S	NS	**	**	**
G x C	**	*	**	**
S x C	**	*	**	**
G x S x C	**	**	**	**

Means along the same column having different letter(s) are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$ * = significant at $P \leq 0.05$

Table 12. Interaction between groundnut and sorghum on number of leaves of groundnut varieties 10 WAS at Minjibir

	Groundnut			
Sorghum	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	500.70a	270.70d	145.40f	282.20d
Farafara	378.70b	228.40e	265.60d	329.80c
SE±		11.320		

Table 13. Interaction between groundnut and cropping system on number of leaves of groundnut varieties 10 WAS at Minjibir

	Groundnut			
cropping System	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	434.00b	288.80d	195.80g	241.30ef
1:2	391.70c	190.80g	213.30fg	395.30bc
2:4	493.30a	269.00de	207.30fg	281.30d
SE±		13.870		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table14. Effect of crop arrangement and companion sorghum on number of branches of groundnut varieties weeks after sowing at BUK

	4 WAS	6 WAS	8 WAS	10 WAS
Groundnut variety (G)				
Samnut 21	6.89a	9.00a	10.22a	11.39a
Samnut 22	5.33b	6.94b	7.94bc	8.61bc
Samnut 23	4.44c	6.61b	77.56c	8.39c
Kampalu	5.06b	6.89b	8.17b	8.94b
SE±	0.129	0.138	0.149	0.143
Companion sorghum variety(S)				
ICSV 400	5.78	7.69	8.89	9.44
Farafara	5.08	7.03	8.06	9.22
SE±	0.092	0.101	0.101	0.109
Cropping system (C)				
1:1	5.42	6.83b	7.83b	8.58b
1:2	5.75	8.96b	10.29b	10.92b
2:4	5.13	6.29c	7.29c	8.50b
SE±	0.113	0.123	0.123	0.133
Interaction				
G x S	**	**	**	**
G x C	**	**	**	**
S x C	NS	NS	**	**
G x S x C	**	**	**	**

Means along the same column having different letter(s) are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$

Table 15. Interaction between groundnut and cropping system on number of branches of groundnut varieties 10WAS at BUK

	Groundnut			
Cropping System	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	10.83bc	8.50ef	7.83fg	7.17g
1:2	13.17a	10.00d	9.50d	11.00b
2:4	10.17cd	7.33g	7.83fg	8.67e
SE±		0.252		

Table 16 equally shows the results of the interaction between cropping system and sorghum on groundnut number. According to the results, groundnut planted in combination with ICSV 400 at 1:2 crop arrangement, had the highest number of branches while groundnut planted in combination with ICSV 400 at 1:1 crop arrangement produced the least number of branches.

The results of the interaction between groundnut, sorghum and cropping system on groundnut number of branches is presented in Table 17.

Table 16: Interaction between sorghum and cropping system on number of branches of groundnut varieties 10WAS at BUK

	Cropping System		
Sorghum	1:1	1:2	2:4
ICSV400	8.00e	11.67a	8.67cd
Farafara	9.17c	10.7b	8.33de
SE$\pm$		0.188	

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 17. Interaction between groundnut sorghum and cropping system on number of branches of groundnut varieties 10WAS at BUK

		Groundnut			
Sorghum	Crop.Sys.	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	1:1	9.67def	7.67ij	8.33g-j	6.33k
	1:2	15.67a	12.33b	8.33g-j	10.33de
	2:4	11.67bc	7.33jk	7.33jk	8.33g-j
Farafara	1:1	12.00b	9.33efg	7.33jk	8.00hij
	1:2	10.6cd	7.67ij	10.67cd	11.67bc
	2:4	8.67f-i	7.33jk	8.33g-j	9.00fgh
SE$\pm$			0.356		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

The results of the interactions showed that Samnut 21 grown with ICSV400 at 1:2 crop arrangement gave the highest number of branches and was statistically significantly different from others. Samnut 22/ICSV400 which at 1:2 crop arrangement had the next highest number of branches was at parity with Samnut 21/Farafara and Samnut 21/ICSV400 at 2:4 respectively. The least number of branches was produced by Kampala/ICSV400 at 1:1, followed by Samnut 22/ICSV400 at 2:4 and Samnut 22/ICSV400 at 2:4 crop arrangements, respectively.

Table 18 shows the responses of number of branches of four groundnut varieties to cropping system and companion sorghum at Minjibir. Varieties and cropping systems had effect on groundnut number of branches throughout the sampling periods except at 10WAS where variety did not have effect on number of branches. At 10WAS highly significant interaction was observed between groundnut and sorghum, groundnut and cropping system and between groundnut, sorghum and cropping system. However, there was no significant interaction between sorghum and cropping system. Table 19 shows the results of the interaction between groundnut and sorghum on groundnut number of branches at Minjibir. The results showed that Samnut 21 planted in combination with ICSV400 gave the highest number of branches while samnut 22 grown in combination with Farafara had the least number of branches.

The results of Table 20 shows that Kampala grown at 1:2 crop arrangement produce the highest number of Branches and was at par with Samnut 21 grown at 2:4 cropping pattern. Kampala grown at 2:4 crop arrangement had the lowest number of branches.

The results of the interaction between groundnut, sorghum and cropping system on groundnut number of branches is shown in Table 21. The results of the interaction showed that Samnut 21 grown in combination with ICSV400 at 2:4 crop arrangements produced the highest number of branches and was significantly different from others. The second highest number of branches was produced by Kampala grown in Combination with Farafara at 1:2 crop arrangements. Furthermore, the least number of branches was from Kampala planted in combination with Farafara at 2:4 cropping system.

Leaf area per plant (cm^2)

Table 22 shows the effect of cropping system and companion sorghum on groundnut leaf area at BUK. Variety and cropping system had effect on groundnut leaf area in all the sampling periods. At 10 WAS the interactions between groundnut and sorghum, groundnut and cropping system, sorghum and cropping system,, and between groundnut, sorghum and cropping system were observed to be highly significant.

Table18. Effect of crop arrangement and companion sorghum varieties on number of branches of groundnut varieties weeks after sowing at Minjibir

	4 WAS	6 WAS	8 WAS	10 WAS
Groundnut variety (G)				
Samnut 21	4.500a	5.556a	7.167a	8.167
Samnut 22	3.778b	4.333c	5.667c	6.556
Samnut 23	4.167ab	4.667bc	6.167b	6.611
Kampala	4.000b	4.833b	6.500b	6.778
SE±	0.1425	0.1612	0.1332	0.1145
Companion sorghum variety(S)				
ICSV 400	4.139	4.889	6.361	7.250
Farafara	4.083	4.806	6.389	6.806
SE±	0.1005	0.0934	0.1344	0.1323
Cropping system (C)				
1:1	4.417a	4.958	6.083b	6.625b
1:2	4.042ab	4.917	6.875a	7.542a
2:4	3.875b	4.667	6.167b	6.917b
SE±	0.1231	0.114	0.1646	0.1621
Interaction				
G x S	NS	NS	**	**
G x C	NS	*	**	**
S x C	NS	NS	NS	NS
G x S x C	**	**	**	**

Means along the same column having different letter(s) are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$ * = significant at $P \leq 0.05$

Table 19. Interaction between groundnut and sorghum on number of branches of groundnut varieties 10WAS at Minjibir

	Groundnut			
Sorghum	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	8.667a	7.444bc	5.889e	7.000cd
Farafara	7.667b	5.667e	7.333bc	6.556d
SE$\pm$		0.1929		

Table 20. Interaction between groundnut and cropping system on number of branches ofgroundnut varieties 10WAS at Minjibir

	Groundnut			
Cropping system	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	8.167bc	6.667ef	6.000ghi	5.667hi
1:2	7.667cd	6.667efg	6.667efg	9.167a
2:4	8.667ab	6.333egh	7.167de	5.500i
SE$\pm$		0.2362		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 21. Interaction between groundnut, sorghum and cropping system on number of branches of groundnut varieties 10 WAS at Minjibir

		Groundnut			
Sorghum	Cry.Sys.	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	1:1	8.667c	7.667df	5.333o-r	5.667h-o
	1:2	6.667fgh	8.667cd	6.667f-l	8.667cd
	2:4	10.667a	6.000h-0	5.667h-q	6.667f-m
Farafara	1:1	7.667efg	5.667i-p	6.667hij	5.667i-p
	1:2	8.667c-e	4.667prs	6.667g-k	9.667b
	2:4	6.667ghi	6.667g-n	7.667b-e	4.333s
SE±			0.3340		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table22. Effect of Crop arrangement and companion sorghum on leaf area of groundnut varieties weeks after sowing at BUK.

	4 WAS	6 WAS	8 WAS	10 WAS
Groundnut variety (G)				
Samnut 21	873.0a	2036.0a	3668.0a	5079.0a
Samnut 22	737.0b	1655.0b	2496.0b	3422.0b
Samnut 23	451.0d	1150.0c	1838.0c	2486.0c
Kampala	591.0c	1555.0b	25330.b	34360.b
SE±	31.10	46.10	67.50	80.40
Companion sorghum variety(S)				
ICSV 400	637.0	1299.0 2	199.0	3049.0
Farafara	689.0	1899.0	3069.0	4163.0
SE±	21.60	46.40	53.40	110.00
Cropping system (C)				
1:1	708.0	1608.0b	2583.0 3	613.0b
1:2	635.0	1328.c	2321.0c	3109.0c
2:4	646.0	1860.0a	2998.0a	4095.0a
SE±	23.70	34.60	45.40	49.90
Interaction				
G x S	**	**	**	**
G x C	**	**	**	**
S x C	NS	**	NS	**
G x S x C	**	**	**	**

Means along the same column having different letter are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$

The results of the interactions as shown in tables 23, 24, 25 and 26 showed that at 10 WAS Samnut 21 grown in combination with Farafara at 2:4 crop arrangement had the highest leaf area and was observed to be significantly different from other groundnut varieties. The results also revealed that Samnut 22 grown in combination with ICSV400 at 1:2 crop arrangement had the lowest leaf area at BUK. The second lowest leaf area was produced by Samnut 22 planted in combination with Farafara at 1:2 cropping pattern.

Table 23. Interaction between groundnut and sorghum on leaf area of groundnut varieties 10WAS at BUK

	Groundnut			
Sorghum	Samnut 21	S amnut 22	Samnut 23	Kampala
ICSV400	4800.0b	2762.0d	1859.0e	2774.0d
Farafara	5358.0a	4081.0c	3113.0d	4099.0c
SE±	147.60			

Table 24. Interaction between groundnut and cropping system on leaf area of groundnut varieties 10WAS at BUK

	Cropping System			
Cropping System	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	3844.0cd	4107.0cd	3245.0e	3257.0e
1:2	4842.0b	1956.0g	1857.0g	3781.0d
2:4	6551.0a	4202.0c	2356.0f	3271.0e
SE±		130.50		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 25. Interaction between sorghum and cropping system on leaf area of groundnut varieties 10WAS at BUK

	Cropping System		
Sorghum	1:1	1:2	2:4
ICSV400	3220.0c	2537.0d	3390.0c
Farafara	4006.0b	3681.0c	4801.0a
SE±		124.20	

Table 26. Interaction between groundnut, sorghum and cropping system on leaf area of groundnut variety 10WAS at Buk

		Groundnut			
Sorghum	Cry. Sys.	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	1:1	3134.0fgh	3471.0efg	2925.0gh	3351.0fgh
	1:2	5593.0b	1807.0i	873.0j	1873.0i
	2:4	5673.0b	30090.0fgh	1779.0i	3098.0fgh
Farafara	1:1	4554.0cd	4743.0c	3566.0ef	3163.0fgh
	1:2	4091.0de	2104.0i	2840.0h	5690.0b
	2:4	7428.0a	5396.0b	2934.0gh	3444.0fg
SE±			210.9		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

The results of leaf area per plant of four groundnut varieties as affected by cropping system and companion sorghum at Minjibir is shown in Table 27. From the results, variety and cropping system had effect on groundnut leaf area in all the sampling periods. It was also observed that interaction between groundnut and sorghum, groundnut and cropping, sorghum and cropping system and between groundnut, sorghum and cropping system were all significant in all the sampling periods. The interactions results presented in Table 28, 29, 30 and 31 shows that at 10 WAS Kampala grown in combination with Farafara at 1:2 crop arrangement was observed to have the highest leaf area and was at parity with Samnut 21/ICSV400 at 2:4 crop arrangements.

Table27. Effect of crop arrangement and companion sorghum varieties on leaf area (cm^2) of groundnut varieties weeks after sowing at Minjibir

	4WAS	6WAS	8WAS	10WAS
Groundnut variety (G)				
Samnut 21	270.4a	1015.0a	2111.0a	2985.0a
Samnut 22	183.6c	639.0c	1286.0c	1754.0c
Samnut 23	230.7b	540.0d	1009.0d	1270.0d
Kampala	197.4c	820.0b	1919.0b	2334.0b
SE±	10.66	2960	46.30	101.40
Companion sorghum variety(S)				
ICSV 400	196.3	767.0	1560.0	2007.0
Farafara	244.8	740.0	1602.0	2164.0
SE±	5.74	18.90	40.50	64.80
Cropping system (C)				
1:1	209.5b	724.0	1454.0b	2101.0
1:2	247.9a	782.0	1685.0a	2018.0
2:4	204.3b	755.07	1604.0a	2138.0
SE±	7.17	22.00	37.20	60.30
Interaction				
G x S	**	*	**	**
G x C	**	*	**	**
S x C	**	*	**	**
G x S x C	**	**	**	**

Means along the same column having different letter are significantly different at $p \leq 0.05$ using DMRT. **=significant at $p \leq 0.01$ * = significant at $P \leq 0.05$

Table 28. Interaction between groundnut and sorghum on leaf area of groundnut varieties 10 WAS at Minjibir

	Groundnut			
Sorghum	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	3080.0a	1735.0c	888.0d	2327.0b
Farafara	2890.0a	1774.0c	1652.0c	2340.0b
SE±		140.10		

Table 29. Interaction between groundnut and cropping system on Leaf area of groundnut varieties 10 WAS at Minjibir

	Groundnut			
Cropping System	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	2833.0ab	2288.0cd	1344.0f	1941.0de
1:2	2839.0ab	1376.0f	1236.0f	2619.0bc
2:4	3283.0a	1599.0ef	1230.0f	2441.0bc
SE±		163.60		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 30. Interaction between sorghum and cropping system on leaf area of groundnut varieties 10 WAS at Minijibir

	Cropping System		
Sorghum	1:1	1:2	2:4
ICSV400	2079.0a	1749.0b	2195.0a
Farafara	2124.0a	2287.0a	2082.0a
SE±		95.10	

Table 31. Interaction between groundnut sorghum and cropping system on leaf area of groundnut varieties 10 WAS at Minijibir

		Groundnut			
Sorghum	Cry.Sys.	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	1:1	2977.0bcd	2166.0e-h	875.0im	2298.0d-g
	1:2	3308.0abc	1628.0h-k	735.0m	1324.0i-m
	2:4	2966.0bcd	1410.0i-l	1054.0klm	3360.0ab
Farafara	1:1	2688.0cde	2410.0def	1812.0f-i	1585.0h-k
	1:2	2371.0d-g	1125-9j-m	1736.0g-j	3915.0a
	2:4	3610.0ab	1787.0f-i	1407.0i-l	1522.0h-l
SE±			235.10		

Means along the same column and row having different letter(s) are significantly different at p≤0.05 using DMRT.

The results also revealed that Samnut 23 grown in combination with ICSV400 at 1:2 cropping system had the lowest leaf area, followed by Samnut 23 planted in combination with ICSV400 at 1:1 crop arrangement.

4.1.2 Groundnut yield parameters at BUK and Minjibir in 2012 wet season.

Pod yield kg/ha

Pod yield per hectare for the four groundnut varieties as influenced by cropping pattern and companion sorghum varieties is presented in Table 32. At BUK variety and cropping system did not have effect on pod yield. Interactions between groundnut and cropping system was observed to be significant. The results of the interactions as presented in Table 33 showed that Samnut 22 planted in combination with ICSV400 at 2:4 crop arrangement produced the highest pod yield per hectare but was not statistically significantly different from Samnut 21 at 1:1 Samnut 21 at 1:2 and Samnut 23 at 2:4, respectively.

Table 32 equally shows pod yield kg/ha at Minjibir. While Table 33 presented the interaction between groundnut and croppy system on pod yield kg/ha of groundnut varieties at BUK.

Table 32. Effect of Crop arrangement and companion sorghum varieties on pod yield kg/ha at BUK and Minjibir

	BUK pod yield (kg/ha)	Minjibir pod yield (kg/ha)
Groundnut variety (G)		
Samnut 21	1213	521ab
Samnut 22	1126	635a
Samnut 23	1173	511b
Kampala	1096	430b
SE±	98.7	2.5
Companion sorghum variety(S)		
ICSV 400	1104	517
Farafara	1201	531
SE±	54.3	35.3
Cropping system (C)		
1:1	1170	480
1:2	1055	601
2:4	1231	493
SE±	66.5	43.3
Interaction		
G x S	NS	NS
G x C	*	NS
S x C	NS	NS
G x S x C	NS	NS

Means along the same column having different letter(s) are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, * = significant at $P \leq 0.05$

Table 33. Interaction between groundnut and cropping system on pod yield kg/ha of groundnut varieties at BUK

	Groundnut			
Cropping System	Samnut 21	Samnut 22	Samnut 23	kampala
1:1	1374ab	101bcd	1022bcd	1270abc
1:2	1347ab	806d	1166bcd	900cd
2:4	918cd	1559a	1330ab	1117bcd
SE±		162.3		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Variety had effect on pod yield kg/ha but cropping system did not have. The results also revealed that there was no interaction between groundnut and sorghum, groundnut and cropping system, sorghum and cropping system and between groundnut, sorghum and cropping system. However, Samnut 22 was observed to produce the highest pod yield kg/ha and was similar with Samnut 21 statistically. The lowest pod yield was produced by Kampala but was not statistically significantly different from Samnut 21 and Samnut 23.

Kernel yield kg/ha

The results of groundnut Kernel yield kg/ha as influenced by cropping system and companion sorghum is shown in Table 34. At BUK variety did not have effect on Kernel yield but cropping system affected Kernel yield kg/ha. From the result significant interaction was observed between groundnut and sorghum, and between groundnut and cropping system. The results of the interactions as presented in Tables 35 and 36 showed that the highest Kernel yield was produced by Samnut 22 / ICSV 400 at 2:4 crop arrangements but was similar statistically with Samnut 21 at 1:1, Samnut 21 at 1:2 and Kampala at 1:1 crop arrangements. The lowest Kernel yield kg/ha was from Samnut 22 planted at 1:2 crop arrangements, followed by Samnut 21 grown at 2:4 cropping pattern.

Table 34 equally shows the results of Kernel yield kg/ha as influenced by cropping system and companion sorghum at Minjibir.

Table 34. Effect of Crop arrangement and companion sorghum varieties on Kernel yield kg/ha at BUK and Minjibir

	BUK Kernel yield (kg/ha)	Minjibir Kernel yield (kg/ha)
Groundnut variety (G)		
Samnut 21	677	252b
Samnut 22	659	346a
Samnut 23	683	209b
Kampala	637	204b
SE±	63.3	27.8
Companion sorghum variety(S)		
ICSV 400	630	225
Farafara	698	251
SE±	45.1	18.4
Cropping system (C)		
1:1	6.85ab	228b
1:2	5.88b	291a
2:4	719a	240ab
SE±	55.2	22.6
Interaction		
G x S	**	NS
G x C	**	NS
S x C	NS	NS
G x S x C	NS	NS

Means along the same column having different letter(s) are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$

Table 35. Interaction between groundnut and sorghum on Kernel yields kg/ha of groundnut varieties at 4WAS at BUK

	Groundnut			
Sorghum	Samnut 21	Samnut 22	Samnut 23	kampala
ICSV 400	492c	753a-d	784ab	4.91cd
Farafara	861a	5.65bcd	582bcd	782abc
SE±		89.7		

Table 36. Interaction between groundnut and cropping system o Kernel yield kg/ha of groundnut varieties at BUK

	Groundnut			
Cropping system	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	831ab	549de	502cde	797abc
1:2	801abc	395e	726bcd	429e
2:4	397e	1034a	762bcd	684bcd
SE±		109.8		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Variety and cropping system affected kernel yield kg/ha at Minjibir. There was no interaction between groundnut and sorghum, groundnut and cropping system, sorghum and cropping system, and between groundnut, sorghum and cropping system. However Samnut 22 was observed to produce the highest kernel kg/ha and was statistically significantly different from other tested groundnut varieties. The lowest yield was produced by Kampala and was similar statistically with Samnut 21 and Samnut 23. The highest kernel yield was produced from Samnut 22 in combination with Farafara at 1:2 crop arrangement and was not statistically different from 2:4 crop arrangement. The lowest kernel yield kg/ha was from Kampala / ICSV 400 at 1:1 crop arrangement and was similar to 2:4 crop arrangement statistically

Haulm yield kg/ha

The results of the effect of crop arrangement and companion sorghum on haulm yield kg/ha at BUK and Minjibir is shown in table 37. At BUK variety and cropping system did not have effect on groundnut haulm yield. However Samnut 21 was observed to produce the highest haulm yield, followed by Kampala, Samnut 22 and Samnut 23, respectively. There was interactions between sorghum and cropping system. The results of the interactions between sorghum and cropping system on haulm yield as presented in Table 38 showed that Samnut 21 grown with farafara at 2:4 crop arrangements had the highest haulm yield. There was interaction between sorghum and cropping system.

Table 37 equally shows the results of the effect of crop arrangement and companion sorghum on groundnut haulm yield at Minjibir.

Table 37. Effect of Crop arrangement and companion sorghum varieties on haulm yield kg/ha at BUK and Minjibir

	BUK haulm yield kg/ha	Minjibir haulm yield kg/ha
Groundnut variety (G)		
Samnut 21	3252	1700a
Samnut 22	2709	1393ab
Samnut 23	2678	1194c
Kampala	2763	1628ab
SE±	218.7	92.0
Companion sorghum variety(S)		
ICSV 400	2595	1437
Farafara	3106	1520
SE±	132.9	62.5
Cropping system (C)		
1:1	2910	1437ab
1:2	2643	1671a
2:4	2999	1328b
SE±	162.7	76.5
Interaction		
G x S	NS	NS
G x C	NS	NS
S x C	*	NS
G x S x C	NS	NS

Means along the same column having different letter(s) are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, * = significant at $P \leq 0.05$

Table 38. Interaction between sorghum and cropping system on haulm yield kg/ha of groundnut varieties at BUK

	Cropping System		
Sorghum	1:1	1:2	2:4
ICSV 400	2724bc	2725bc	2336c
Farafara	3095ab	2561bc	3662a
SE±		517.9	

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Variety and cropping system had effect on groundnut haulm yield. Samnut 21 was observed to have the highest haulm yield kg/ha and was statistically similar to Samnut 22 and Kampala. Samnut 23 was observed to produce the least haulm yield. The highest haulm yield was from 1:2 crop arrangement and was not statistically different from 1:1 cropping pattern. The least haulm was produced by 2:4 crop arrangement. Samnut 21 grown with farafara at 1:2 crop arrangement had the highest haulm kg/ha. No interaction was observed between groundnut and sorghum, groundnut and cropping system, sorghum and cropping system and between groundnut, sorghum and cropping system.

Shelling percentage

The results of the effect of crop arrangement and companion sorghum varieties on groundnut shelling percentage at BUK and Minjibir is shown in Table 39. At BUK variety and cropping system did not have effect on shelling percentage. However Kampala was observed to have the highest shelling percentage, followed by Samnut 23 and Samnut 22, respectively. Samnut 21 recorded the lowest shelling percentage. The highest shelling percentage was from 1:1 crop arrangement, followed by 2:4 cropping system while crop arrangement 1:2 had the least. There was no interaction between groundnut and sorghum and between sorghum and cropping system. The interaction between groundnut and cropping system was however highly significant. The results of the interaction between cropping system and groundnut as presented in Table 40 showed that Samnut 22 grown at 2:4 crop arrangement had the highest shelling percentage while Samnut 21 planted at 2:4 recorded the lowest shelling percentage.

Table 39 equally shows groundnut shelling percentage at Minjibir. Variety and cropping system did not have effect on groundnut shelling percentage. However Samnut 22 was observed to have the highest shelling percentage while Samnut 23 recorded the lowest.

There was no interaction between groundnut and sorghum, groundnut and cropping system, and between groundnut, sorghum and cropping system. However, the interaction between sorghum and cropping system was observed to be highly significant as presented in Table 41.

Table39. Effect of Crop arrangement and companion sorghum varieties on groundnut shelling % at BUK and Minjibir

	BUK Shelling %	Minjibir Shelling %
Groundnut variety (G)		
Samnut 21	53.6	48.3
Samnut 22	55.6	53.2
Samnut 23	56.8	38.2
Kampala	57.1	47.5
SE±	2.52	2.09
Companion sorghum variety(S)		
ICSV 400	54.2	47.7
Farafara	57.6	45.9
SE±	2.63	1.22
Cropping system (C)		
1:1	56.9	45.4
1:2	54.3	47.4
2:4	56.4	47.6
SE±	3.22	1.49
Interaction		
G x S	NS	NS
G x C	**	NS
S x C	NS	**
G x S x C	NS	NS

Means along the same column having different letter are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$

Table 40. Interaction between groundnut and cropping system on groundnut shelling percentage of groundnut varieties at BUK

	Groundnut			
Cropping System	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	60.4a-d	51.1b-e	52.9b-e	63.2ab
1:2	58.9a-d	49.3cde	61.2abc	47.7de
2:4	42.4e	66.4a	56.4a-d	60.4a-d
SE±		4.96		

Table 41. Interaction between sorghum and cropping system on shelling percentage of groundnut varieties at Minjibir

	Cropping System		
Sorghum	1:1	1:2	2:4
ICSV400	50.2a	47.4ab	45.5a-d
Farafara	40.7bd	47.3abc	49.6a
SE±		2.11	

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Showed that groundnut planted with ICSV 400 at 1:1 crop arrangement had the highest shelling percentage but was at par with others except groundnut planted with Farafara at 1:1 crop arrangement.

4.1.3 Sorghum growth parameters at BUK in 2012 wet season

Plant height (cm)

The plant height results of sorghum varieties as affected by companion groundnut varieties and crop arrangement is shown in Table 42. Groundnut varieties and cropping system had effect on sorghum plant height almost in all the sampling periods. Interactions between groundnut and sorghum, groundnut and cropping system, sorghum and cropping system and between groundnut, sorghum and cropping system were observed to be highly significant. The results of the interactions as presented in Tables 43, 44, 45 and 46 showed that Farafara grown in combination with Samnut 23 at 1:1 crop arrangement produced the tallest sorghum plant and it was statistically significantly different from other crop combinations and arrangements.

Table 42. Effect of crop arrangement and companion groundnut on plant height of sorghum varieties weeks after sowing at BUK

Treatment	4 WAS	6 WAS	8 WAS	10 WAS
Groundnut variety (G)				
Samnut 21	60.0	102.5b	156.2a	187.5b
Samnut 22	54.8	114.6b	160.7a	199.3a
Samnut 23	61.8	116.6a	160.2a	201.2a
Kampalu	52.3	87.0c	132.6b	176.1c
SE±	2.15	3.46	3.63	3.73
Companion sorghum variety(S)				
ICSV 400	57.9	117.9	142.7	170.3
Farafara	56.5	92.4	162.1	211.7
SE±	1.03	3.60	4.09	4.06
Cropping system (C)				
1:1	61.3	109.5	162.3a	201.3a
1:2	59.0	103.0	141.6c	184.8b
2:4	51.3	103.0	153.4b	186.8b
SE±	1.08	2.15	2.38	3.15
Interaction				
G x S	**	**	**	**
G x C	**	**	**	*
S x C	**	**	NS	**
G x S x C	**	**	**	**

Means along the same column having different letter are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$ * = significant at $P \leq 0.05$

Table 43. Interaction between groundnut and sorghum on plant height of sorghum varieties 10 WAS at BUK

	Groundnut			
Sorghum	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	173.0def	179.8de	167.5ef	161.0f
Farafara	201.9c	218.8b	234.9a	191.2cd
SE±		6.11		

Table 44. Interaction between groundnut and cropping system on plant height of sorghum varieties 10WAS at BUK

	Groundnut			
Cropping System	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	208.8b	209.7b	232.1a	154.8e
1:2	183.7cd	209.1b	177.3cd	169.2de
2:4	170.0de	179.0cd	194.2bc	204.2b
SE±		6.42		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT

Table 45. Interaction between sorghum and cropping system on plant height of sorghum varieties 10 WAS at BUK

	Cropping System		
Sorghum	1:1	1:2	2:4
ICSV400	170.9c	172.5c	167.5c
Farafara	231.7a	197.2b	206.2b
SE$\pm$		5.45	

Table 46. Interaction between groundnut, sorghum and cropping system on plant height of sorghum varieties 10 WAS at BUK

		Groundnut			
Sorghum	Cry.Sys.	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	1:1	208.5cde	174.4fgh	173.2fgh	127.6j
	1:2	173.0fgh	221.9bc	157.0hi	138.0ij
	2:4	137.4ij	143.0ij	172.4gh	217.3bcd
Farafara	1:1	209.0cd	245.0b	291.0a	182.0e-h
	1:2	194.3c-g	196.3c-g	197.7c-g	200.4c-f
	2:4	202.5cde	215.0cd	216.0cd	191.1d-g
SE$\pm$			9.61		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT

Farafara planted in combination with Samnut 22 at 1:1 crop arrangement produced the second tallest sorghum plant. The shortest sorghum plant was produced by ICSV400 grown in combination with Kampala at 1:1 crop arrangement and was not significantly statistically different from ICSV400/Kampala at 1:2, ICSV400/Samnut 22 at 2:4 and ICSV400/Samnut 21 at 2:4 crop arrangements.

Table 47 shows the effect of crop arrangement and companion groundnut varieties on sorghum plant height (cm) at Minjibir. Groundnut variety and cropping system had effect on sorghum plant height in the sampling periods especially at 10 WAS. At 10 WAS highly significant interactions was observed between groundnut and sorghum, groundnut and cropping system and between groundnut, sorghum and cropping system. The results of the interactions as presented in Tables 48, 49, 50 and 51 showed that the tallest sorghum plant was produced by Farafara grown in companion of Kampala at 2:4 crop arrangement and was similar to Farafara/Samnut 22 at 1:2, Farafara/Samnut 21 at 1:1, Farafara/Samnut 22 at 1:1 and Farafara/Samnut 22 at 1:2 crop arrangements.

Table 47. Effect of crop arrangement and companion groundnut on plant height (cm) of Sorghum varieties weeks after sowing at Minjibir

	4 WAS	6 WAS	8 WAS	10 WAS
Groundnut variety (G)				
Samnut 21	18.2	43.1b	88.8b	137.6a
Samnut 22	12.4	49.2b	87.3b	139.6a
Samnut 23	12.0	45.9b	76.7b	116.2b
Kampala	15.7	64.4a	104.3a	140.7a
SE±	3.06	2.46	4.85	4.21
Companion sorghum variety(S)				
ICSV 400	14.2	47.2	86.4	122.6
Farafara	14.9	54.1	92.1	144.4
SE±	1.87	2.62	1.19	2.70
Cropping system (C)				
1:1	13.9	57.9a	90.9	133.6
1:2	11.3	41.3b	80.1	133.6
2:4	18.5	52.8ab	96.9	133.3
SE±	2.69	3.62	4.57	3.36
Interaction				
G x S	NS	NS	**	**
G x C	NS	**	**	**
S x C	NS	NS	NS	*
G x S x C	NS	**	**	**

Means along the same column having different letter are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$ * = significant at $P \leq 0.05$

Table 48. Interaction between groundnut and sorghum on plant height of sorghum varieties 10 WAS at Minjibir

	Groundnut			
Sorghum	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	112.0d	126.4cd	115.2d	136.9bc
Farafara	163.1a	152.9ab	117.1d	144.4b
SE±		5.82		

Table 49. Interaction between groundnut and cropping system on plant height of sorghum varieties 10 WAS at Minjibir

	Groundnut			
Cropping system	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	140.7b	166.5a	115.3d	111.8d
1:2	142.4b	139.8b	114.0d	138.2bc
2:4	129.6bcd	112.5d	1192cd	172.0a
SE±		7.16		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 50. Interaction between sorghum and cropping system on plant height of sorghum varieties 10 WAS at Minjibir

	Cropping System		
Sorghum	1:1	1:2	2:4
ICSV400	120.6c	116.7c	130.7bc
Farafara	146.5a	150.6a	136.0ab
SE±		4.73	

Table 51. Interaction between groundnut sorghum and cropping system on plant height of sorghum varieties 10 WAS at Minjibir

		Groundnut			
Sorghum	Cry.Sys.	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	1:1	118.1ghi	153.0b-e	102.2i	109.0i
	1:2	104.81i	107.4i	105.4i	149.1c-f
	2:4	113.2hi	118.8ghi	138.1d-h	152.7b-e
Farafara	1:1	163.3a-d	180.0ab	128.3e-i	114.5hi
	1:2	180.0ab	172.3abc	122.7f-i	127.4e-i
	2:4	146.0c-g	106.2i	100.3i	191.3a
SE±			10.11		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

The shortest plant in height was recorded from Farafara grown in combination with Samnut 23 and ICSV 400 planted with Samnut 23 both at 1:1 crop arrangement.

Number of leaves per plant

Table 52 shows the effect of crop arrangement and companion groundnut on sorghum number of leaves weeks after sowing at BUK. At all the sampling periods groundnut significantly affected sorghum number of leaves. At 10 WAS, highly significant interactions were observed between groundnut and sorghum, and between sorghum and cropping system while the interaction between groundnut and cropping system was significant. The results of the interactions as presented in Tables 53, 54, and 55 showed that Farafara grown in combination with Samnut 21 at 2:4 crop arrangement was observed to have produced the highest number of leaves while the lowest number of leaves was from ICSV400 planted in combination with Kampala at 2:4 crop arrangement.

Table 52. Effect of crop arrangement and companion groundnut on number of leaves of sorghum varieties weeks after sowing at BUK

	4 WAS	6 WAS	8 WAS	10 WAS
Groundnut variety (G)				
Samnut 21	6.500a	7.889b	9.610ab	11.220a
Samnut 22	6.333a	9.056a	10.000a	11.330a
Samnut 23	6.000b	8.167b	8.940bc	10.390b
Kampala	5.833b	7.667b	8.830c	9.330c
SE±	0.0989	0.1800	0.2410	0.2480
Companion sorghum variety(S)				
ICSV 400	5.444	7.389	8.250	8.780
Farafara	6.889	9.000	10.440	12.360
SE±	0.0874	0.2005	0.1820	0.1890
Cropping system (C)				
1:1	6250	7.583b	8.670	10.620
1:2	6.167	7.958b	9.170	10.210
2:4	6.083	9.042a	10.210	10.880
SE±	0.1070	02456	0.2230	0.2320
Interaction				
G x S	**	**	**	**
G x C	**	**	NS	*
S x C	**	**	**	**
G x S x C	**	**	NS	NS

Means along the same column having different letter(s) are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$ * = significant at ≤ 0.05

Table 53. Interaction between groundnut and sorghum system on sorghum number of leaves 10 WAS at BUK

	Groundnut			
Sorghum	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	8.670e	10.110d	8.780e	7.560f
Farafara	13.780a	12.560b	12.000bc	11.110cd
SE±		0.3580		

Table 54. Interaction between groundnut and cropping system on sorghum number of leave 10 WAS at BUK

	Groundnut			
cropping system	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	10.830ab	11.000ab	11.170ab	9.500cd
1:2	11.830a	11.170ab	9.500cd	8.330d
2:4	11.000ab	11.830a	10.500bc	10.170bc
SE±		0.4390		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 55. Interaction between sorghum and cropping system on sorghum number of leave 10 WAS at BUK

	Cropping System		
Sorghum	1:1	1:2	2:4
ICSV400	8.250d	9.670c	8.420d
Farafara	13.000a	10.750b	13.330a
SE±		0.3280	

Means along the same column and row having different letter are significantly different at $p \leq 0.05$ using DMRT.

Table 56 shows the results of effect of crop arrangement and companion groundnut on number of leaves of sorghum varieties weeks after sowing at Minjibir. According to the results, companion groundnut varieties affected sorghum number of leaves in all the sampling periods. At 10 WAS interactions between groundnut and sorghum, groundnut and cropping system and between groundnut, sorghum and cropping system were highly significant. However, interaction between sorghum and cropping system was observed not significant. According to the interactions results as presented in Tables 57, 58 and 59 the highest number of leaves was observed to be from Farafara, grown in combination with Kampala at 2:4 crop arrangement and was statistically significantly different from others.

Table56. Effect of crop arrangement and companion groundnut on number of leaves of sorghum varieties weeks after sowing at Minjibir

	4 WAS	6 WAS	8 WAS	10 WAS
Groundnut variety (G)				
Samnut 21	4.500b	6.333a	8.111a	10.278a
Samnut 22	4.500b	6.056ab	7.833ab	9.722b
Samnut 23	4.333b	5.778b	7.000c	8.056c
Kampala	5.056a	6.389a	7.778b	10.556a
SE±	0.1313	0.1211	0.1039	0.1547
Companion sorghum variety(S)				
ICSV 400	4.861	6.111	7.000	7.389
Farafara	4.333	6.167	8.361	11.917
SE±	0.1028	0.0708	0.1135	0.1861
Cropping system (C)				
1:1	4.750	6.292a	7.917	9.792
1:2	4.458	5.875b	7.333	9.458
2:4	4.583	6.250a	7.792	9.708
SE±	0.1259	0.0867	0.1390	0.2280
Interaction				
G x S	NS	NS	**	**
G x C	NS	*	**	**
S x C	*	**	NS	NS
G x S x C	NS	NS	**	**

Means along the same column having different letter(s) are transfer to growth parameters significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$, * = significant at $P \leq 0.05$

Table 57. Interaction between groundnut and sorghum on number of leaves of sorghum varieties 10 WAS at Minjibir

	Groundnut			
Sorghum	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	7.111e	7.778d	7.111e	7.556de
Farafara	13.444a	11.667b	9.000c	13.556a
SE±		0.2656		

Table 58. Interaction between groundnut and cropping system on number of leaves of sorghum varieties 10 WAS at Minjibir

	Groundnut			
Cropping System	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	10.333abc	10.000bc	8.333	10.500abc
1:2	10.667ab	9.500c	7.833d	9.833c
2:4	9.833bc	9.667bc	8.000d	11.333a
SE±		0.3252		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 59. Interaction between groundnut sorghum and cropping system on number of leaves of sorghum varieties 10 WAS at Minjibir

		Groundnut			
Sorghum	Cry.Sys.	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	1:1	7.000h-k	7.667h-k	7.000h-k	8.000hi
	1:2	7.333h-k	7.667h-k	7.667h-k	7.667h-k
	2:4	7.000h-k	8.000h	6.667ik	7.000h-k
Farafara	1:1	13.667b	12.333cde	9.667f	13.000bc
	1:2	14.000b	11.333de	8.000g-j	12.000cde
	2:4	12.667bcd	11.333e	9.333fg	15.667a
SE±			0.4600		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

The second highest number of leaves was from Farafara/Samnut 21 at 1:2, followed by Farafara/Samnut 21 at 1:1 crop arrangements and were similar to the number of leaves of Farafara planted in combination with Kampala at 1.1 crop arrangement. The lowest number of leaves produced by sorghum plants was observed to be from ICSV400, grown in combination with Samnut 23 at 2:4 cropping pattern.

Leaves area (cm^2)

Table 60 shows results of effect of crop arrangement and companion groundnut on sorghum leaf area weeks after sowing at BUK. According to the results, groundnut varieties affected sorghum leaf area at all the sampling periods. Likewise, cropping system affected sorghum leaf area across the sampling periods. At 10 WAS interaction between groundnut and sorghum and between sorghum and cropping system were observed to be highly significant. However interaction between groundnut and cropping system, and between groundnut, sorghum and cropping system showed not significant. From the results of the interactions as presented in Tables 61 and 62 Farafara grown in combination with Samnut 21 at 2:4 crop arrangements gave the highest leaf area. While the results of interaction between sorghum and cropping system showed that Farafara had more leaf area than ICSV400 in all crop arrangements.

Table60. Effect of crop arrangement and companion groundnut on leaf area of sorghum varieties weeks after sowing at BUK

	4 WAS	6 WAS	8 WAS	10 W
Groundnut variety (G)				
Samnut 21	8454a	35334ab	74000a	128519a
Samnut 22	6846bc	46614a	60909b	96961b
Samnut 23	7088b	36214ab	52865b	89197b
Kampala	6044c	21934b	39842c	56777c
SE+	306.3	5160.1 4	375.2	6143.8
Companion sorghum variety(S)				
ICSV 400	5546	21488	26994	36643
Farafara	8670	48561	86814	149084
SE+	145.6	4399.8	288.4	5711.4
Cropping system (C)				
1:1	8520a	26939	51379b	105627a
1:2	6764b	33879	46232b	72987b
2:4	6040b	44254	73101a	99976a
SE+	263.4	5400.5	3798.8	4031.1
Interaction				
G x S	**	NS	**	**
G x C	**	NS	**	NS
S x C	NS	NS	**	**
G x S x C	**	NS	NS	NS

Means along the same column having different letter are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$

Table 61. Interaction between groundnut and sorghum on leaf area of sorghum varieties 10WAS at BUK

	Groundnut			
Sorghum	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	35412d	45391d	41764d	24003d
Farafara	221627a	148531b	136629b	89550c
SE$\pm$		9446.7		

Table 62. Interaction between sorghum and cropping system on leaf area of sorghum varieties 10WAS at BUK

	Cropping System		
Sorghum	1:1	1:2	2:4
ICSV400	36050c	33530c	40347c
Farafara	175204a	112444b	159605a
SE$\pm$		7368.0	

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

The results of effect of crop arrangement and companion groundnut on sorghum leaf area at Minjibir is presented in Table 63. It was observed that companion groundnut varieties had effect on sorghum leaf area at all the sampling periods. It was equally observed that cropping system did not affect sorghum leaf area. Furthermore, interactions between groundnut and sorghum, groundnut and cropping system and between groundnut, sorghum and cropping system were highly significant. However, sorghum and cropping system interaction was not significant. According to the results as presented in Tables 64, 65 and 66 Farafara grown in combination with Kampala at 2:4 crop arrangement gave the highest leaf area but was similar with Farafara/Samnut 21 at 1:1 and Farafara/Samnut at 1:2 crop arrangements while the leaves with the lowest leaf was observed to be from ICSV400 grown in combination with Samnut 21 at 1:2 cropping pattern.

Table 63. Effect of crop arrangement and companion groundnut on leaf area of sorghum varieties weeks after sowing at Minjibir

	4 WAS	6 WAS	8 WAS	10 WAS
Groundnut variety (G)				
Samnut 21	6571b	38318a	70065a	68717a
Samnut 22	5110c	26461b	47811c	49704b
Samnut 23	3181d	13323c	23465d	25402c
Kampala	8787a	35741a	62694b	67415a
SE±	255.4	1368.7	2482.0	2948.8
Companion sorghum variety(S)				
ICSV 400	4066	9917	15768	16588
Farafara	7759	47004	86249	2371.6
SE±	178.2	780.7	1383.2	2371.6
Cropping system (C)				
1:1	5743b	30401	55066	59186
1:2	4852b	26140	47427	50749
2:4	7143a	28838	50533	48494
SE±	346.7	1852.8	3358.8	4669.5
Interaction				
G x S	**	**	**	**
G x C	**	**	**	**
S x C	NS	NS	NS	NS
G x S x C	**	**	**	**

Means along the same column having different letter are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$,

Table 64. Interaction between groundnut and sorghum on leaf area of sorghum varieties 10WAS at Minjibir

	Groundnut			
Sorghum	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	13489d	20280d	14273d	18312d
Farafara	123946a	79129b	36532c	116517a
SE±		4320.6		

Table 65. Interaction between groundnut and cropping system on leaf area of sorghum varieties 10WAS at Minjibir

	Groundnut			
Cropping System	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	79563abc	61772bd	36310fg	59099de
1:2	80384ab	44353def	23928gh	54332def
2:4	46204def	42989ef	15969h	88813a
‘				
SE±		8592.2		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 66. Interaction between groundnut, sorghum and cropping system on leaf area of sorghum varieties10 WAS at Minjibir

		Cropping System			
Sorghum	Cry.Sys.	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	1:1	16503fg	24260fg	11420fg	13653fg
	1:2	8047g	10581fg	13638fg	23643fg
	2:4	15916fg	25999fg	17762fg	17640fg
Farafara	1:1	142623a	99283bc	61200d	104544b
	1:2	152722a	78124bcd	34219ef	85021bcd
	2:4	76492cd	59979de	14177fg	159987a
SE$\pm$			8592.2		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

(iv) Panicle length

Table 67 results of sorghum panicle length at BUK showed that they were not affected by companion groundnut and crop arrangement. No interaction was also observed between groundnut and sorghum, and between sorghum and cropping system. At Minjibir, Farafara grown in combination with Samnut 22 at 1:2 crop arrangement produced sorghum with the longest panicle. At both BUK and Minjibir, Farafara had longer panicle length than ICSV 400

Table 67. Effect of crop arrangement and companion groundnut on sorghum panicle length at BUK and Minjibir

	BUK Paniclelength	Minjibir Paniclelength
Groundnut variety (G)		
Samnut 21	28.56	20.07
Samnut 22	29.00	21.73
Samnut 23	28.50	20.56
Kampala	27.89	20.94
SE±	1.423	1.327
Sorghum variety(S)		
ICSV 400	19.11	18.83
Farafara	37.86	22.81
SE±	0.825	1.076
Cropping system (C)		
1:1	29.50	18.22
1:2	27.54	22.54
2:4	28.42	21.71
SE±	1.010	1.318
Interaction		
G x S	NS	NS
G x C	NS	NS
S x C	NS	NS
G x S x C	NS	NS

NS= not significant.

4.1.4 Sorghum yield parameters at BUK in 2012 wet season.

Grain yield kg/ha

Table 68 shows effect of crop arrangement and companion groundnut on yield components of sorghum varieties at BUK. According to the results companion groundnut did not have significant influence on sorghum grain yield kg/ha while crop arrangement significantly affected grain yield. The results of the interactions between groundnut and cropping system, and between cropping system and sorghum as presented in Tables 69 and 70 showed that ICSV400 in combination with Samnut 22 at 1:1 crop arrangement had the highest grain yield. No interaction between groundnut and sorghum was observed while interaction between sorghum and cropping system was significant.

Table68. Effect of crop arrangement and companion groundnut on sorghum grain yields at BUK and Minjibir

	BUK Grain Yield	Minjibir Grain Yield
Groundnut variety (G)		
Samnut 21	1877	2237.0c
Samnut 22	1950	4226.0a
Samnut 23	1726	3188.0b
Kampala	1465	2915.0bc
SE±	198.8	257.90
Sorghum variety(S)		
ICSV 400	2131	4980.0
Farafara	1378	1304.0
SE±	93.9	249.50
Cropping system (C)		
1:1	2137a	3915.0a
1:2	1621b	2987.0ab
2:4	1505b	2523.0b
SE±	115.0	305.60
Interaction		
G x S	NS	**
G x C	*	**
S x C	NS	*
G x S x C	**	**

Means along the same column having different letter(s) are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$ * = significant at $P \leq 0.05$

Table 69. Interaction between groundnut and cropping system on sorghum grain yield at BUK

	Groundnut			
Cropping system	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	1785bcd	3005a	2049abc	1709bcd
1:2	1565bcd	1851bcd	1579bcd	1490bcd
2:4	2283ab	994d	1548bcd	1196cd
SE±		319.5		

Table 70. Interaction between sorghum and cropping system on sorghum grain yields at BUK

	Cropping System		
Sorghum	1:1	1:2	2:4
ICSV400	2795a	1846b	1750b
Faratara	1479b	1396b	1396b
SE±		230.0	

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 68 equally shows the results of effect of crop arrangement on grain yield kg/ha, panicle length, panicle weight and threshing percentage of sorghum varieties at Minjibir. Companion groundnut had effect on grain yield of sorghum. There was interaction between groundnut and sorghum, sorghum and cropping system, groundnut and cropping system, and between groundnut, sorghum and cropping system. The results of the interactions as presented in Tables 71, 72, 73 and 74 showed that ICSV400 in combination with Samnut 22 at 1:1 crop arrangement gave the highest yield. Yield of sorghum planted with Samnut 23 and Kampala were at par while sorghum grown with Samnut 21 that produced the lowest was not statistically significantly different from yield of sorghum planted in combination with Kampala. The results further revealed that crop arrangement 1:1 which produced the highest yield was not significantly different from the yield 1:2 cropping pattern statistically. The yields of 1:2 and 2:4 cropping patterns were observed to be similar.

Table 71. Interaction between groundnut and sorghum on sorghum grain yields kg/ha at Minjibir

Sorghum	Groundnut			
	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	3182.0c	7142.0a	5182.0b	4413.0b
Farafara	1292.0d	1311.0d	1193.0d	1418.0d
SE±		402.50		

Table 72. Interaction between groundnut and cropping system on grain yield at Minjibir

Cropping system	Groundnut			
	Samnut 21	Samnut 22	Samnut 23	Kampala
1 : 1	2750.0b-f	6614.0a	262.0b-f	3666.0b
1 : 2	2068.9cef	3096.0b-f	3436.0bcd	3349.0b-c
2 : 4	1892.0f	2969.0b-f	3499.0bc	1731.0f
SE±		493.00		

Means along the same column and row having different letter(s) are significantly different at p≤0.05 using DMRT.

Table 73. Interaction between sorghum and cropping system on grain yield kg/ha at Minjibir

Sorghum	Cropping System		
	1 : 1	1 : 2	2 : 4
ICSV400	6574.0a	4575.0b	3790.0b
Farafara	155.0c	1400.0c	1256.0c
SE±		432.2	

Table 74. Interaction between groundnut sorghum and cropping system on grain yield kg/ha at Minjibir

Sorghum	Cry.Sys	Groundnut			
		Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	1 : 1	4547.0b-e	11675.0a	4225.0b-f	5851.0b
	1 : 2	3064.0c-g	4656.0	5595.0b	4984.0bcd
	2 : 4	1935.5gh	5095.0bc	5727.0b	2404.0fgh
Farafara	1 : 1	954.0h	1554.0gh	1033.0h	1480.0gh
	1 : 2	10730	1536.0gh	1277.0gh	1714.0gh
	2 : 4	1850.0gh	844.0h	1270.0gh	1059.0h
SE±			497.20		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

(i) Threshing %

The results of threshing percentage of sorghum varieties at BUK as observed in Table 75 showed that groundnut and cropping system did not influence the outcome. Sorghum variety, ICSV400 had the higher threshing percentage when compared to Farafara. No interaction was observed between groundnut and sorghum, sorghum and cropping system and between groundnut, sorghum and cropping system. The interaction between groundnut and cropping system was highly significant. The interaction results as presented in table 76 showed that samnut 21 planted in combination with sorghum at 2:4 crop arrangement had the highest threshing percentage.

The results of threshing percentage of sorghum varieties at Minjibir also in Table 75 also showed that companion groundnut did not have effect on it. The interactions between groundnut and cropping system was highly significant. There was also interaction between sorghum and cropping system which was highly significant. The interaction results as presented in Tables 77 and 78 reveals that samnut 21 grown in combination with ICSV 400 at 1:1 crop arrangement, had the highest threshing percentage and was at parity with ICSV 400 planted at 1:2 cropping pattern.

Table75. Effect of crop arrangement and companion groundnut on sorghum threshing percentage at BUK and Minjibir

	BUK Threshing %	Minjibir Threshing %
Groundnut variety (G)		
Samnut 21	27.24	54.48
Samnut 22	27.19	54.37
Samnut 23	27.31	54.62
Kampala	25.84	51.69
SE±	0.795	1.591
Sorghum variety(S)		
ICSV 400	36.75	73.51
Farafara	17.04	34.51
SE±	0.527	1.054
Cropping system (C)		
1:1	25.75b	51.51b
1:2	28.44a	56.87a
2:4	26.50b	52.99b
SE±	0.645	1.291
Interaction		
G x S	NS	NS
G x C	**	**
S x C	NS	**
G x S x C	NS	NS

Means along the same column having different letter are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$

Table 76. Interaction between groundnut and cropping system on sorghum threshing percentage at BUK

	Groundnut			
Cropping system	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	24.40cde	27.73abc	24.63cde	26.26b-e
1:2	27.42a-d	29.86ab	28.66ab	27.81abc
2:4	29.91a	23.97de	28.64ab	23.47e
SE±		1.356		

Table 77. Interaction between groundnut and cropping system on sorghum threshing percentage at Minjibir

	Groundnut			
Croping System	Samnut 21	Samnut 22	Samnut 23	Kampala
1 : 1	48.80cde	48.80cde	49.25cde	52.52b-e
1 : 2	54.83a-d	59.72ab	57.32ab	55.62abc
2 : 4	59.82a	47.93de	57.28ab	46.93e
SE±		2.713		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 78. Interaction between sorghum and cropping system on sorghum threshing percentage at Minjibir

	Cropping System		
Sorghum	1 : 1	1 : 2	2 : 4
ICSV400	75.51a	74.16ab	70.85b
Farafara	27.51e	39.58c	35.13d
SE+		1.825	

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Panicle weight (g)

Table 79 shows the result of panicle weight at BUK and Minjibir. Companion groundnut varieties did not have any effect on panicle weight kg/ha at BUK but cropping system influenced the sorghum panicle weight. The highest panicle weight was observed in Farafara (sorghum Local) grown in combination with Samnut 22 at 1:1 crop arrangement. No interaction was observed between sorghum and groundnut, sorghum and cropping system, groundnut and cropping system and between groundnut, sorghum and cropping system.

The results of panicle weight kg/ha as observed in Table 79 showed that companion groundnut and cropping system had effect on sorghum panicle weight at Minjibir. The results of the interactions as presented in Tables 80, 81 and 82 revealed that ICSV400 planted with Samnut 22 at 1:1 crop arrangement gave the highest panicle weight and was statistically significantly different from the result of ICSV 400 and Farafara grown in combination with Samnut 21, Samnut 23 and Kampala.

Table 79. Effect of crop arrangement and companion groundnut on yields and threshing percentage of sorghum varieties at BUK

Treatment	BUK Panicle Weight	Minjibir Panicle Weight
Groundnut variety (G)		
Samnut 21	7247	3997c
Samnut 22	7431	6684a
Samnut 23	7103	5255b
Kampala	6009	5159b
SE±	565.6	358.8
Sorghum variety(S)		
ICSV 400	5760	6709
Farafara	8135	3839
SE±	284.2	361.7
Cropping system (C)		
1:1	890ba	6561a
1:2	6141b	4883b
2:4	5796b	4378b
SE±	348.0	443.0
Interaction		
G x S	NS	NS
G x C	NS	**
S x C	NS	**
G x S x C	NS	**

Means along the same column having different letter are significantly different at $p \leq 0.05$ using DMRT. NS= not significant, **=significant at $p \leq 0.01$

Table 80. Interaction between groundnut and sorghum on panicle weight kg/ha at Minjibir

	Groundnut			
Sorghum	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	4268c	9272a	6919b	6375b
Farafara	3726c	4096c	3592c	3743c
SE±		569.1		

Table 81. Interaction between groundnut and cropping system on panicle weight kg/ha at Minjibir

	Groundnut			
Cropping System	Samnut 21	Samnut 22	Samnut 23	Kampala
1 : 1	5093b-f	9877a	5000b-f	6274b
1 : 2	3645c-f	4855b-f	5349bcd	5681b
2 : 4	3253f	5320b-e	5417bc	3522df
SE±		697.0		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 82. Interaction between groundnut, sorghum and cropping system on panicle weight kg/ha at Minjibir

		Groundnut			
Sorghum	Cry-sys	Samnut 21	Samnut 22	Samnut 23	Kampala
ICSV400	1 : 1	6037bcd	14805a	5920b-c	7723b
	1 : 2	4094def	5895b-e	7289bc	7591bc
	2 : 4	2674f	7115bc	7548bc	3812def
Farafara	1 : 1	4149def	4949b-f	4079def	4825c-f
	1 : 2	3196ef	3815def	3410def	3770df
	2 : 4	3833def	3525def	3285def	3232def
SE±			985.7		

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

The lowest panicle weight was produced by Farafara in combination with Samnut 21. The results further revealed that 1:2 and 2:4 crop arrangement were at parity. The interaction between groundnut and sorghum and between sorghum and cropping system were highly significant.

1000 seed weight (g)

The results of 1000 seed weight at BUK is shown in Table 83. Effect of crop arrangement and companion groundnut on 1000 seed weight (g) of sorghum showed that ICSV400 planted in combination with Samnut 22 at 1:1 cropping pattern had the highest weight. No interaction was observed between groundnut and sorghum sorghum and cropping system, groundnut and cropping system, and between groundnut and sorghum and cropping system.

The results of Table 83 further revealed that companion groundnut and crop arrangement did not have significant effect on 1000 seed weight of sorghum varieties at Minjibir. However, Farafara in combination with Samnut 22 at 1:2 crop arrangement had the highest weight. No interaction between sorghum and groundnut, sorghum and cropping system, groundnut and cropping system and between groundnut, sorghum and cropping system were observed.

Table 83. Effect of crop arrangement and companion groundnut on sorghum 1000 seed weight (g) at BUK and Minjibir

	BUK 1000 Seed weight (g)	Minjibir 1000 Seed weight (g)
Groundnut variety (G)		
Samnut 21	30.89	27.28
Samnut 22	31.00	27.39
Samnut 23	28.94	26.33
Kampala	30.67	27.39
SE±	1.522	0.542
Sorghum variety(S)		
ICSV 400	30.64	26.97
Farafara	30.64	27.22
SE±	1.130	0.718
Cropping system (C)		
1:1	31.17	26.92
1:2	29.88	27.25
2:4	30.08	27.12
SE±	1.226	0.896
Interaction		
G x S	NS	NS
G x C	NS	NS
S x C	NS	NS
G x S x C	NS	NS

NS= not significant.

Stover yield kg/ha

The results of stover yield kg / ha at BUK is presented in Table 84 from the results, companion groundnut and cropping system did not have effect on sorghum stover yield. However, the results of the interactions between groundnut and cropping system and between sorghum and cropping system were observed to be significant. The results of Tables 85 and 86 revealed that Farafara planted at 1:1 crop arrangement had the highest stover yield while ICSV 400 planted at 1:1 crop arrangement recorded the lowest stover yield.

Table 84 equally shows the results of stover yield at Minjibir. It was observed that companion groundnut and crop arrangement did not have effect on sorghum stover yield. However the interaction between groundnut and cropping system was significant. The results of the interactions in Table 87 showed that Samnut 22 grown at 1:1 crop arrangement had the highest mean while Samnut 22 planted at 1:2 cropping patter had the lowest mean.

Table 84. Effect of crop arrangement and companion groundnut on stover yield of sorghum varieties at BUK and Minjibir

	BUK Stover yield	Minjibir Stover yield
Groundnut variety (G)		
Samnut 21	12178	12643
Samnut 22	10863	13365
Samnut 23	11148	12215
Kampala	10363	11922
SE±	1095.2	682.2
Sorghum variety(S)		
ICSV 400	6922	7497
Farafara	15.354	17575
SE±	591.9	459.8
Cropping system (C)		
1:1	11491	12862
1:2	10850	12541
2:4	111.03	12205
SE±	691.8	500.2
Interaction		
G x S	NS	NS
G x C	*	*
S x C	*	NS
G x S x C	NS	NS

NS= not significant, * = significant at P $\leq$ 0.05

Table 85. Interaction between groundnut and cropping system on stover yield kg/ha of sorghum varieties at BUK

	Groundnut			
Cropping System	Samnut 21	Samnut 22	Samnut 23	Kampala
1:1	12300abc	12322abc	10789a-d	10434a-d
1:2	10622bcd	11567a-d	9456cd	11756a-d
2:4	13611a	8700d	13200ab	8900d
SE±		1573.4		

Table 86. Interaction between sorghum and cropping system on stover yield kg/ha of sorghum varieties at BUK

	Cropping System		
Sorghum	1:1	1:2	2:4
ICSV400	6317c	7861c	6589c
Farafara	16606a	13839b	15617ab
SE±		1002.0	

Means along the same column and row having different letter(s) are significantly different at $p \leq 0.05$ using DMRT.

Table 87. Interaction between groundnut and cropping system on stover kg/ha of sorghum varieties at Minjibir

	Groundnut			
Croping system	Samnut 21	Samnut 22	Samnut 23	Kampala
1 : 1	11833c	14411a	11689c	10889c
1 : 2	14011ab	11485c	12189bc	12478abc
2 : 4	12084bc	14200ab	12767abc	12399abc
SE±		1064.3		

Means along the same column and row having different letter(s) are significantly different at p≤0.05 using DMRT.

4.1.5 Correlation analysis between growth and yield components

The results of the correlation analysis of responses between kernel growth and yield parameters of groundnut and Sorghum crops at BUK and Minjibir are presented in Table 88, 89, 90 and 91 respectively.

Table 88. Simple correction matrix between growth and yield parameters of groundnut at BUK

	1	2	3	4	5	6	7
1	1.00						
2	0.20	1.00					
3	-0.09	0.12	1.00				
4	-0.16	0.04	-0.16	1.00			
5	-0.03	0.23	0.23*	0.48**	1.00		
6	-0.04	-0.04	0.18	-0.41**	0.27*	1.00	
7	0.94**	0.23*	-0.05	-0.13	0.00	-0.03	1.00

1 = Kernel yield kg per hectare

2 = Haulm yield kg per hectare

3 = Leaf area (cm^2) at 10 WAS

4 = Number of branches at 10 WAS

5 = Number of leaves at 10 WAS

6 = Plant height (cm) at 10 WAS

7 = Pod yield kg per hectare

Table 89. Simple correlation matrix between growth and yield parameters of Sorghum at BUK

	1	2	3	4	5	6	7
1	1.00						
2	-0.10	1.00					
3	-0.09	0.13	1.00				
4	0.56**	0.03	0.55**	1.00			
5	0.65**	-0.15	-0.29**	0.27*	1.00		
6	0.69**	-0.05	-0.29**	0.36**	0.91**	1.00	
7	0.50**	-0.26**	-0.11	0.41**	0.59**	0.56**	1.00

* = significant at $P \leq 0.05$ ** = Significant at $P \leq 0.01$

1 = Grain yield kg per hectare
2 = 1000 seed weight g per hectare
3 = Grain yield kg per hectare
4 = Panicle weight kg per hectare
5 = Number of leaves at 10 WAS
6 = Leaf area (cm^2) at 10 WAS
7 = Plant height (cm) at 10 WAS

Table 90. Simple correlation matrix between growth and yield parameters of groundnut at Minjibir

	1	2	3	4	5	6	7
1	1.00						
2	0.30*	1.00					
3	0.07	0.39**	1.00				
4	0.16	0.15	0.39**	1.00			
5	0.05	0.28*	0.91**	0.57**	1.00		
6	-0.30*	-0.18	-0.19	-0.08	-0.20	1.00	
7	0.89**	0.28*	-0.00	0.11	-0.04	-0.25*	1.00

* = significant at P $\leq$ 0.05 ** = Significant at P $\leq$ 0.01

1 = Kernel yield kg per hectare
2 = Haulm yield per hectare
3 = Leaf area (cm^2) at 10 WAS
4 = Number of branches at 10 WAS
5 = Number of leaves at 10 WAS
6 = Plant height (cm) at 10 WAS
7 = Pod yield per hectare

Table 91. Simple correlation matrix between growth and yield parameters of Sorghum at Minjibir

	1	2	3	4	5	6	7
1	1.00						
2	0.04	1.00					
3	-0.58**	0.05	1.00				
4	0.95**	0.03	-0.38**	1.00			
5	-0.53**	0.13	0.79**	-0.37**	1.00		
6	-0.48**	0.16	0.74**	-0.33**	0.93**	0.93**	
7	-0.08	0.29*	0.40**	0.40	0.52**	0.51**	1.00

* = significant at P $\leq$ 0.05 ** = Significant at P $\leq$ 0.01

1 = Grain yield kg per hectare
2 = Weight of 1000 seeds (g)
3 = Stover kg per hectare
4 = panicle weight kg per hectare
5 = Leaf number at 10 WAS
6 = Leaf area (cm^2) at 10 WAS
7 = Plant height (cm) at 10 WAS

At BUK there were negative correlations between grain yield and growth characters such as leaf area, number of branches, number of leaves and plant height for groundnut crop. However, the correlation between pod yield kg/ha and number of leaves was positive. The correlation between grain yield and panicle weight of sorghum was positive and highly significant. Negative and significant correlation was observed between grain yield and growth parameters such as number of leaves and leaf area.

At Minjibir, groundnut kernel yield had positive correlation with leaf area, number of branches and number of leaves. However the correlation between kernel yield and plant height was negative and significant. Positive correlation was equally observed between haulm yield and growth parameters such as number of leaves and leaf area. The correlation between pod yield kg/ha and number of branches was positive while the response between pod yield and plant height was negative and significant. The results of correlation for sorghum crop between growth and yield parameters showed that there was negative and significant correlation between grain yield kg/ha and growth parameters such as number of leaves and leaf area. The correlation between 1000 seed weight (g) and growth parameters were observed to be positive but not significant. Stover yield equally showed positive and highly significant correlation with growth characters such as number of leaves, leaf area and plant height.

4.1.6 Land equivalent ratio

The overall results of the Land Equivalent Ratio (LER) as presented in Table 92 showed that intercropping had yield advantage over sole cropping.

Table 92. Effect of crop arrangement and companion crop on Land Equivalent Ratio (LER) of Sorghum/Groundnut intercropping

Crop Combination	Cropping System	BUK	Minjibir
ICSV 400/Samnut 21	1:1	1.1	0.6
ICSV 400/Samnut 21	1:2	1.2	0.8
ICSV 400/Samnut 21	2:4	1.1	1.3
ICSV 400/Samnut 22	1:1	1.3	1.7
ICSV 400/Samnut 22	1:2	0.8	1.0
ICSV 400/Samnut 22	2:4	1.6	1.3
ICSV 400/Samnut 23	1:1	1.0	0.9
ICSV 400/Samnut 23	1:2	1.8	1.0
ICSV 400/Samnut 23	2:4	1.5	1.1
ICSV 400/ Kampala	1:1	1.1	0.9
ICSV 400/ Kampala	1:2	1.7	1.1
ICSV 400/Kampala	2:4	1.1	0.6
Farafara/Samnut 21	1:1	1.7	1.0
Farafara /Samnut 21	1:2	1.1	1.1
Farafara /Samnut 21	2:4	1.5	1.8
Farafara /Samnut 22	1:1	1.4	1.2
Farafara /Samnut 22	1:2	1.2	1.4
Farafara /Samnut 22	2:4	0.7	1.0
Farafara /Samnut 23	1:1	1.4	1.0
Farafara /Samnut 23	1:2	2.0	1.7
Farafara /Samnut 23	2:4	1.1	1.3
Farafara /Kampala	1:1	1.8	1.0
Farafara / Kampala	1:2	1.8	1.9
Farafara / Kampala	2:4	1.3	1.3
SE±		0.07	0.13

At BUK Farafara / Samnut 23 at 1:2 crop arrangement had the highest LER, followed by ICSV400/samnut 23 at 1:2, Farafara / Kampala at 1:1 and sorghum local/groundnut local at 1:2 crop arrangements which were at parity. At Minjibir, Farafara / Kampala at 1:2 crop arrangement gave the highest LER and was closely followed by Farafara / Samnut at 1:2 crop arrangements. At both BUK and Minjibir, most of the crop combination and arrangements had LER greater than 1.00

4.2 Discussion

The overall results of the experiments showed that companion sorghum crop had effect on growth and yield paremeters of groundnut at both BUK and Minjibir because there was interaction between them. This is in line with the findings of Vandermeer, (1992) that when two crops are planted together they will interact either or both in competition (for light, water and nutrients) and facilitation. The canopy differences between sorghum and groundnut in the intercrop resulted greater improvement in radiation because the taller sorghum crop do not completely utilize the incoming radiation. Thus groundnut which is at the lower level utilized the light environment at the ground which could have wasted (Vandermeer 1989; Harris, 1990).

The results of plant height of sorghum and groundnut showed progressive increase over the 10-week period of trial indicating rapid growth potential particularly for the variety with highest plant height as recorded. The differences in plant height as observed in tested groundnut and sorghum varieties could be strongly controlled by genetic constitution of the crops. Apart from genetic influence on plant height, environmental factors during development also affected the growth of the tested crops. Genetic potentials can only be fully expressed under condusive environment. Thus combination of genetic constituents and ability of the crop to utilized the available resources could be said to be responsible for the differences in heights as recorded. Local sorghum, Farafara is taller than ICSV400 genetically and that was observed in this trial. But that ICSV400 also produced some very tall plants like farafara could be due to influence of microclimate. Shade effect on groundnut created by companion sorghum especially at 1:1 crop arrangement could have affected groundnut plant height as they struggle to get sunlight, which usually promotes vertical growth in plants. Progressive increase in the number of leaves, branches and leaf area (cm^2) were observed within the study period. In general, the progressive increase over 10-week period indicates the rapid growth potential of the tested varieties such as Samnut 21 that had the highest number of leaves, and leaf area at Minjibir and BUK. Sorghum local variety, Farafara equally had higher number of leaves, and leaf area. Both Samnut 21 and Farafara mainly expressed their genetic potentials for good vegetative growth.

The 1:1 crop arrangement had close association between the groundnut and sorghum crops hence nitrogen fixed by the groundnut plant was available for the sorghum for its effective vegetative growth. This is in agreement with Singh *et al.* (1986) who reported the possible transfer of nutrient to cereal crop in cereal/legume mixture grown in alternate row arrangements. This is also in line with the findings of Reddy *et al.* (1989) that component crops in intercrops were able to intercept more Photosynthetically Active Radiation (PAR) at closely association arrangements under cereal/legume intercrop than wider arrangement. Each row of sorghum was bordered by each row of groundnut which of course made them to benefit more from the nitrogen fixed by the neighbouring groundnut. Crop arrangement 1:1 caused sorghum to cast shadow on groundnut, resulting to low yield of groundnut per hectare. This agrees with the findings of Ajeigbe *et al.* (2010) that any varieties of plant that can cast a shadow effect on cereal crop will definitely reduce the grain yield of the cereal crop.

The 1:2 crop arrangements had a row of sorghum bordered by two rows of groundnut at both side. This reduced the amount of shadow casted on the groundnut plants by sorghum plants. However the sorghum plants benefit more from the nitrogen fixed by the neighbouring groundnut. The groundnut plants received more sunlight compared with those planted at 1:1 crop arrangement. The sorghum plants grown under 2:4 crop arrangement had enough space which existed at both side of the plant since the sorghum crop was bordered with shorter groundnut plants. This enabled enough light and carbon dioxide to reach the sorghum plants for good growth and development. The differences in yields between

ICSV400 and Farafara could be due to differences in their individual ability to adapt to the local conditions and their differences in growth habit. The sorghum that produced the heaviest panicle and higher grain yield kg/ha was ICSV400. However, Farafara produced higher 1000 seed weight when compared to ICSV400. This could be explained by the fact that morphologically, the seed sizes of local sorghum (Farafara) are bigger than that of improved sorghum, ICSV400. The differences in 1000 grain weight among tested sorghum varieties were probably due to differences in their individual ability to exploit resources especially water and nutrients (Falconer, 1989). Further more, differences in their performance could also be due to their differences in genetic make up (Anion, 1972). Farafara have taller plants, higher number of leaves and leaf area compared to ICSV400 which support higher light interception and dry matter production. However, only small quantity of the assimilate were probably partitioned to the reproductive parts resulting to low grain yield when compared to ICSV400. Similar results were observed at Minjibir where Farafara had better vegetative growth but less grain yield kg/ha when compared to ICSV400. The high grain yield produced by ICSV400 is probably an expression of its genetic yield potentials.

The results of sorghum grain yields at both BUK and Minjibir showed that ICSV400 in combination with Samnut 22 at 1:1 crop arrangement produced higher grains than Farafara. This could be due to the compatibility of ICSV400 and Samnut 22 in addition to their adaptability to the local environmental conditions. Farafara was observed to have higher 1000 seed weight than ICSV400. This could be explained by the fact that mosphologically, the seed sizes of local sorghum are bigger and heavier than the seed of ICSV400. The high yield of sorghum under intercrop could probably due to the fact that legume fix atmospheric nitrogen which was utilised by host plant or was excreted from the nodules into the soil and was utilised by sorghum. This is in line with the findings of Andrew 1979; Shen and Chu, 2004 that legume can transfer fixed N to intercropped cereals during their joint growing periods.

The high pod weight recorded for Samnut 22 at Minjibir could be partly due to high Mg and P content of the soil. Samnut 22 variety grown in combination with ICSV400 at 1:2 crop arrangement produced the highest kernel yield. This indicated high yielding attribute of Samnut 22 and its compatibility with ICSV400 under 1:2 crop arangement. The BUK environmental condition favoured Samnut 22 grown in combination with Farafara at 2:4 crop arrangement. Although Samnut 21 had higher pod yield per hectare than Samnut 22, the shelling percentage of Samnut 21 was lesser than that of Samnut 22. Hence Samnut 22 had higher grain yield over Samnut 21. This could be explained that more assimilate were probably partitioned at the shell than the grain in the case of Samnut 21 while reverse took place in the case of Samnut 22. The poor performance of some varieties of groundnut and sorghum in this trial as reflected by growth and yield parameters at both BUK and Minjibir could be due to defective planting system and use of low yielding varieties which greatly reduced the efficacy of the system and cause considerable reduction in output. Singh and Ajeigbe, (2010) also gave similar report. The tested groundnut and sorghum varieties showed different responses to cropping systems and environmental adaptation. This could be used to identify suitable varieties for intercropping. This equally agrees with the findings of Smith, (2002).

Higher stover was recorded by local sorghum (Farafara) while Samnut 21 produced the highest haulm yield at both BUK and Minjibir. The differences in shoot dry matter observed among the varieties could largely be due to varying genetic potentials to attain different sizes under the same environmental condition. It could also be as a result of the differences in population of sorghum or groundnut plants created by crop arrangement. When plants are in higher population density there is reduced dry matter per plant but it is more than compensated for by the additional plants, resulting in higher stover compared to plants in lower population. For example, crop arrangement 1:1 has more sorghum plants than 1:2 and 2:4 cropping systems. This probably could be the reason while 1:1 crop arrangement had the highest stalk yield at both BUK and Minjibir. Furthermore, crop arrangement 1:1 provides more cover to the soil than 1:2 and 2:4 crop arrangement thereby reducing temperature and moisture loss through evaporation. The higher conserved moisture content of the soil created by the micro-climate could have caused sufficient nutrient uptake which encouraged vegetative growth, bigger plants and significantly higher weights of stalks. Farafara produced taller and bigger plants than ICSV400 thereby providing more shade on the under-growing groundnut plants grown in their combination. This could be the reason for low haulm yields in 1:1 Crop arrangement which have Farafara as companion crop. Groundnut planted with ICSV400 had less shade effect and received more sunlight which led to good vegetative growth in the presence of moisture, especially in 2:4 crop arrangement. This probably is the reason for the high haulm yields recorded.

The overall results of this trial showed that intercroppig has yield advantage over monocropping at both BUK and minjibir. This is because greater yields were produced by intercropping on a given piece of land by making use of resources that would otherwise not be utilized by a single crop, sorghum or groundnut. This is in ageement with the report of Willey, (1979). The results of this trial also showed that intercropping has higher and more stable yields in wide range of crop combination.

The significant positive correlation between some yield and growth parameters of tested crops (groundnut and sorghum) could be attributed to direct and indirect effects of growth components in determining yield. This is in line with the findings of Vissoh, *et al,* (2004) that yield of groundnut was directly enhanced by growth components.

The LER result showed that it would therefore be beneficial to farmers in BUK environment that have small area of land available for farming to grow Farafara / Samnut 23 at 1:2, ICSV400/samnut 23 at 1:2, sorghum local/groundnut local at 1:1, and sorghum local/groundnut local at 1:2 crop arrangements for better utilization of space and tim**e**. Likewise farmers at Minjibir environment with small available land for farming could also plant Farafara / Kampala at 1:2, ICSV400/ Samnut 22 at 1:1 and Farafara / Samnut 23 at 1:2 crop arrangement.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMENDATION

5.1 Summary:

Two field experiments were carried out at research farms of the Faculty of Agriculture, Bayero University, Kano and Agricultural Research Station (ARS) of the institute for Agricultural Research (IAR), Minjibir to determine the performance of groundnut and sorghum varieties in intercrops.

The treatment consisted two sorghum varieties (ICSV400 and Farafara) and four groundnut varieties which include Samnut 21, Samnut 22, Samnut 23 and Kampala. The sorghum and groundnut varieties were intercropped at 1:1, 1:2 and 2:4 crop arrangements and were replicated three times in a split plot design. The result of the treatments were subjected to analysis of variance as described by Snedecor and Cochran, (1967). Significantly different means were compared using Duncan Multiple Range Test (DMRT).

The results of the study revealed that grain yield per hectare of ICSV400 was higher than that of Farafara at both BUK and Minjibir. At both location, higher grain yield was produced from sorghum planted at 1:1 crop arrangement with Samnut 22. For the groundnut varieties, Samnut 22 grown with Farafara at 2:4 crop arrangements gave the highest kernel yield but was not significantly different from Samnut 22, Samnut 23 and kampala at BUK. Likewise, Samnut 22 grown with ICSV400 at 1:2 produced significantly the highest kernel yield at Minjibir. Samnut 21 grown with Farafara at 1:2 crop arrangements had the highest haulm yield at Minjibir while samnut 21 grown with Farafara at 1:1 crop arrangement had the highest haulm yield at BUK. Likewise, Farafara grown with Samnut 21 at 1:1 crop arrangement, gave higher stover yield at BUK while Farafara planted with Samnut 22 at 1:1 cropping system gave higher yield at Minjibir.

The results of the correlation analysis between growth and yield parameters of sorghum and groundnut showed positive at both locations. At both BUK and Minjibir, most of the crop combinations and arrangement had LER greater than 1.00 which is an indication that intercropping had yield advantage over sole cropping.

5.2 Conclusion:

Conclusively, shading had more effect on Kampala, Samnut 21 and Samnut 23 which produced the least kernel yield than Samnut 22 that gave the highest kernel yield at Minjibir. Similarly, shading had less effect on Samnut 23 that produced the highest kernel yield at BUK than had on 21, Samnut 22 and Kampala that gave lesser yields though there was no significant difference among all the varieties. Farafara gave higher sorghum grain yields than ICSV400 at both BUK and Minjibir, an expression of its genetic yielding potentials.

5.3 Recommendations:

1. For groundnut kernel production at BUK, farmers could be advice to plant Samnut 22/Farafara at 2:4 crop arrangements while for haulm yield, Samnut 21/Farafara at 2:4 is suggested. Farafara/Samnut 21 at 1:1 crop arrangement is suggested for stover yield while ICSV400/Samnut 22 at 1:1 cropping system is suggested for sorghum grain yield.

2. It could be suggested to farmers at Minjibir to grow Samnut 22/ICSV400 at 1:2 crop arrangements for groundnut kernel yield, while Samnut 21/Farafara at 1:2 cropping system could be used for haulm yield. Likewise, ICSV400/Samnut 22 at 1:1 crop

arrangement is suggested to farmers for sorghum grain yield while Farafara/Samnut 22 at 1:1 is crop arrangement suggested for stover yield.

3. For land equivalent ratio, Farafara/Samnut 23 at 1:2 crop arrangement is suggested for farmers at BUK while farmers at Minjibir could be adviced to plant Farafara/Samnut 21 at 2:4 crop arrangement.

4. Further research should be undertaken in order to evaluate many groundnut varieties for shade tolerance.

REFERENCES

Abdel-Rahman, M.S., (1982). The Presence of Trihalomethanes in Soft Driks. *J. Applied of Toxicol.,***2**:165-166

Aggarwal, P.K., Garrity, S.P., Liboon, S.P. & Morris, R.A. (1992). Resource use and plant interactions in

Ajeigbe H.A., Singh, B.B., Ezeaku, I.E. and Adeosun,, J.O. (2010) on-farm evaluation of improved cowpea-cereals cropping systems for crop-livestock farmers. Cereal-cowpea system in Sudan Savanna zone of Nigeria.*African journal of Agric/ Research.***5** (17) pp. 2297-2304.

Alemseged, Y.B., G.W. King, V.L. Coppock, and J.C. Tothil,(1991). Maize- legume intercropping in semi- arid area of Sidamo Region, Ethiopia. 1. Maize response. *East African Agricultural and Forestry Journal***8** (1)77- 84.

Alemseged. Y.B., King G.W, Coppock L.R. and Tothill. J.C. (1996b). A Preliminary Investigation of the Potential for Maize-Legume Intercropping in the Semi-Arid Area of Sidamo Region, Ethiopia I. Maize response. *S. Afr. J. Plant Soil* **13:**120-124.

Alemseged. Y.B., King G.W. Coppock L.R and Tothill J.C. (1996b). APreliminary.

Andrew D. J (1974). Responses of Sorghum Varieties to Intercropping *Experimental Agriculture* **10** (01):57 - 63.

Andrew, R.W. (1979) Intercropping. Its importance and research need 1. Competition and yield advantages. *Field crops Abstract*. **32:**1-10, 11. Agron.Res. Approaches. *Field crops Abstracts.* Pp. 73-85.

Anion, I. (1972). Crop production in dry region leanerd hill books, 158 buckingham palace road, London.

Ayoade, J.O. (2002) introduction to Agricultural climatology *Ibadan Vintage pub.*215pp.

Baldy. C. and Stigter, C.J. (1997). Agrometeorology of Multiple Cropping in Warm Climates. INRA. Paris.

Banik, P.,P. Sasmal, K. Ghosal and D.K. Bagchi, (2000), Evaluation of mustard (*Brassica compestris* var. Toris) and legume intercropping under 1:1 and 2:1 row-replacement series system. *J. Agro. Crop Sci.***185** (1):9−14.

Black, C.A. (1965). Methods of soil Analysis II. Chemical and Microbiological properties. Madison Wisconsin America Soceity of Agronomy. PP. 341-350

Chakma, R., M.A. Aziz, A.K.M.M. Rahman, M.F. Khatun and M. Sultana, (2011). Intercropping popcorn with bushbean and pea at different planting systems in hill valley areas. *J. Expt. Biosci.***2** (2):35−38.

Chemeda, F. (1996). Effect of bean and maize intercropping on bean common bacteria blight and rust diseases. *Int. J. Pest Manag.***42** (1):51−54.

Chemeda,F. (1997). Effects of planting pattern, relative planting date and intra-row spacing on a haricot bean/maize intercrop. *Afr. Crop Sci. J.***5** (1):15−22

Craufard, P.Q.,(2000), Effect of plant density on the yield of sorghum-cowpea and pearl millet-cowpea intercrops in northern Nigeria. *Exp. Agric.* **36** (3):379−395.

Dahmardeh, M. A. Ghanbari, B. Syasar and M. Ramroudi (2009), Effect of intercropping maize with cowpea on green forage yields and quality evaluation. *Asian J. Plant Sci.***8**(3): 235−239.

Dahmardeh,M., A. Ghanbari, B.A. Syahsar and M. Ramrodi, (2010), The role of intercropping maize (*Zea mays* L.) and Cowpea (*Vigna unguiculata* L.) on yield and soil chemical properties. *African J. Agric. Res.***5** (8):631−636.

Dhima, D.K. Lithourgidis A.A, I.B. Vasilakoqlou and C.A. Dordas, (2007). Competition indices of common vetch and cereals intercropping in two seeding ratio. *Field Crops Res.***100** (1−3):249−258.

Duncan, D. B. (1955). Multiple Range and Multiple F test Biometrics **11:**1-42

Exner D.N. and R.M. Cruse, (1993). Interseeded forage legume potential as winter ground cover, nitrogen source, and competitor. *J. Prod. Agric.***6**(2):226−231.

FAO (Food and Agriculture Organization) of the United Nations. FAOSTAT data, (2002-2013) www.fao.org

FAO, (2011). The state of the world's land and water research for food and agriculture. Managing systems at risk.Food and Agriculture organisation of the United Nationals, Rome.

FAO. 2006. FAO Production Year book. **Vol. 60.** Rome. Italy.

Fisher. N.M. (1977b). Studies in Mixed Cropping. II. Population Pressures in Maize Bean Mixtures. *Exp. Agric.***13:**185-191

Folcaner, D.S. (1989). Introduction to quantitative genetics, 3rd edition. Longman scientific and technical essex England.

Fukai. S. and B.K. Trenbath. (1993). Processes determining intercrop productivity and yields of component crops. *Field Crops Research.* **34**(3-4): 247-271.

Giller,G.E. and G. Cadisch, (1995). Future benefits from biological nitrogen fixation: An ecological approach to agriculture. *Plant Soil***174** (1−2):255−277.

Harris P.M. (1990). Potato crop radiation use: a justification for intercropping. *Field crops research***25:**25-39.

Harris. D.M. Natarajan and R.W. Willey (1987). Physiological basis for yield advantage in a sorghum/groundnut intercrop to drought. i. dry-matter production. Yield and light interception. *Field Crop Research* **(17),** 3-4: 273-288.

Hauggaard-Nieson, H.,P. Ambus and E. S. Jensen, (2001). Temporal and spatial distribution of roots and competition for nitrogen in pea-barley intercrops. A field studies employing 23P techniques. *Plant Soil* **236:**63−74

Ilu, I.Y. and Damisa, M.A. (2002). Commodity Chain Analysis of Groundnut: Case Study of KRIP Area, Kano State. Department Published by: Agricultural Development in Nigeria (ADENI) ABU, Zaria. Nigeria pp. 24.

Jeranyama, P.,O.B. Hesterman, S.R. Waddington and R.R. Harwood, (2000), Relay-Intercropping of Sunnhemp and Cowpeas into a smallholder maize system in Zimbabwe. *Agron. J.* **92:**239−244.

John, C.M. Seshadri, C.R. and Bhavani Shavani, Rao, M. (1943). Mixed Cropping of Groundnut. *Madras Agricultural Journal* **31:** 191-200.

Jones, M.J. and Wild, A. (1975) soil of the West African Savanna.Commonwealth of soil. Tech. Committee No. 55 Harpenden, England: CBS.

Kassam, A. H. (1972). Effect of plant p…… and interspecific competition on yield of sorghum and groundnut under mixed cropping institute for agricultural research reports. 1969-72. Sameru Nigeria.

Keating, B.A. and P.S. carberry (1993). Research capture and use in intercropping; solar radiation. *Field crops Research* **34** (3-4). 273-301.

Ker. A. (1995). System of the African Savana Published by International Development Reseach Centre, Canada.

Kowal. J.M. and Kassam, A.H. (1978). Agricultural Ecology of Savana. Oxford: *Clarendon Press* pp. 403.

Langot M.C., Okiror M.A., Ouma J.P, Gesimba R.M. (2006). The effect of intercropping Groundnut *(Arachis Hypogaea .L.)* with sorghum *(Sorghum bicolour* L. Moench) on Yield and cash income. *Agricultural Tropical et subtropical* Vol. **39** (2).

Li, L.,J.H. Sun, F.S. Zhang, X.L. Li, S.C. Yang and Z. Rengel, (2006), Wheat/maize or wheat/soybean strip intercropping I. Yield advantage and interspecific interactions on nutrients. *Field Crop Res.***71:**123−137.

Lingegounda. B.K. Shantaveerabadara'ah, S. Amdar, S.S., Prithuiraji, and Brishmuthy K. (1972). Studies on mixed Copping of groundnut Hybrid and Hybrid Sorghum. *India Journal of Agronomy* **17** (1):1-10.

Lithourgidis, A.S. I.B. Vasilakoglou, K.V. Dhima, C.A. Dordas and M.D. Yiakoulaki, (2006), Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. *Field Crop Res.***99:** 106−113.

Malithano, A.D. and J.V. Leeuwen. (1980). Groundnut- maize intercropping in Southern Mozambique. pp 75- 76. In: C.L.Keswani and B.J.Ndungura (eds.) Intercropping: Proceedings of the Second Symposium on Intercropping in Semi- Arid Areas, 4-7August 1980, Morogoro, Tanzania.

Marshal B. and R.W. Willy, (1983), Radiation interception and growth in an intercrop of Pearl millet/groundnut. *Field crops Res.,***7:**141−160.

Mathews. R.B.S.N Azam-Ali, R.A. Saffell, J.M. Peacock, J.H. Williams. (1991). Plant growth and development in relation to the microclimate of a sorghum/groundnut intercrop. Agricultural and Forest Meteorology. **53** (4):285-301.

Morris. R.A. and D.P. Grarrity, (1993). Resource capture and utilization in intercropping water. *Field Crops Research.***34** (3-4): 303-317.

Mukhalae, (1998) Radiation and Water Utilization Efficiency by Mono-Culture and Inter-Crop to Suit Small-Scale Irrigation Farming. Ph.D. Thesis. Univ. of the Orange Free State. Bloemfontein.

Natarajan M. And R.W. Willey (1986). The effects of water stress on yield advantages of intercropping systems. *Field Crops Research* **13**:117-131.

Nwokolo, E. (1996). Peanut *(Arachis Hypogaea L.).* In food and feed from legumes and oilseeds. Chapman and Hall, New York, pp. 49-63.

Odion, E.C., Yusuf, Y. and Labe, D.A. (1990), Performance of Millet and cowpea in Mixed stands in the Sudan Savanna of Nigeria. *Samara journal of Agricultural Research.* 2000. **16:**53-62.

Ofori F. and Stem. W.R. (1987). Cereal-Legume Intercropping System. *Adv. Agron* **41:**41-90

Ofori F. and W.R. Stern, (1987), Cereal and legume intercropping systems. *Advances in Agron.* **41:**41−90.

Ofuso-Amin, J. and N.V. Limbani, (2007). Effect of intercropping on the growth and yield of cucumber and okra. *Int. J. Agric. Biol.***9**(4):594−597.

Ogbanna (2011). Current developments in malting and brewing trials with sorghum in Nigeria: a review.

Okigbo, B.N. and Greenland, D.J (1976). Intercropping Systems in Tropical Africa pages 66-100 in Multiple Cropping. American Society of Agronomy Special Publication No. 27, Madison, Wisconsin USA.

Okiror . Ipomal, S.O. and Subrahmanyan P. (1997). Overcoming Constraints to increased Groundnut Production in Kenya. Result of a Survey on Groundnut Production Constraints in Western Kenya. 28p.

Olabanji. O.G. Elemo. K.A. Ogunlela V.B and Thao. R. (1997). Mixture as Influenced by Component Preparation of Cowpea Variety and Sowing Date. *Samara Journal of Agricultural Research* (2002). **18:**3-11.

Olufajo. O.O. (1990). Sorghum Soyabean Intercropping as Affected by Cultivar and Plant Arrangement in a Sub-Humid Tropical Environment. *Savana Journal of Agricultural Research* (1995). **12**:3-11

Pilbeam. C.J. Okelebo, J.R, Simmonds L.P. and Gathua, K.W. (1994). Analysis of Maize-Common Bean Intercrops in Semi-Arid Kenya. *J. Agric. Sci. Camb.* **123:**177-184.

Quayyum, M.A.,A. Ahmed and A.K. Chowdhury, (1999), Crop weed competition in maize + black gram in sole and intercropping system.*Bangladesh J. Agril. Res.* **24** (2): 249−254.

Rahman,A., K.P.Singh,Y.P. Singh, A. Rafey, A.K. Bhagat and R.K.Singh. (1982). Effect of intercropping pulses, oilseeds and tuber crops in maize on yield and net returns. Indian Journal of Agronomy **27** (1): 1- 6.

Rao, M.R. and Willey, R.W, (1980). Evaluation of yield stability in intercropping studies on sorghum/pigeon pea. *Experimental Agriculture* **16:**105-116.

Reddy, G.B., Rami Reddy, S. And Sankara Reddi, G.H. (1980). Frequency and depth of irrigation for groundnut, *Agric. Water manage,***3:**45-72.

Reddy, S.N. Redy, E.V.R, Reddy, V.M. Reddy.M.S. and reddy, P.V. (1989).Row arrangement in groundnut/pigeon pea intercropping.*Tropical agriculture,***66:**309-312.

Rosenberg. N.J. Bland. B.L. and Verma, S.B. (1983). Microclimate: the Biological Environment (2nd Edn.) John Wiley and Sons. New York.

Ruthenberg. H. (1980). Farming System in the tropics 3rd edn. Oxford Clarendon Press, England, United Kingdom.

Shen Q.R. and G.X. Chu, (2004), Bi-directional nitrogen transfer in an intercropping system of peanut with rice cultivated in aerobic soil. *Biol. Fertil. Soils.***40** (2):81−87.

Siddiq A., Mohammed Ali, Adam A., Mohammed, Ali H., Bashir, Abdulmohsin R. Khairelseed. Effects of sorghum and groundnut intercropping on some soil chemical properties and crop yield under rain-fed conditions. *ARRN Jonsnal of Science and Technology.*ISSN 2225 7217, **Vol 3.** No. 1, January 2013.

Singh, B.B. and H.A Ajeigbe, (2002).Improving cowpea-cereal-based cropping system in the Dry Savannas of West Africa. In challenges and opportunities for enhancing sustainable cowpea production Eds., Fatokun, C.A., S.A. Tarawali, B.B. Singh, P.M. Komawa and M. Tamo. International Institute of Tropical Agriculture (UTA) Ibadan, Nigeria, pp. 278-286.

Singh, L. (1986). Soil Fertility and yield in savannna zones of Nigeria. Proceedings of the international drought symposium held in Kenyatta conference centre, Nairobi, Kenya. 19-23rd May, pp. 19-23.

Smith, A.F. (2002). Peanuts: The illustrious History of the Goober pea. *Chicago University of Illinois Press,* Illinois.

Smith, A.F., (2003). Peanuts: the illustrious History of the Goober pea. *Chicago University of Illinois Press,* Illinois.

Snedecor, G.W. and Cochran, W.G. (1967).Statistical Methods.*The Lowa State University Press* Ames Lowa U.S.A, P. 507.

Sterner, K. G. (1982). Intercropping in irepical smallholder agriculture with special references to West Africa. Pp. 303.

Stigter. C.J. and Weiss, A (1986). In quest of tropical Micrometeorology for on-farm Weather Advisories. *Agric. For. Meteorol.***36:**289-296.

Sullivan, P. (2003). Intercropping principles and production practices. ATTRA Publication Companion Planting in http://www.attra.org/attra-pub/PDF/Intercrops.pdf

Takim, F. O. (2012), Advantages of Maize-Cowpea intercropping over sole cropping through competition indices. *J. Agric. Biod. Res.,***1**(4): 53−59.

Taru. V.B., Kyagya. I.Z., Mshelia, S.I. and Adebayo, E.F. (2008). Economic efficiency of Resource use in Groundnut Production in Adamawa State of Nigeria. *World Journal of Agricultural Science.***4:**896-900

Tefera, T. and T. Tana (2002). Agronomic Performance of sorghum and Groundnut cultivars in sole and intercrop cultivation under semiarid conditions *journal of Agronomy and crop science.* 188(3):212-218.

Tsubo M.,and S. Walker, H.O. Ogindo, (2005), A simulation model of cereal-legume intercropping systems for semi-arid regions: l. Model development. *Field Crops Res.* **93**(1):10−22.

USAID markets (2009-2013). Investing in Nigeria Agriculture-sorghum Mil increases food security.

Van Rheenen, H.A.,D.E. Hasselbach and S.G.S. Muigai, (1981).The effect of growing beans together with maize on incidence of bean diseases and pests.*Euro. J. Plant Path.***87** (5):193−199.

Vandermeer, J.H. (1989). The ecology of intercropping *Cambridge Univ. Press.* Cambridge, UK.

Vanderneer. J.H., (1992). The Ecology of intercropping, Cambridge university press.

Wilken. G.C. (1972). Microclimate Management by Traditional Farmers. Geogr. Rev. **62:**544-560.

Willey R.W. (1985). Evaluation and Presentation of Intercropping Advantages. *Exp. Agric.* **21:**119-133.

Willey R.W. (1990). Resource Use in Intercropping Systems. *Agric. Water Management.* **17:215-231.** Research article.

Willey. R.W. (1981). A Science Approach to intercropping research. Pages 4-10.

Willy R.W. (1976). Intercropping: its importance and research needs. i. competition and yield advantage *field crop abstr.* **32**:1-10.

Appendix I

Table 1.Meterological data covering the Experimental Period at Kano, 2012

Month	Rainfall (mm)	Temperature (^0C)		Relative Humidity (%)	
	Min	Min	Max	Min	Max
May	21.1	21	43	21	86
June	229.3	20	37	44	80
July	231.0	20	34	41	86
August	384.2	20	34	54	95
September	73.2	20	37	45	91
October	1.0	19	38	23	8

Source: Agricultural Research station (ARS). Meteorological services. Minjibir.