IMPACT OF SPATIAL ARRANGEMENT ON GROWTH, YIELD AND PROFITABILITY OF MAIZE – GROUNDNUT INTERCROPPING SYSTEM

BY

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Declaration

I hereby declare that this thesis is the result of my original work and that no part of it has been presented for another degree in this University or elsewhere:

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We hereby declare that the preparation and presentation of this thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies.

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Abstract

In 2017, two separate experiments were carried out at Vani in East Gonja District and Zoggu in Savelugu Municipal in Northern Region of Ghana to evaluate the impact of row spatial arrangement on growth and economic profitability of maize-groundnut intercropping system. The purpose of the study was to determine the growth and yield of maize and groundnut in intercropping system. It was also to determine the economic and cost benefit analysis of the maize-groundnut intercropping system. There were six treatments comprising1:1, 1:2 row, 2:1, 2:2 row arrangement respectively for maize and groundnut. Sole maize and sole groundnut were used as control to the intercrops. The experiment was organized in randomized complete block design in three replications per each location. There were significant effects of spatial arrangement on plant height of maize, maize yield and kernel yield of groundnut at Vani. However, there were no significant difference among cob length, cob weight, and pod diameter and pod length of groundnut at Vani. At Zoggu, both maize yield and kernel yield of groundnut were significantly affected by the intercropping. 1:1 row arrangement had the highest land equivalent ratio at both locations. The estimated net profit and monetary advantages index of the various spatial arrangements produced a definite gain for some of the spatial arrangements at both locations. Benefit cost ratio were consistently greater than 1 in both locations except 2:1 row arrangement at Zoggu. It can be concluded that having equal rows of maize and groundnut following each other is the best intercropping system for maize and groundnut. Therefore, based on the findings reported, it can be recommended to use 1:1 row and 2: 2 row arrangement for maize -groundnut intercropping in areas where land has become scarce for monoculture.

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To all the people who contributed to this work physically, emotionally and academically, my friends who stood by me throughout the journey may Almighty Allah bless you all.

Dedication

To my entire family and friends.

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List of Abbreviations

BCR: …………………………………………………………………...benefit cost ratio

M……………………………………………………………………………. Meter

cm: ……………………………………………………………………Centimeter (s)

Mm: …………………………………………………………………………..millimeter

Kg: ………………………………………………………………………….Kilogram

Ha: ……………………………………………………………………………hectare

g: ……………………………………………………………………………..grams

et al.:…………………………………………………………………et alli (and others)

m^2: ……………………………………………………………………Meter square

Fig: ………………………………………………………………………………..Figure

N: …………………………………………………………………………Nitrogen

P: …………………………………………………………………………Phosphorus

K: ………………………………………………………………………..Potassium

LSD: …………………………………………………………Least Significant difference

CV: ……………………………………………………………Coefficient of Variation

LER:…………………………………………………………………Land equivalent ratio

GMR: ……………………………………………………………Gross monetary Returns

LEC:…………………………………………………………Land equivalent coefficient

NP: ……………………………………………………………………………….Net profit

P: ……………………………………………………………………………Probability value

RoM:…………………………………………………………………………Row (s) of maize

RoG:……………………………………………………………………… Row(s) of groundnut

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Intercropping, the concurrent planting of two or more crops on one field is based on basic ecological principles such as diversity and level of competition among the component crops (Hauggaard-Nielsen *et al.*, 2006).

It is a system of crop production by which more than one crop are grown on the parcel of land to derive food, fiber, monetary income etc. for human benefits (Mir *et al.*, 2016). Planting plants such as cereals and legumes is crucial for the development and growth of sustainable food production and food safety systems among livelihood farmers with restricted inputs and production land (Eskandari, 2011). This is due to extra yield advantage that are achieved from the complementary relationship among the crops in the system. Importance of intercropping includes more effective use of accessible resources, leading to higher productivity compared to sole cultivation (September, 2015). It is also recognized that intercropping increases grain yields and stability, reduces weed stress and maintains plant health or reduces the incidence of pests and illnesses. (Phule and Vidyapeeth, 2014).

Maize is a major food crop recognized as a staple in many developing countries especially in sub-Saharan Africa (Marinangeli and House, 2017). By way of classification, maize is noted as member of the family *Poaceae,* which is mainly a family of grasses (du Plessis, 2003). It is thought to have originated in South America from Mexico and was later brought by Portuguese and Arab explorers in West and East Africa to Africa in the 1500s (Matsuoka *et al.*, 2002) Maize is discovered worldwide and its domestication started at least 6000 years ago, making it one of the world's most adaptable staple food plants (Piperno and Flannery, 2001).

Different maize varieties can be hybrid or openly pollinated (Setimela and Kosina, 2006).

Groundnut has been reported to have first cultivated in South America and later spread to other parts of America such as Brazil, Southern Bolivia and North-Western Argentina. Groundnut was introduced by the Portuguese from Brazil to West Africa and then to South-Western India in the 16th century (Talawar, 2004).

Groundnut is one of the most essential source of cash crops smallholder farmers in Ghana grow. It is ranked as thirteenth most essential cash crop and the fourth most essential source of oil to the world (Ani *et al.*, 2013). Nutritionally, the kernel consists of 48 % -50 % of edible oil and 26 %-28 % of protein. It is noted as major source of dietary vitamins, minerals, and fiber. Worldwide, it is produced in over 66 million acres with a grand production of 37.1 million metric tons and a productivity of 1.4 Mt/ha on average. Groundnut is produced in over 100 nations across the globe. Groundnut producing country normally consist of developing nations. This developing countries constitute 97 % of the groundnut production area across the globe and about 94 % of the world production of this crop (Talawar, 2004). About 56 % of the world groundnut is grown in Asia whiles about 40 % is grown in Africa (Talawar, 2004). Ani *et al.*(2013) stated that, the main producers of groundnut around the globe are China (40.1 %), India (16.4 %), Nigeria (8.2 %), the USA (5.9 %) and Indonesia (4.1 %)(Ani *et al.*, 2013). In Ghana, groundnut are normally grown by smallholder farmers on small scale (Banterng *et al.*, 2006). Groundnut is usually cultivated in mixtures with other food crops or in pure stands from home compounds to large fields (Konlan *et al.*, 2014).

West African Guinea savanna is defined by bad and decreasing soil fertility owing to ongoing mono-cropping systems based on cereals without sufficient replenishment of soil nutrients. (Kermah *et al.*, 2017). In Ghana, the primary crop systems in the agro-ecological area of Northern Guinea Savannah are still based on traditional mixed crop production (Dwomo and Quainoo, 2012).

1.2 Problem statement

Maize and Groundnut are two most economical and widely cultivated cereal and legume respectively in Northern Region. Competition between crops for limited land holdings by farmers in the Northern Ghana who need to produce them to feed the family and get from cash crops has become a bigger challenge to the farmers (Konlan *et al*., 2013). Again, the population of the world is increasing all time. Food production should be preserved in an environmentally friendly manner without deteriorating vegetation and the environment. The prevalence of diseases and pest in sole cropping systems that leads to complete loss of crop hence increasing food insecurity has put more emphasis on intercropping. Monoculture, in the event of crop failure either biotic or abiotic factors can lead to either part or complete production failure (Ramert *et al.*, 2002). Much research and findings has not gone into the yield, socio-economic and environmental impact of intercropping to the farmer and the environment as large. There is therefore the need to clearly study understand the most sustainable patterns of intercropping in other to reduce competition among or in between component crops. Furthermore, recommendation is needed both economically and mechanically to farmers as a convincing reason to adopt this sustainable cropping system instead of monoculture. World agriculture is particularly dependent on chemical insecticides, chemical fertilizers, hybrid seeds and various equipment in latest times. This modernization of agriculture that put monoculture as fore front for ensuring food security to the neglect of sustainability, soil heath, diseases and pest is partially due to lack of precise economic benefits that can be associated with intercropping. Agricultural sustainability can be accomplished by ensuring minimum degradation of the environment

(Sarwar, 2012) through various conservation methods including intercropping of cereals and legumes.

1.3 Justification

According to (Kheroar *et al.*, 2013), the idea of intercropping is to boost productivity per unit area of soil and time despite the judicious use of growing resources. Intercropping has proven to have higher yield and economic advantage as compared to component crops grown in sole cropping system (Mir *et al.*, 2016). This benefit is due to the supplementary use of the growth resource at various phases of the crop life cycle (Mir *et al.*, 2016). Yields are more stable intercrop compare to the component crops grown in monoculture (Carlson, 2008). Intercropping provides soil cover for the whole year or longer than monoculture farming. This cover protects the soil against drying and erosion (Gebru, 2015). By growing more than one crop, farmers use efficiency to boost nutrients and water while minimizing soil erosion (Gebru, 2015). Intercropping maize with legumes such as groundnut is well recognized for controlling soil erosion**.** Historically, the fact that intercropping is able to maintained its importance since time in memorial justifies the importance of the cropping system to the socio-economic life of the farmers(Anders *et al.*, 1996). Intercrop can smother weeds in the farm hence reducing weeds growth. Chemical control might be difficult immediately the component crops are established hence component crops aid in weeds management (Sekamatte *et al.*, 2003). Either in a form of biological control or otherwise, intercropping is able to control pest in the field better than monoculture (Malézieux *et al.*, 2009).

1.4 Objectives

1. To compare the growth and yield of maize and groundnut in intercropping system.
2. To determine and compare economic and cost benefit analysis of maize-groundnut intercropping system

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

The commonest cropping systems in Ghana include mono-cropping, crop rotation; relay cropping, mixed cropping and inter-cropping. Among these crop systems, the intercropping system is dominant among smallholder farmers in West Africa's semi-arid tropics (Fussell and Serafini, 1985). According to Ntare (1990), subsistence farmers with low inputs are particularly dependent on intercropping. Steiner (1982) estimated that intercrops cover over 75 % of the cultivated area in the West African tropics. According to Preston (2003) intercropping systems are characterized by the following: Each of the many possible intercropping patterns is appropriate for a particular range of conditions and inappropriate for others. Usually, each intercropping pattern is selected to relieve a specific resource restriction. Intercropping is generally associated with small land holdings.

In an intercrop scheme, row settings (arrangements) change the quantity of light transmission to lower crop layers and influence species competition for light, water and nutrients. There are four kinds of intercropping row configurations: mixed intercropping, which cultivates component plants concurrently in full mixtures; row intercropping, which cultivates component plants concurrently in distinct rows; strip intercropping, which cultivates component plants simultaneously in distinct sections; and relay intercropping, which cultivates component plants in relays so that development cycles overlap.

All farmers use one way or other a particular crop production system that would enhance their benefits in terms of increasing their yield and income per acre as well as making their method of production more sustainable and more economical (Legwaila *et al.*, 2012). So far, various cropping systems has been adopted and practice or used commonly among farmers across the globe including tropical Africa as a way of creating a self -sustainable cropping production system (Legwaila *et al.*,2012). Growing of a number of crops of different species (example maize/groundnut) on the same piece of land within a period of time is a predominant farming practice among farmers in tropical Africa (Takim, 2012). This farming system is believed to have been one of the oldest farming system ever practice in the tropics (Reddy *et al.*, 1976).

Intercropping, a more prevalent practice of growing two or more plants mainly belonging to distinct families or species, is thought to provide extra advantages in terms of soil modification or maintenance, yield per unit area, among other advantages as a result of greater soil nutrient exploitation and usage, and labour (Kermah *et al.*, 2017). Output of intercrops can be high than the counterpart monoculture crop in some cases as virtue of effective and more efficient use of nutrients and water (Lithourgidis *et al.*, 2006). Growing cereals such as corn along with other leguminous crops such as groundnuts plays a critical role in ensuring food production and safety in developing countries (Dahmardeh *et al.*, 2010).

A continuous decrease in crop output of smallholder farmers in Ghana in recent times coupled with exponential growth in our population and decreasing number of farm lands in Ghana calls for urgent need to develop more self-sustainable cropping systems (Kermah *et al.*, 2017).

2.2 Maize

2.2.1 Maize history and origin

Teosinte (*Zea mexicana*) is usually thought to be an ancestor of worldwide maize, although views differ as to whether maize is a domesticated variant of teosinte (Galinat, 1988). *Zea* is a Graminae family (*Poaceae*) genus, frequently known as the family of grasses. Since time in memorial, maize (*Zea mays,* L.) remains a major staple in the lives of many Africans more specifically Sub-Sahara Africa (SSA) and other developing nations in Asia (Marinangeli and House, 2017). By way of binomial classification, maize belongs to the family *poaceae* mainly compose of grasses (du Plessis, 2003). Originally, the crop is noted to have first domesticated in the South Americans particularly Mexico in about 7000 to 10000 years ago (Pruitt, 2016). Later in around 1500s the crop was introduced to Africa by explorers from the land of Arabia (Matsuoka *et al.*, 2002). It is a prevalent crop cultivated worldwide in all nations and agro-ecological areas and is therefore considered one of the most adaptable staple food plants in the history of the world (Piperno and Flannery, 2001). It is ranked 3rd in terms of area under production after rice and wheat (Matsuoka *et al.*, 2002). Maize is noted as a stable food for about 1billion people across Africa, Asia and the Americans. Maize throughout the world is considered to be the most important crop because of its many uses as human food, livestock feed and many other industrial uses (Hossain *et al.*, 2016). Because of its many end uses as human food and livestock feed, it has emerged as a crop of worldwide significance and serves as an significant element for diverse industrial products (Hossain *et al.*, 2016).

2.2.2 Categorization of maize varieties

In recent times, the domestication and development of maize has received a lot of research attention. This has led to release of many different types of maize. In a broad picture, maize varieties may be categories as open pollinated varieties and hybrid varieties. Historically, maize was domesticated as an open pollinated crop which does not require external effort in transferring pollen from the male florescent to the female florescent. This category of maize was known as open pollinated maize varieties. On the other hand, the hybrid maize are cross deliberately using a selected parents with preferred characters of your choices such as high protein content, high yielding, resistance to pest and diseases etc. (Setimela and Kosina, 2006). In this regards, the original plants crossed (parents) are mostly known as inbred lines though in recent times there might be other parental lines (MacRobert *et al*, 2014). Common characteristics of hybrids are mostly even in colour, height, days to maturity and most other agronomic traits. Setimela and Kosina (2006) noted that the uniformity of hybrid crops allows farmers to perform certain activities at the same moment, such as harvesting, which is of excellent benefit to farmers who use combine harvesters. Hybrids are less resistant to harsh weather conditions such as drought, disease and pest attacked etc. and seed cannot be recycled for planting in subsequent years (Kutka, 2011).

Open-pollinated varieties (OPV's) on the other hand exhibit more variability in terms of yield, growth parameters. Seed of OPV,s can be planted more than one season and can still give more stable yield to the farmer for over three years (Kutka, 2011), hence is of great advantage to the resource poor famers.

2.2.3 Maize botany and ecology

Maize (*Zea mays* L.) can be planted grow mature and harvest within a single growing period of two to six months. Such crops are called annual crops (du Plessis, 2003). Maize is noted with fine adventitious roots beneath the soil that spread over a large area in the soil in such of growth nutrients and water (du Plessis, 2003). Immediate above the soil is the prop root that supports the plant to resist harsh winds and water that might cause lodging. The root system supports the increasing plant by increasing the nutrient and water consumption connected with enhanced surface area (Nkosi *et al.*, 2010). Mature roots can grow up to about 1.5 m, indicating profound soil profile penetration (Eskandari, 2011). Depending on the variety, the height ranges from less than 0.6 m to 5.0 m (Hoopen and Maiga, 2012). The crops are split into nodes and internodes with cylindrical, strong stems. The first four internodes do not lengthen, according to Matsuoka *et al.* (2002), whereas the ones below the sixth, seventh and eight leaves lengthen to roughly 25, 50 and 90 mm, respectively, which depends heavily on variety. Matsuoka *et al.* (2002) further narrated that the total number of nodes and internodes can vary from as low as eight for short varieties to 21 for taller varieties. The plant forms about eight to twenty leaves spirally arranged on the stem. The leaves can expand to a width of 10 cm and 1 m (du Plessis, 2003). The leaf comprises of a sheath, ligules, auricles and a blade on its own (Matsuoka *et al*., 2002). On the tassel the masculine flowers are born while on the ear the female flowers are born (du Plessis, 2003). The ears are enclosed by bracts, and for about three weeks they develop silks that stay receptive to pollen. However, after the 10th day of creation, receptivity reduces. Therefore, pollination is followed by kernel development (dent or flint) consisting of an endosperm, embryo, pericarp and tip cap (Setimela and Kosina, 2006). Maize is a short day plant with a photoperiodism rate of less than 12 hours / day (Afonso, 2013). Maize is best grown in soils with a good efficient depth, favourable morphological characteristics, excellent inner drainage, and adequate, balanced amounts of plant nutrients and chemical properties, according to du Plessis (2003). Maize needs an annual growth and development rainfall of 500mm to 750 mm that is greater than the average annual rainfall in Ghana. For optimum production, it often needs additional irrigation, particularly during its critical growth phases, because water deficiency is generally the most yield-limiting factor, as in any other agronomic production practice (Matsuoka *et al.*, 2002). Water deficiencies in maize lead in shriveled grains at the grain filling point, resulting in poor seed quality and compromised yields. But too much rainfall can also trigger yield losses at maturation level (du Plessis, 2003)

2.2.4 Importance of maize

The importance of maize (*Zea mays* L.) as staple crop in Africa cannot be under estimated in fighting food security of African nations (Kitonyo, 2010). After wheat and rice, it is considered the most important food crop in the globe (du Plessis, 2003). Pursuance to the importance of maize, 736 million metric tons were reported between 2005 and 2007 making it number one in terms of global volumes of production (Pruitt, 2016). Maize in Ghana is a significant staple crop (Bidzakin and Fialor, 2014). Across the globe, mays are used as important ingredient in both livestock and poultry feeding and industrially, for brewing. It is also a significant element of poultry and animal feed and a substitution in the brewing industry to a smaller extent. Maize is a major commodity in sub-regional trade in West Africa, especially between Ghana, Burkina Faso, Mali, Togo and Niger, primarily through informal trade (Bidzakin and Fialor, 2014). Maize is cultivated throughout Ghana with an estimated 15 % growth in the country's northern industry. The quantity of corn generated in Ghana improved by 13.3 % in 2012 on average. Nutritionally, the crop plays a vital role as a staple diet especially in developing countries. Kutka (2011) stated that almost all the plant parts of maize can be utilized into edible or non-edible products. The kernels are an endosperm, an embryo, a pericarp cap, and a tip cap. The endosperm includes approximately 80 % of carbohydrates, 20 % of fat and 25 % of minerals, while the embryo includes approximately 80 % of fat, 75 % of minerals and 20 % of protein. (du Plessis, 2003). Robertson *et al.* (2012) indicated that some of the kernels contain starch used in food and many other goods such as adhesives, apparel, paper and pharmaceuticals. Recently, the crop has been receiving more and more attention since it was found capable of being used to generate bioethanol which in turn can be used as a biofuel (Robertson *et al.*, 2012).

2.2.5 Maize as a staple food in Ghana

The total area under production for maize has increase from 793,000ha in 2006 to 880,000ha in 2015 representing about 11 % increment in area under production of maize within 9 years (MOFA, 2010). Most maize generated in Ghana is the white variety, but only a small amount of yellow maize is manufactured, all of which are primarily used for human consumption. Approximately 87 % to 90 % of Ghana's corn is consumed locally either as human food or as feed for livestock. Since 1990, the per capital consumption of maize continues to grow from averagely 40.30 kilograms in 1990 to 45 kilograms in 2015 increasing by 4 % (MOFA, 2010). Up to 58 % of Ghana's corn is consumed directly by farming families and the remaining amounts are marketed for consumption, economic and industrial use (MOFA, 2010). Most of the demand for yellow maize are met by importation and mostly used in animal feed production.

2. 2.6 Nutrient requirements in maize production

Low nutrients content in the soil among other factors are noted as a limiting factors to maize production in Ghana (Adu *et al.*, 2014). Major nutrients needed by maize for optimal development and yield include nitrogen (N) needed to achieve maximum yield and quality (FAO, 2007). The increasing tips of the plant for root growth and development require phosphorus (P) in particular. Potash (Potassium K) is needed by maize as much as possible. During tasseling, nitrogen, phosphorus and potassium assimilation reaches a peak (du Plessis, 2003). Maize also needs Sulfur (S), a protein component along with nitrogen and magnesium (Mg), an important chlorophyll component used for photosynthesis (Delgado *et al.*, 2006). Maize is not highly susceptible to deficiencies in trace elements. However, boron, copper, zinc, manganese and iron may occasionally be deficient in soils which may also affect the production (Delgado *et al.*, 2006).

2.2.7 Adaptation of hybrid and open pollinated maize varieties in Ghana

Simple adaptation relates to excellent output results and other agronomic features at a specified moment in a specified setting (Brown *et al*., 1986). The plant environment includes all the conditions during the increasing period (from pre-sowing to harvesting maturity). The primary environmental factors are: daily peak and minimum temperatures, soil temperature and humidity, atmospheric humidity in the immediate area of the plant, wind movement, daytime length, light intensity, air pollution, soil type, soil fertility, competition from other plants as neighbors, weeds and the disease-insect complex. These variables interact in a way that creates stress on the plant. Genetic control and differences between hybrids are the plant response to stress (Brown *et al*., 1986). Obatampa is well adapted to the increasing circumstances in the lowland tropics and has been widely adopted in Northern Ghana and many other parts of the nation and in many other African nations (Sallah *et al.*, 2003). Obatampa was by far the dominant corn variety in the main season of 2012 and was planted in 41 % of the corn region. Over the years, it has become more common, from 16 % in 1997 to 40 % in 2013. Hybrids promoted by the private sector accounted for 3 % of the corn region. Local or traditional varieties were planted in 40 % of the corn region (Aburowhoma and Ativi were the most common). The hybrid varieties are also well suited and increasingly accepted, but the issue of financial seed manufacturing has restricted them. Obatampa, an OPV, accounted for around 96 % of accredited seed manufacturing between 2001 and 2011 and around 2,500 tons in 2011 (3,466 tons average between 2009 and 2011). Given the nationwide cultivation of 0.95 million hectares and an average seed rate of 20 kg per hectare, Obatampa's annual licensed seed production could cover 18 % of the maize region with new seed annually. (Alene and Mwalughali, 2012).

2.2.8 Impact of hybrids on maize production

The greatest impact of hybrids on maize production could be linked or associated with the high increases in yields of maize. For example, the potential yields of Obatampa and other OPVs could be between 1.5 to 4 tons ha of grain, while that of hybrid such as Mamaba and Pan53 could range between 6-7 tons ha (Buah *et al*., 2010). Kanungwe (2009) also reported of hybrid potential yields above 8 tons ha as compared to 1.5 tons from the local varieties such as Dorke and Okomasa. Other attributes of hybrids include improvement in the protein nutrition of consumers (Buah *et al.*, 2010). The capacity to improve the efficiency and efficiency of other inputs such as fertilizers, agrochemicals and labor is adapted to weeds, insects, illnesses, accommodation and other stresses. Other hybrid effects on production have resulted in modifications in crop management methods such as row planting and agricultural mechanization. Significant investment in maize studies has resulted in enhanced production techniques that have enabled farmers to react to demand and supply changes. Farmers who develop enhanced hybrids participate in more management methods such as enhanced fertilizer use, herbicides and insecticides with higher frequency than those who grow local varieties because it brings financial returns to them.

Hybridization, on the other side, has been recorded to result in the loss of traditional corn and environmental biodiversity that these farmers and their ancestors have been stewards of for decades as worldwide financial integration increases pressure on agro-biodiversity (Almekinders, 2001). Policymakers, institutions and infrastructure favored hybrid at the cost of local plants in adopting enhanced techniques and their effect on productivity and welfare (Doss, 2006).

In the North and Ghana as a whole, the major limitations to hybrid adoption included, insufficient seeds, high cost of seeds, inaccessibility of seeds at the onset of seasons, high cost of accompanying inputs such as fertilizers and chemicals, insufficient knowledge on the management practices, unreliable rainfall, striga problems as well as price fluctuations which failed to guarantee the return for the producers (Dogor, 2013). Many scientists, including Monsanto Corporation, estimated that by 2030 the world population will be around 10 billion and warned that low-tech agriculture will not generate enough food to feed the world's increasing population. They stressed that only developments in biotechnology would boost crop yields without needing extra farmland while preserving precious rainforests and animal habitats (Kimbrell, 1998).

2.3 Groundnut

2.3.1 History, origin and areas of production

It is thought that groundnut (*Arachis hypogaea* L.) originated in South America (Hammons, 1994). Historically, it was first grown in Southern America from which it spread to the rest of the South American countries such as Brazil, Argentina Southern Bolivia (Bhatnagar *et al.,* 2012). In West Africa, groundnut was first introduced and cultivated colonial Portuguese travelled from Brazil to West Africa for trade and exploration in the 16th century (Talawar, 2004).

Groundnut (*Arachis hypogaea* L.) is considered to be one of the economic crops that generate revenue for families and people, particularly smallholder farmers in developing countries (Ajeigbe *et al.*, 2014). It is ranked 13th most essential crop globally and also, it has gotten a world recognition as the 4th most essential oil crop (Ani *et al.*, 2013).

In recent times, over 100 countries produce groundnut worldwide. Asia is major producer of the world groundnut with over 72 % percent out -put per annum (Owusu *et al.*, 2017).

African is the world's second biggest groundnut producer, with Ghana being one of Africa's top six nations with an average production of 440,000 tons per year between 2003 and 2007 (Owusu *et al.*, 2017)

In Ghana, groundnut are normally grown by smallholder farmers to complement the staple crops grown for both consumption and sale (Banterng and Hoogenboom, 2006).

Groundnut is usually cultivated in mixtures with other food crops or in pure stands from home compounds to large fields (Konlan *et al.,*2014).

2.3.2 Botany and ecology

Groundnut plant is member of the family *Leguminosae* the sub-family *Papilionoidae* and the tribe *Aeschnomeneae* (Holbrook and Stalker, 2003). It belongs to genus *Arachis* and species *hypogaea* (Holbrook and Stalker, 2003). '*Arachis'* is a Greek word, meaning spineless in description to the lack of erect branches and the word *hypogaea* from Greek 'hupo-ge' means inside the earth which relates to the flower stalk or pegs that grows into the soil to produce the pods. (Hammons, 1994).

Groundnut is divided into two major subspecies: *hypogaea* and *fastigiata.* This sub-classification is based on branching pattern distinctions. *Hypogaea* has alternate branching whilst *fastigiata* has patterns of sequential branching. *Hypogaea* is divided into *virginia* and *hirsuta* and *fastigiata* into *barcelona, peruvian* and *aequatorian*. (Ani *et al.,*2013). Virginia are normally bold seeded whiles Spanish is the runner kind of groundnut (Hammons, 1994).

It is a self-pollinated crop and flowers are usually born close the plant base in the axils of the leaves and have yellow petals in general. Subsequent fertilization is ovarian elongation to form pegs that subsequently evolve into ovaries in the soil (Prasad and Brook, 2005). Pegs grows about 7 cm into the soil through a positive geoptropism. Pod matures about 60 days after fertilization.

2.3.3 Socio-economic importance

In African, the major producers of groundnut is South Africa whiles in Latin America the lead producer is Argentina which produces almost half the total tonnage in Latin America (Owusu *et al.,* 2017).

It is a well-known fact that there is commercial value in any portion of a groundnut. Groundnut oil has been recognized with so many uses in both the domestic and cosmetic industries since time immemorial (Variath and Janila, 2017). Domestically, groundnut is kernel is process into cooking oil for family consumption. Groundnut is utilized many ways industrially in making soap, fuel, cosmetics, shaving cream, leather dressings, furniture cream, lubricants and others (Variath and Janila, 2017). It is also used as preservative. Groundnut oil is used to produce a variety of ointments, plasters, syrups and medicinal emulsions (Talawar, 2004).. Additionally, groundnut is use to make categories of food delicacies and similar products such as butter, milk, candy and chocolate and related products. The kernels of groundnut may be fried , boil or roasted and eat directly by the family (Variath and Janila, 2017). Sometimes families use kernels as a vegetable in dishes. Cake and haulm is use to feed different domestic animals (Talawar, 2004).. Shell or husk can be used as fuel in African homes (Snapp *et al.,*1998). In compost preparation, straw can be used together or in isolation. (Mesike *et al.,* 2009).

2.3.4 Utilization

Groundnut is the 13th largest food crop and the world's third largest oilseed next to soybean and cotton (Taru *et al.,* 2010). The crop is cultivated primarily for oil, protein and carbohydrates (Abdzad and Amiri 2010). The groundnut plant's numerous uses make it a significant crop for domestic consumption and export of food and money.

Overall, 50 % of the total manufacturing of groundnut is used for petroleum extraction, 37 % for confectionery and 12 % for seed (Taru *et al.*, 2010).

In Tanzania, the crop is listed fifth as a source of edible oil after cotton seeds and sunflower. Although cultivated primarily for cakes, groundnut is a food crop eaten within the family, although it can be sold for revenue (Katundu *et al.*, 2012). Farm animals can also use the crop as a fodder while the residue is returned to the soil as organic matter. In West Africa, however, groundnut is essential for smallholder farmers ' economic prosperity and dietary well-being (Kamara *et al.*, 2011). Groundnut is the main source of dietary protein, oil / fat, and vitamins like thiamine, riboflavin, and niacin. Groundnut paste is a significant source of calories for young kids, especially those who are sewed (Kamara *et al.*, 2011). Improvements in productivity and production of groundnut will enhance farming systems ' sustainability, effect on rural employment, trade and purchasing power for resource-poor smallholder households, reinforce women's financial position and enhance household nutrition (Kamara *et al.*, 2011).

2. 3.5 Climatic and soil requirements

Groundnut needs a lengthy and hot growing season as an important tropical crop (Weiss *et al.*, 2000). The favorable groundnut climate is a well-distributed rainfall of at least 500 mm during the growing season, with plenty of sunlight and comparatively hot temperatures. Weiss *et al.* (2000) reported the optimum temperature for plant development in the range of 25 °C to 30 °C. The significant environmental variables that limit pod returns in the Semi-Arid tropics are heat and/or drought-induced stresses. Craufurd *et al*. (2006) found that high day / night temperature (38/22 °C) from 21 to 90 days after planting decreased complete dry weight by 20 % to 35 %, seed harvest index by 0 to 65 % and seed dry weight by 23 % to 78 %.

2.4 Cropping systems

FAO (2007) defined crop systems as a plant community managed by a farm unit to attain different human objectives, in which case the crop system is geared towards enhancing the soil's fertility status in order to boost crop production. In relation to the resources and input management and technology employed in the production of the desired goods, Okigbo (1978) labeled it as a crop production scheme consisting of the crop pattern in terms of crop combination, spatial arrangement and crop sequences. The best crop environments are found in tropics where rainfall is adequate; plants can be cultivated throughout the year, not just in hot seasons as in temperate regions. And yet, despite these natural benefits, yields are comparatively small in tropical crop systems. Two significant fallow systems that are commonly practiced in tropical Africa are long and short fallows. Due to the alarming population growth, crop production has decreased dramatically in Africa under the long fallow scheme. In a discussion on increasing staple food crop production in Africa, soil fertility is an important issue. Ghana's condition is no exception where 60% of the population is dependent on subsistence farming, with an average of 27% living in extreme poverty (MOFA, 2011). Farmers initially used to replenish soil nutrients by moving crops or land rotation, but this is no longer viable due to enhanced population growth. The unpredictability of climate variables and the absence of plant growth nutrients in many soils restrict crop output in tropical crop systems (Ogle *et al.*, 2005). While there are restricted possibilities for climate change, different methods can be used to fix the soil fertility issue. Producing nutrients in the form of mineral fertilizers is an excellent alternative, but this is mostly hard for a multitude of social, economic and political reasons, particularly in Africa (Giller, 2001).

Among Ghana's numerous cropping methods are crop rotation, continuous cropping and bush fallow, and various types of inter-cropping. However, these crop systems vary from one system of land use to another.

Given the extensive incidence of nutrient stress worldwide, a thorough understanding of the acquisition, use and recycling of organic and mineral nutrient types is essential (Arihara and Karasawa 2000).

2.4.1 Crop rotation

The benefit of crop rotation is to boost yields and productivity, enhance soil fertility physical features and decrease weeds, diseases and populations of insect pests, and increase farm revenue (Oswald and Ransom, 2001). Crop rotation includes growing separate crops sequentially on the same piece of land, altering the sort of crops growing in the field each crop season, for instance, as practiced in southern Ghana, where maize is cultivated in the primary season and the same field is cultivated for cowpea in the minor season of the year after harvest (Kombiok *et al.*, 2005).

Researchers have pointed out that crop rotation is essential to the long-term productivity and sustainability of agriculture in combination with other fertility management techniques (Kumar and Goh, 1999).

2.4.2 Continuous cropping

Under the continuous cropping system, land is cultivated year after year. Practice is widespread where agricultural land is scarce owing to fast population growth. Studies have shown that constant cultivation results in reduced exchangeable Ca, K, Mg (Juo *et al.,* 1996), organic C, total N content and enzyme activity (Riffaldi *et al.*, 1994) and efficient cation exchange capacity than natural bush and fallow cultivation. Soil under continuous maize cultivation, for example, also results in soil acidification (Juo *et al.,* 1996) compared to fallow plots as seen by reduced pH and higher exchangeable Al and Mn values. Soil acidification and depletion of soil K, Zn, organic C and complete N depletion were noted under long-term peanut, soybean and maize manufacturing in summer and wheat in winter (Bell *et al.*, 1995). Hati *et al*. (2007) observed excessive reductions with fertilizer therapy in soil accessible Zn and Cu in an experiment with continuing cassava cultivation, while manure from the farmyard had the opposite effect.

2.4.3 Intercropping

A prevalent practice in sustainable crop production is to grow two or more crops nearby to improve communication between or between component crops (September, 2015). Hauggaard-Nielsen *et al*. (2009) defined intercropping as a way to produce two plants simultaneously on the same piece of soil. It is also known as multiple cropping or polyculture.

Multiple crop systems have been researched for a lengthy moment, especially in West Africa's intercropping scheme involving significant staple and leguminous crops (Ogola *et al.,* 2013). Although little is known about the first appearance of intercropped field, but according to historians (De Wet and Harlan, 1975), intercropping probably existed early in the life of agriculture but disappeared from many regions as a consequence of the emergence of mechanization and specialization dominated by contemporary agriculture.

In practice, in most intercropping studies undertaken in the sub-regions, economic gains have been achieved since the Land Equivalent Ratio (LER) has always been more than one (Kombiok *et al.,* 2005). Some elaborate reasons for the persistence of this crop system are, however, primarily due to income uncertainty, instability, and poor soil fertility maintenance (Kombiok *et al.,* 2005).

Kombiok *et al.* (2005) observed that intercropping cassava with grain legumes increased farmers ' net incomes; increased soil fertility and reduced weed and erosion relative to monocropping. Jones, (2016).) noted that the inclusion of cassava in an intercropping scheme of forage legumes resulted in the balance of harmful soil nutrients, promoting the need to review the option for cassava to replace nutrients.

Intercropping schemes are widespread in tropical latitudes, and interest in quantifying their potential would therefore be a major contribution to food and revenue safety. The word "intercropping" applies to the process of simultaneously cultivating two or more plants on the same piece of land (Jones, 2016). Farmers handle more than one crop on the same field and at the same moment under this farming scheme. Traditionally, farmers in Ghana have undertaken intercropping by growing two or more plants with no different row arrangement and low crop densities component. Although intercropping is common because of the renowned benefit of greater productivity relative to sole cultivation, its practice in Ghana is defined by overuse of local low yielding varieties (Ennin *et al.,*1999). Twumasi-Afriyie (1991) reported that 88% of farmers intercropped cowpea with sorghum or millet in the Guinea Savannah agro-ecological area, while 40% of farmers in the transitional forest savannah area practiced cowpea intercropping with other staples. The predominance of intercropping in low-risk precipitation areas leaves little doubt as to the potential for improved crop yield and income stability (Jodha, 1976). For many generations, particularly in the tropics, low-input farmers have learned to manage and sustain their farming systems without having a major effect on the financial resource base. The function of intercropping as a means to boost agricultural output and productivity has become essential since agricultural land is a decreasing proportion (Midmore, 1993). Several scientists (Adu-Gyamfi *et al.*, 1997) and (Dalal, 1974), for instance, showed greater nutrient absorption through intercropping. This has very often been reported as the ultimate reason to determine whether the cause or effect of higher returns was higher acceptance. Apart from the possible differences in rooting pattern and vertical root distribution, the mechanisms by which nutrient uptake is increased are far from clear.

An option is that even if increasing periods are similar, crops may have their greatest nutrient requirement at different stages of growth, a temporary effect that can help ensure demand does not exceed the nutrient supply rate (Yaradua and Shah 2018). Differences in soil N and component crop competitiveness may, however, boost N fixation (Ledgard and Steele, 1992).

There are always a major crop and one or more crop(s) with secondary or tertiary importance (Masindeni, 2006). Mostly, the two or more crops are belonging to different species of plants (Mondal *et al.,* 2012). To some simple combinations, the component crops at times can be either lines, cultivars or varieties or a tree crop or ornamentals (Seran and Britha, 2010). At times there is no need planting the component crops at the same time. One crop can be planted before the other crop or even when the other crop is just about maturing on the field (Anderson *et al.*, 2009). Intercropping comes with different crop combinations such as cereal-cereal, cereal-legume, cereal–vegetables, cereal- tree crops, legumes- vegetables etc. or in more complicated combinations such as cereal –legume-vegetable –tree crop etc. (Hugar and Palled, 2008). This can also involve either annuals- biennials or even perennial.

Very limited understanding exist about the symbiotic relationship among component crops, however, morphological and physiological features of the crops easily gives a hint to benefit that would evolve from the interaction (Alhassan and Egbe, 2014). In legume-cereal cropping system, both crops benefit mutually from the association through complementary usage of growth nutrients (Akuda, 2001). Though this cropping system comes several benefits, Alhassan and Egbe (2014) reported that, the main reason for practicing intercropping is to increase yield per unit area.

The practice of growing two or more plants in the same location and at the same moment is prevalent among smallholder farmers (Seran and Brintha, 2010), this prevalent intercropping system combination primarily includes plant legumes (Ijoyah, 2012). Scientists have published research on cereal-legume intercropping (Egbe, 2010; Osman *et al.*, 2011; Ijoyah, 2012), with effective intercropping in comparison with monocrop. This allows farmers to generate particular agro-climatic conditions for sites to be exploited for enhanced production (Bhagad *et al.*, 2006). As they capture and use radiant energy more effectively (Matusso *et al.*, 2012), available water and nutrients, intercropping systems are known to use growth factors more efficiently (Sullivan, 2003). Pest and disease prevention and enhancement, weed suppression and soil fertility (Sanginga and Woomer, 2009, Seran and Brintha, 2010). The crop system applies to the spatial and temporal layout of different plants with the aim of exploiting natural resources and increasing productivity per area and time (Singh, 2010). Spatial crop arrangement enables soil, soil moisture, nutrients, and solar radiation to be used effectively. This is accomplished by selecting suitable plants with variable morpho-physiological features and planning their planting geometry to decrease mutual resource competition and increasing complementarities to boost general productivity. Overall, this is accomplished through the interaction of the scheme (Singh, 2010).

2.4.4 Types of intercropping

Many types of intercropping have been reported. This ranges from irregular to regular row arrangement such as mixed intercropping and row intercropping (Mir *et al.*, 2016). To a larger extent crops can be intermixed as it occurs in strip cropping, row intercropping and mixed intercropping. Row intercropping involves growing the component crops in a regular row pattern. In row intercropping the main crop and intercrop are grown in separate rows and a regular pattern (Mir *et al.*, 2016). In intercropping strips, two or more plants are cultivated broad enough in bands or strips to offer mechanization space (Sarkodie and Abdul-Rahaman 2012). Relay intercropping is method growing two crops at different time intervals in such a way that, crop B is planted when crop A is in the reproductive stage (Dolijanović *et al.*, 2009). Mixed intercropping is nearly the reverse of row intercropping where component plants are cultivated without separate row provisions (Mir *et al*., 2016). In blended intercropping, the crops are completely blended without arrangement in separate rows in the accessible room.

Several rows of a plant species are alternated with several rows of other plant species with strip intercropping (Sarwar, 2012).

2.4.4.1 Cereal - legume intercropping

In the tropics, the practices of growing cereals and legumes together for food and income is a predominant farming system among peasant farmers in the tropics (Alhassan and Egbe, 2014). The practice is ancient and dates back to ancient cultures. This system has been estimated since time immemorial as a crop approach to enhance ground cover, thereby reducing weed competition, suppressing soil erosion and providing nitrogen (N) use to the component crops (Tsubo *et al.,* 2005). This offers a chance to minimize the use that is harmful to the ecology in organic fertilizers, weedicides and pesticides (Tsubo *et al*., 2005). Cereals are generally used as major crops in intercropping systems for cereal-legumes, i.e. they are of primary importance for economic or food production reasons. Maize-beans, maize-cowpea, maize-soybean, maize-groundnuts, millet-groundnuts, sorghum-cowpea, wheat-soybean and rice pulses are common combinations of cereal-legume crops (Makgoga, 2013). In a symbiosis connection with rhizobial bacteria, the system can fix atmospheric nitrogen (Lemlem, 2013). Matusso *et al*. (2013) noted that legumes were discovered to provide a stable yield when intercropped with maize in Africa and improve food security for smallholder farmers. The system also offers a more stable yield and offers farmers with insurance under different climatic circumstances in the case of complete loss (Seran and Britha, 2010).

2.4.4.2 Sorghum intercropping with groundnut

Simultaneously, sorghum is planted at the end of the growing season to avoid the danger of crop failure owing to poor and erratic rainfall. Soil fertility reduces as its nutrient content reduces and/or changes its physical, chemical and biological composition in ways that reduce plant maintenance and feeding ability. Thus, the fertility and productivity of these lands can be enhanced by incorporating mineral or organic nutrients, introducing crop rotations or partly returning them through crop residues and multiple crops. The latter option could be accomplished by increasing cereals in combination with legumes, offering the greatest chance to preserve soil fertility by fixing nitrogen and returning higher quantities of organic matter to the soil, thereby enhancing its exchange ability and physio-chemical environments (Schmidt, 2003). In Sorghum Groundnut, the decrease in organic matter and therefore the percentage of oxygen could be attributed to its decomposition and use by growing crops or generating less organic matter as a result of the stress on moisture during the flowering and seed development phases of groundnut plants in the second phase of the next season (Ali *et al.*, 2018). This also link to diminishing photosynthetic potential as a virtue of partial shading effects on groundnut which leads to minimizing nodulation and nitrogen fixation. By comparing three lines of intercropping systems, i.e. alternating single lines of sorghum and groundnuts , two lines of sorghum with single lines of groundnuts, single rows of sorghum with two rows of groundnuts plus sole sorghum as control , single rows of sorghum with two rows of groundnuts treatment recorded the largest percentages of organic matter and total nitrogen at end of two seasons (Ali *et al.*, 2018). The decrease in percentages of nitrogen and organic matter in intercropped treatments relative to sole sorghum can be mainly attributed to the effect of legume residue on organic matter formation and nitrogen fixation. This additionally, indicates that intercropping fulfills one of its major of objectives of improving availability of nitrogen and organic materials by leguminous inclusion to the general population and henceforth maintaining the soil fertility. Research indicates that one rows of sorghum planted with two rows of peanut treatment was generally higher in pod yield of peanut and in all areas of sorghum productivity, exception in terms of productive tillers per plant where the control treatment exhibited superior performance over the intercrops in two seasons (Ali *et al.,* 2018). Other experiments such as from the International Crop Research Institute of Semi-Arid Tropics with this combination offered yield benefits of up to 38 percent.

2.4.4.3 Groundnut and pearl millet intercropping

Millet and groundnut are used in heavier soils and are discovered in India as well as in West Africa. It is typical intercropping combinations by which there is very little distinction among the growing phases of the two component plants but some difference in canopy height; more specially, it is typical of combinations of cereal / low canopy legumes that are so common in many areas of the world. In the growth trends and yields of a one-row millet and three-row groundnut intercropping scheme, the accumulation of dry matter in the groundnut intercrop was lower than the expected output of the sole crop, suggesting that the millet intercrop reduced its growth (Reddy and Willey, 1981). But it was able to recover from this effect towards the end of the season, particularly after the millet harvest, and the actual yield was similar to the ' expected ' yield at the final harvest. By contrast, the accumulation of dry matter in intercrop millet was more than twice its expected level of sole crop and even more percentages were recorded of the sole crop at the final harvest yield. The combination of these dry matter returns into a comparative maximum yield gave a general benefit of 36 percent intercropping; for seed yields the benefit was slightly lower due to slight reductions in both millet and groundnut harvest indices. In these two intercrop combinations, the manner resources were used more effectively is indicated by the pattern of light interception and the effectiveness with which intercepted light was transformed into dry matter (Reddy and Willey, 1981). Although it was possible to observe some temporal difference between the crops in the millet / groundnut combination, by the end of the season the total amount of light intercepted by the intercrop was virtually the same as expected from the patterns of sole crop interception. As for the use of other resources in these two combinations, there is some increase in soil profile water extraction compared to sole crops and an increase in complete water efficiency due to a greater proportion of evapotranspiration moving through the plant as transpiration rather than loss as soil surface evaporation. There is also some proof of increased dry matter output per unit of water transpired in recent studies with millet / groundnut. The pattern for nutrient use was the same for both combinations because any increase in yield over sole crops is associated with an increase in nutrient consumption equivalent (Reddy and Willey, 1981). The Millet and Groundnut study showed that although intercropping did not reduce the production of groundnut dry matter per plant, the fixation rate remained considerably lower (Nambiar *et al.*, 1983). These effects were primarily ascribed to the shading effect of the cereal and the fact that a reduction in photosynthesis could affect fixation more readily than development. Strictly speaking, intercropping is only beneficial if the nitrogen benefit is greater than in some alternative sequential systems where only legumes are followed by non-legumes. The possibility of lower fixation rates in intercropping shows that the net nitrogen benefit in a single crop sequence could be greater if the farmer's objective is to develop a balanced proportion of both crops (for example, millet and groundnut system). But, of course, if a farmer grows disproportionate amounts of legumes and non-legumes, the easiest way to distribute any nitrogen benefit uniformly across the non-legumes may be to distribute both crops across the same region.

2.4.4.4 Maize intercropping with groundnut

Groundnut's stimulating impact on maize can be explained first by the immediate release from Groundnut of fixed nitrogen. This can verify the fact that leguminous nodules only become active in flowering phases and in turn release nitrogen that has been taken straight from the soil and integrated into the structure of ears / plants, secondly by releasing certain allo-chemicals from leguminous plants that boost the development and yield components of the related corn crop (Ahmad *et al.*, 2008). The rise in full production and higher decline in groundnut in intercropping systems relative to the sole groundnut system may be correlated with the above ground competition for light in mixtures between corn and groundnut (Willey, 1979). Due to the excess nitrogen fertilizer application, there would be low nitrogen fixation and groundnut depended on the mineral nitrogen supply of the soil and was therefore highly competitive with maize. Application of nitrogen did not decrease competition between the two species as nitrogen fixation contributed further to the nitrogen supply of Groundnut. After the advantages were effectively generated, the application of nitrogen to maize not only decreased the nodule weight per plant but also the fixation rate per nodule weight unit (Nambiar *et al.*, 1983). Maize-groundnut mix cropping gained more than 1 land equivalent ratios and produced higher financial outputs. The yields gathered from the intercrops were found to be directly relative to their population densities, indicating that the overall plant population could be skewed to favor one crop in the intercrop depending on the farmers precedence or the individual plant profitability (Langat *et al.*, 2006). Groundnut maize intercropping systems through decades of scientific research, as a matter of principle, current promising varieties of maize and groundnut should be evaluated and published only to farmers based on their ability to meet the demands of current intercropping systems. Due to the shading effect of maize crops, the reduction in leaf area indices of intercropped groundnut was probable due to reduced photosynthesis. Less dry matter was therefore available to encourage new leaf development and development, leading in a reduced leaf area index compared to its sole counterpart in groundnut intercropped (Dalley *et al.*, 2004). Accessibility of sunlight will be critical to the development of photosynthesis and has played a vital part in the development of leaves and the development of larger LAI, which has subsequently supported more photosynthesis (Dalley *et al.*, 2004). Results from intercropping studies conducted by Rwamugira and Massawe (1990) showed that maize intercropped with groundnut responded to fertilizer up to 60 kg N ha^{-1} while sole maize responded to 120 kg N ha^{-1}. In the study of the absorption of nitrogen from intercropped maize and groundnut, the nitrogen content of intercropped maize was found to be higher at low nitrogen levels than that of sole maize, indicating a certain transfer of fixed N from groundnut to maize. The comparative yield gain from intercropping was 44 % at zero nitrogen levels compared to single crops, but this decreased with an increase in applied nitrogen and zero at the smallest nitrogen level

(Rao *et al.,* 1979). In practice, this has significant repercussions because it suggests that intercropping may be more advantageous under low fertility circumstances.

2.4.4.5 Legume-legume intercropping

The ultimate goal of legume-legume intercropping is to increase nitrogen yields by legumes and henceforth the quantity of nitrogen returnable to the soil after the plant has decomposed an incorporated into the soil structure. Comparatively between or among short duration legumes such as groundnut and long maturing legumes such as pigeon pea biologically fix more nitrogen to improve the accessibility of phosphorus and subsequent improve crop yields (Kerr *et al.,* 2007). It has been commonly noted however that, short maturing legumes basically have a greater grain yield or output potential than long maturing legumes but the however contributes lower in terms of soil structure and nutrients composition (Hardarson and Atkins, 2003). Intercropping two or more legumes with varying maturity days would enhance additional merits of improving soil fertility and increasing financial returns to the farmer. Most of the genotypes of short length such as groundnut are cultivated for commercial reasons, while counterparts of lengthy duration such as pigeon pea can be adapted to relay intercrops and subsistence cultivation systems (Rego and Rao, 2000). Legume integration needs consideration of the intercropping competitive impact on water and the accessibility of nutrients to plants (Kerr *et al.,* 2007). The advantages of legume integration into crop systems rely on the amounts of biomass generated and the management of residues (Kerr *et al.,* 2007).

Apart from grain, edible legumes are generally collected and cooked for pleasure or used as animal feed, thus decreasing nutrient input into the soil (Kerr *et al.,* 2007). Regular and adequate addition of organic materials (plant residues) is reported to maintain good soil tilt, improve soil fertility and productivity, control weeds and water erosion, and prevent nutrient loss through run-off and leaching

2.4.4.6 Sesame based intercropping and biological importance

Freyman and Venkateswarlu (1977) found that one row of sunflower or sesame intercropping in groundnut planted at 30 cm x 5 cm achieved a total output of 787 kg N ha^{-1} and 852 N ha^{-1}, respectively. The intercropping of sunflower, wheat and green gram (*Viana radiatax* L.) in groundnut provided a maximum yield of 364 kg N ha^{-1}, 368 kg N $ha^{-1}$and 378 kg N ha^{-1}, compared with the production of 281 kg N ha^{-1}- 312 kg N ha^{-1}in pure groundnut, respectively. Baskaran *et al*. (1991) studying the impact of intercropping sesame in the ratio 1:4 with pearl millet or groundnut recorded a decrease of approximately 40 % in the shoot web of sesame compared with sole plants. Samui and Roy (1990) study on groundnut intercropping with sesame reported the highest pod and seed yield of 1489 and 1624 kilogram per hectare, respectively from single crops, but intercropping increased overall pods and seed yield. The largest complete yield of pod sand seed was in sesame and groundnut from one row of sesame to two rows of groundnut (992 kg N $ha^{-1}$and 1038 kg N ha^{-1}). Sarkar *et al.* (1995) researched the sustainability of the pulse and oil plants intercropping scheme and revealed that the most beneficial intercropping of groundnut with sesame was observed. The highest sesame equivalent yield (1245 kg N ha^{-1}) and soil equivalent ratio (1.35) and financial advantage were higher compared to the sole crop among the intercropping related sesame + groundnut under 2:1 row arrangement.

2.4.4.7 Groundnut and castor intercropping

Reddy *et al*. (1965) observed that increasing castor mixed with groundnut would be better than increasing a pure castor crop, with economic yields 61.9 % higher than pure castor. They also stated that in cultivation mixed with groundnut, castor yield was greater than castor mixed with green gram, cowpea, Setaria, millet or sorghum. There was a definite increase in manufacturing compared to sole crop manufacturing when castor bean and groundnuts were grown together.

2.4.4.8 Intercropping of groundnut and cassava

The introduction of an additional crop such as groundnut between traditionally wide-ranging plantations of cassava would enhance the efficiency of cassava-planted soil production and maintain soil moisture and fertility. An experiment at KhonKaen University, Thailand, produced higher yields of cassava (26,756 kg ha^{-1}) alone when intercropped with groundnuts compared to cassava (24,538 kg ha^{-1}). Intercropped groundnut increased yield of cassava by supplying additional nitrogen from nitrogen fixation. This groundnut / cassava combination produced about twice the net income relative to cassava sole planting.

2.5 Effect of groundnut intercropping on the succeeding crops

It has been indicated that grain legumes such as groundnut provide an amount of 60- N ha^{-1}successive non-legume crops (Ghosh *et al.,* 2009). Several reports of improved cereal production following groundnut were reported in the crop sequence. Bado *et al.,* (2006) noted that in order to obtain the same yield outcomes, reduced doses of N (20 kg N ha^{-1}) fertilizer were needed by groundnut sorghum compared to cowpea sorghum (60 kg N ha^{-1}). Similarly, the yield of wheat after groundnut was greater than after pearl millet (Ghosh *et al.,* 2007). The intercropping of groundnut and maize increased the oxygen consumption and yield of consecutive wheat plants and the intercropping of groundnut sorghum supposedly reduced the nitrogen fertilizer requirement of consecutive wheat plants by 30 kg N ha^{-1}- 84 kg N ha^{-1}over pure sorghum (Nair *et al.,* 1979). The groundnut included in the crop system is known to assist fix insoluble P in the soil, improve soil physical environment, increase soil microbial activity, restore organic matter and smother weeds (Ghosh *et al.,* 2007). The groundnut and maize experiment followed by a post-rainy season crop of sorghum to study the remaining effect of sole verses intercropped groundnut showed that if no nitrogen was applied to groundnut and maize intercrop, the following sorghum had a favorable residual effect. (Rao *et al.,* 1979).

2.5.1 Effect of intercropping different vegetables with groundnut

Intercropping provides greater stability, less risk, better resource utilization, and broad diversity in food production. People suffer from various nutritional deficiencies such as protein and calories as well as vitamins and minerals because of land restrictions. Horizontal development, such as intercropping among other techniques, could therefore play a major part in enhancing production. Intercropping was acknowledged as a potentially useful crop production system. In addition to stabilizing production in the rain fed fields, the intercropping system improves total output (Rao and Willey, 1980). The overall productivity can be improved by introducing adequate conventional geometry in the intercropping scheme. Intercropping yields are greater and more reliable than crop yields (Rao *et al.,* 1979). Groundnut and vegetables are seeded plants that are usually rowed and cultivated in the same season. Groundnut development in the winter season is very slow. The space between two rows of groundnut can therefore be used during this moment by growing vegetables as intercrops.

2.5.2 Bambara nut intercrop effects on maize development and yield

Bambara's potential to contribute to food safety has given rise to increased interest in research (Ambede *et al.,* 2012). Karikari (2004) disclosed that the quantity of cobs and seed weight in maize was not affected by Bambara nut intercropping maize. It was also observed that yield was not reduced or improved in the intercrop of sorghum and Bambara nuts (Legwaila *et al.,* 2012). On the contrary, when maize is intercropped with Bambara nut, Ogah and Ogbodo (2012) reported a significant increase in total maize production in the intercrop relative to sole maize. 2:2 intercrop of maize / bambara nut produced considerably more cobs, seed volumes and less infested seed weights than 1:1 intercrop of maize / bambara (Ogah and Ogbodo 2012). In maize plants grown in intercrop with Bambara nut, a substantial reduction in larva density, quantity of borers and percentage of dead heart was also found (Ogah and Ogbodo, 2012).

2.5.3 Groundnut effects on maize growth and yield

Groundnut is very often intercropped with maize in Southeast Asia and Africa. It has been reported from western Cameroon that maize groundnuts are grown at a comparatively low density with remarkable high yield per pure stand (Reddy and Reddi, 2007). Another study revealed a very rapid rate of millet development in intercrop, with 8134 kg ha^{-1} of dry matter achieved in 85 days by groundnuts. However, in 105 days of dry matter, sole groundnut growth rate was slower, reaching 4938 kg ha^{-1}. The mean groundnut yield was also found to be considerably greater when sown four (4) weeks previously than corn in another groundnuts / maize intercropping research. Generally, several trials have shown that the output of groundnut in the maize / groundnut intercropped is readily reduced by maize rivalry (Seran and Britha, 2010). In contrast, ICRISAT recorded poor crop development in the intercrop of maize / groundnut without utilization of N-fertilizer, and there was no visual proof of improved development if the intercrop of groundnuts was present. Where nitrogen was applied to maize, however, growth was suppressed (Seran and Brintha, 2010), and the remaining advantages decreased quickly (Rao and Willey, 1980). Bhagad *et al*. (2006) also emphasized that maize yield mechanisms such as cob length and regular cob weight were considerably higher once groundnut + sweet crop was intercropped in a 3:1 ratio. Koli (1975) also reported a tiny quantity of maize-groundnut mix productivity which he said was likely due to a relatively elevated maize population so that the closeness of maize to groundnut did not make the two crops significantly compatible in space.

2.5.4 Effect of Legumes Intercrop and Cropping System on Soil Fertility

Soil fertility problems are not only an agronomic issue, they are also strongly related to financial and social issues. Intercropping tends to enhance some of the fertility constraints of poor farmland. Adeleke and Haruna (2012) noted the usual intercropping of cereal pulses improved soil productivity. In a research, Vesterager *et al*. (2008) found corn and cowpea intercropping as helpful to poor nitrogen soils. Maize / cowpea intercropping improves the amount of nitrogen, phosphorus and potassium associated with monocrop maize (Dahmardeh *et al.,* 2010). Degraded and infertile soils are developed as a result of continuous monocropping and insufficient reprocessing of organic matter, coupled with rainfall variations marked by predominant dry spells (Ngwira *et al.,* 2012). It was also observed that understanding that maintenance and enhancement of soil fertility can only be accomplished through the use of predictable fertilizers (Ngwira *et al.,* 2012). Conservation involves minimal soil disturbance, constant soil cover with living or dead plant products and various crop rotations associated with leguminous crops as a function in leguminous crops as a cover crop (Ngwira *et al.*, 2012). The findings of Adeleke and Haruna (2012) also revealed an enhancement in complete oxygen after growing any of the four legumes (soybean, cowpea, lablab and groundnut) and when the land was left fallow. This monumental increase in full nitrogen was probable due to the ability of legumes to fix atmospheric nitrogen in the soil through symbiotic N fixation. This symbiosis alone accounts for more than 20 % of global biological nitrogen fixation and has been calculated to add 45-50 million tons of fixed N to agriculture annually (Geiler, 2001). Furthermore, the higher Cation exchange capability (CEC) that parcels previously cropped to legumes compared to the previous maize plot and fallow plots could be attributed to leaf litter droppings that serve more or less as mulch and then decomposed to add nutrients to the soil (Adeleke and Haruna, 2012).

2.6 Plant density and resource utilization in intercropping system

Despite the capacity to improve mixed / intercropping efficiency, farmers often fail to realize in portion their beneficial effects because they often plant their crops at sub-optimal population densities (Pal *et al.,* 1993). The associated species and the spatial differences between the component crops determine the complete plant population required to obtain an intercropping benefit. The complete density was also determined depending on the species ' environmental resources and development practices. When severe drought happened, the intercropping of beans with maize led enhanced population stability, as any loss of plant density in one crop tended to be compensated by the other crop, an important factor influencing the choice of intercrops (Willey, 1979). Component populations mainly determine how much each component contributes to the final production. When the component's plant densities are almost equivalent, the aggressively dominant crop appears to determine intercropping productivity and efficiency (Willey, 1979). In an intercropping of maize beans indicating maize density from 18,000 to 55,000 plants ha^{-1}, Ofori and Stern (1987) recorded a 24 % reduction in the leaf area index and a 70 percent reduction in the bean component. Tamado (1994) disclosed that the smallest relative pod production of the groundnut element was 50 % sorghum and 100 % groundnut association relative to the biggest ratios. The study also disclosed that a higher proportion of the sorghum element reduced the dry pod yield, the number of pegs, the plant part, and the groundnut association's dry matter weight more than reduced ratios. Due to the effect of unique arrangements, the intercropping of sorghum and groundnut study with separate special arrangements also showed very significant differences in the dry pod of the related groundnut.

One of the advantages of the intercropping system is the efficient and complete use of growth resources such as solar energy, soil nutrients and water (Francis, 1986). Intercrops are most productive when the growth length of their component crops differs considerably so that their high growth resource demands occur at different times (Fukai, 1993). Plants from the early maturing element should develop with little interference from the late maturing crop for elevated intercrop productivity. The later may be impacted by the related crop, but a lengthy period of further development after the first crop harvest should guarantee excellent recovery and complete utilization of accessible resources (Fukai, 1993). Intercropping enables efficient use of growth resources both in space and time aspects through crop intensification. Vertical and horizontal expansions are the conventional methods of intensifying crop production. Intercropping provides two more dimensions, time and space (Francis, 1986). Significant component of intercropping is the intensification of soil and resource use in the spatial dimension. For instance, with two or more species occupying the same land during a substantial part of the growing season and having distinct patterns of foliage display, improved effective use of light is feasible. Different rooting patterns may explore a higher total volume of soil due to the varying depth of the roots (Palaniappan, 1985). These differences in foliage display and rooting patterns generate the spatial dimension that intercrops. Another important feature is a difference in maturity moment and therefore in the intercropping of nutrient requirement between separate species that will produce the time dimension of the system. By decreasing intercrop component rivalry, the difference in moment dimensions will lead to efficient use of resources (Palaniappan, 1985). The ability of intercrops to intensify spatial and time-dimensional use of resources allows for greater complete use of available development resources than mono-cultivation (Francis, 1986). Research on intercropped sorghum and groundnut has shown that complete dry weight has been enhanced by both sorghum and groundnut. Nutrient Use Efficiency (NUE) of individual crops in an intercrop is significantly lower than the crops concerned. However, in most cases, the cumulative NUE of an intercropping system was higher than either of the single crops (Chowdhury and Rosario, 1994).

2.7 Role of legume in integrated soil fertility and weeds management

Poor soil fertility and depletion of nutrients continue to pose enormous barriers to obtaining the necessary SSA harvest (Sanginga and Woomer, 2009). Integrated soil fertility management (ISFM) technologies combining various current soil fertility management methods and where enhanced leguminous crops play multiple roles in soil fertility improvements, food supply and fodder supply, are regarded particularly important in overcoming this scenario in most of the region's smallholder farming schemes (Mugendi *et al.,* 2011). In past few years, several studies have shown the positive impacts of legumes on changes in soil fertility (Sanginga and Woomer, (2009). In Kenya, for example, Mugwe *et al.* (2009) discovered that herbaceous legumes enhanced the characteristics of soil fertility, particularly cations (Ca, K and Mg). Mbaga and Friesen (2003) noted in Tanzania that soil fertility had increased after Dolichos and Mucuna had been incorporated into the soil. In Uganda, Fischler and Wortmann (1999) indicated that maize cultivated after crotalaria yielded considerably greater than that produced without leguminous cover crop, attributing the beneficial effect to elevated nitrogen and phosphorus advantages and leguminous nutrient pumping capacity from deeper horizons. In relation to reports on herbaceous legumes ability to improve soil fertility characteristics, there are also studies demonstrating the enormous contribution of nitrogen-fixing trees to improving soil fertility. Grain legumes, however, are more acceptable to smallholder farmers than herbaceous legumes or nitrogen-fixing trees that occupy food-producing land (Peoples and Craswell, 1992), suggesting certain trade-offs that need to be accommodated (Odendo *et al.*, 2011). For example, Carsky *et al.* (2000) discovered that smallholder farmers preferred cowpea-maize to double-cropping mucuna-maize to retain cowpea-producing grain in the system although cowpea's advantages were less than mucuna's.

It is often stated that traditional intercropping systems provide better control over weeds. Weed development basically depends on the competitiveness of the entire crop group, which primarily depends on the competitiveness of the component crops and their respective plant populations in intercropping. Broadly speaking, where the complete intercrop population is higher than that of single crops (which is very often the case), it is possible to achieve greater weed suppression (Shetty and Rao 1977). Because of the added total dry matter and leaf area index obtained with millet and groundnut, this combination can provide a better suppression of weed than its simple sown ratio could be anticipated.

2.8 Advantages of intercropping

Intercropping is prevalent in rain-fed agriculture with limited resources because one crop can exploit a resource not fully utilized by the other. This is especially important in semi-arid tropics, where the growing season is short and soil moisture and fertility are the main constraints. Intercropping maintains soil water by decreasing the loss of evaporation and decreasing the organic matter of the soil, which in turn increases soil structure, infiltration and retention of water and helps to prevent soil erosion. By biological decomposition and mineralization, organic matter can also increase the quantity of soil nutrients available for plant growth (Ali *et al.*, 2018). Intercropping is carried out according to the definition of extremely leached and some nutrients are removed by erosion and the surface runs off due to its sloping nature, others after harvest together with the crops. In addition to bad land management, the continuing cultivation of the same smallholdings with the same crops (mostly cereals), without rotation or application of fertilizer, also resulted in the degradation and exhaustion of the valuable agricultural property. Because they have straight leaves and are cultivated far apart, the soil is not well covered by large cereals, but legumes like groundnuts cover the soil very rapidly after been grown.

The low-input and high-risk environment of smallholder farmers significantly benefit from intercropping (Rana and Pal, 1999). A prevalent mix of cereals and legumes among farmers is probable owing to the ability of legumes to combat erosion and boost soil fertility (Matusso *et al.,* 2012). Flexibility, maximizing profit, minimizing danger, preserving soil and improving soil fertility are some of the primary reasons why smallholder farmers intercrop their farms / crops (Matusso *et al.,* 2012). They also have the ability to produce higher returns than single crops, greater yield stability and more efficient use of nutrients (Seran and Brintha, 2010). Similarly, enhanced weed control, enhanced quality by variety, while cereal crops require a larger area in an intercropping scheme to produce the same output as cereals (Ijoyah, 2012).

2.8.1 Yield stability

Better control of pests and diseases and the advantages associated with greater relative stress; where these happen, they can provide a helpful buffer against low yields in bad years. The most important thing is that if one crop fails or grows badly, the other can compensate; this compensation will obviously not be feasible if crops develop separately. Jodha (1980) showed that intercropping is often coupled with erratic rainfall / high danger in India, whereas Norman (1974) found farm income in southern Nigeria to be less variable where intercropping is more dependent.

2.8.2 Efficient resource utilization and yield advantage

Cropping systems aims at making efficient use of growth resources so that high productivity can be achieved (Lemlem, 2013). Multiple cropping is the most common traditional cropping system in tropical Africa. It brings to the benefit of the farmer various from a piece of land and enhance the efficient and effective utilization of resources by crops and reduces the danger of complete loss in production due monoculture (Mesike *et al.,* 2009). It also gives scope for increased labour use efficiency and provides early income (Mesike *et al.,* 2009). Intercropping is one of the best techniques in reducing the danger of complete crop failure to farmers. If one component fails the farmer, the other survive and compensate the farmer especially when they crops are of different species, biology and morphology (Malézieux *et al.*, 2009). Additionally, pest damages are kept at minimal thresholds in intercrops due to diversification of the ecology that promote and demote the multiplication of beneficial insects and non-beneficial insects (Malézieux *et al.*, 2009).

Some research findings have argued that there is not direct utilization of nitrogen from legumes but rather indirect utilization through decomposition of residual materials of the legume after harvest. This suggests utilization only for a long duration crop on the field or a crop in the succeeding crop. Yusuf *et al*. (2009) found that maize grain yield was 46 percent significantly higher when grown after soybean than after maize and natural fallow.

2.8.2 Insurance against crop failure

As previously mentioned, individuals practicing intercropping are able to compensate their effort with some amount of yield in unlikely event of complete failure of the main crop (Seran and Britha, 2010). Having more than one crop allowed farmers to escape total crop failure in terms of disaster. In recent times in Africa, intercropping and crop rotation has been highly recommended for control of fall army worms in farmers maize fields. Crops in mixtures leads to pest and disease control due to the fact that, host life cycle is disturbed (Mir *et al.*, 2016). Crop insurance is efficient risk management tool. Odedina *et al.* (2017) observed that, compared to intercropping, pests and diseases were high in monocropping.

2.8.3 Soil fertility management conservation

Research has proven that maize intercropped with legumes reduces water evaporation, improve soil conservation more importantly the soil moisture content is conserved (Dahmardeh *et al.*, 2010). Ideally, crops are able to able to advance their yield over that of monoculture due to the fact that, crops share different ecological niches and competition among crops of different species for nutrients is lesser than that of the competition among crops of the same species (Thobatsi, 2009). Leguminous crops can brings about micro-ecosystem capable of maintaining the ecology in the soil for a good and enhance practices that can protect the soil and insure sustainable soil fertility management (Hauggaard-Nielsen *et al.*, 2009).

2.8.4 Pest and disease management

Critical to any crop production venture is the ability to manage pest and disease more economical, efficient and environmentally friendly. Pest or disease can wash away all crops causing a huge economic impact to the farmer especially in monoculture system of crop production (Matusso and Mugwe, 2013). Pest and disease infestation in sole maize was reported to be greater than maize intercropped with soybean and the amount of maize stem borers in sole maize was reported to be greater than maize intercropped with groundnut. (Matusso and Mugwe, 2013) observed that sole maize infestation was higher than soybean intercropped with maize. The amount of maize stem borers in maize was decreased when soybean was intercropped with maize (Sekamatte *et al*., 2003).

2.8.5 Soil fertility amendment

Through biological nitrogen fixation, intercropping is noted to improve the fertility of the soil better than monoculture (Nyoki and Ndakidemi, 2016). The soil is improve significantly through cereal legume combination where by the legumes fix atmospheric nitrogen when on the field and even when decomposed (Dahmardeh *et al.*, 2010). More especially, impact of the residue of the legumes are greater when ploughed back into the soil in subsequent season (Kermah *et al.*, 2017). Though nutrient can be replenish in legume intercropping, however, nutrients depletion can occur in the soil when nutrients are not fix after been used by the plants (Geiler, 2001). Deep rooting legumes such as pigeon pea have been observed to take nutrients from the soil. This helps to recycle surface-leached nutrients. As a significant instrument in the integrated management of soil fertility, intercropping generally replaces dependence on inorganic materials to maintain soil fertility that causes leakage and increases soil fertility (Magdoff, 1992).

2.8.6 Erosion control

When cereals are intercropped with foliage legumes such as cowpea, groundnut etc. it provides a canopy that secures the soil surface from direct impact of rain drops, wind or running water. Nyi *et al.* (2014) reported decreased in soil fertility in cassava-groundnut intercropping. It was also reported that, cowpea in maize-cowpea intercropping is best noted as cover crop and hence reduces soil erosion. (Onesmus, 2010). The soil pores are covered by the vegetation of the legumes hence prevents surface run off. (Carlson, 2008). Long standing crops such as maize, sorghum, millet and pigeon pea when planted serves as a wind breaks that prevents wind erosion (Mir *et al.*, 2016). Additionally, as a way of preventing mechanical damage, tall plants act as wind breaks for short plants (Reddy *et al.*, 1976).

2.9 Disadvantages of intercropping

Intensive competition may result in a reduction in the yield of component crops (Thole, 2007). It is known as competition in the same environment where two or more plants share each far below their combined demands the same development variables (Thole, 2007). Basic morpho-physiological deviations and agronomic practices such as application of fertilizer, date of planting and proportion of crop mixture are main determinants of competition between crop parts. Where component crops are placed in certain rows, the level of competition is determined by average growth rates, growth duration, and proximity to the roots of the different crops. Cereals usually have advanced growth rate, height and a more uniform fibrous rooting system in a cereal-legume intercrop, which offers it with the higher competitive edge over cereals in the association

Ofori and Stern (1987) reported a significantly lower rate of growth of leguminous crops up to 52 % in a the single crop production season, whereas cereal production was affected by only 11 %. Significantly, the legume was depressed by the cereal element in an intercrop. This has been attributed to screening from cereal crops to reduce photosynthetic active legumes. Maize has been recognized as a common element in most tropical intercropping systems (Ijoyah, 2012). Prasad and Brooks (2005) found a rise in the density of maize plants to have a major effect on the leaf area index of the component. Adesoji *et al.* (2013) noted an increase in maize growth as a result of nitrogen effects resulting in an increase in cell division, cell expansion, and an increase in the size of all its morphological parts. Reddy and Reddi (2007) also noted the output of corn after intercropping with groundnut and green gram separately. Maximum maize-legume association is aimed at achieving total maize output plus selected legume yield (Chui and Richards, 1984). However, corn yield decreased as a consequence of variable intercrop spacing with cowpea. This also agrees with the study by Gangwar and Sharma (1994) that maize yields were lowered as a consequence of intercropping legumes, namely cowpea, clusterbean, sunhemp and dhiancha. Similarly, with growing Lablab population, Maluleke *et al.* (2005) discovered maize dry matter to be lowered. Katundu *et al.* (2012) found that intercropping impacts the vegetative growth of component plants in a mixture. Thayamini and Brintha (2010) noted that the pattern of planting maize and legumes did not affect maize output. Chui and Richards (1984) report that intercropping obstructs maize tasseling and silking for up to two days, particularly at the concentration of complete soybean population. It was found that intercropping maize with cowpea significantly decreased the length of the ear, cob length, dry cob weight, dry grain yield and dry total plant biomass (Egbe *et al.*, 2010). Intra- and interspecific competition is influenced by plant density and has a particularly significant effect on the output of maize grain (Flores-sanchez *et al.,* 2012). Leguminous maize intercrop could considerably enhance the quality and quantity of forage. When legume crops are intercropped with maize, however, it was discovered that the farmers ' field had the largest amount of vegetative biomass (Ngwira *et al*., 2012).

2.9.1 Intercropping inhibits mechanization

In spite of the numerous advantages of intercropping in raising additional income to the farmer, soil fertility, pest and disease management, the practice in recent times is in decline due to agriculture mechanization. Agricultural machinery for fertilizer application, weed management including chemicals and harvesting equipment's are mostly made for commercial farmers with large areas of land usually as monoculture rather than small land size as it is in intercropping (Lithourgidis *et al.*, 2011).

2.9.2 Competition for growth factors

It is a definite fact that both interspecific and intraspecific competition occurs in intercropping. In the association, plants compete for light, water and nutrients which affects the crops negatively (Leela *et al.*, 2015). The result of important competition in the association for growth nutrients, space, water and light can be a reduction in the output of component crops.

2.9.3 Shading effects

One crop can be a pest when overgrown and intercept light from reaching the other crop or crops to the other crop. Legumes can easily become a weed pest by covering the other crop in the association hence would reduce yield or the vise-visa (Alla *et al.,* 2014).

2.9.4 Resource use efficiency in intercropping systems

When plants occupy the same space, there is always a possibility of competition for limiting resources such as moisture organic and inorganic nutrients and radiation (Brooker *et al.*, 2015). According to Hauggaard-Nielsen *et al.* (2006), the competition in sole cropping, where all the plants are of the same species, it is common to occur during times of peak demand. In intercropping, there is an advantage in resource competition since the component crops have different demand for growth resources (Hauggaard-Nielsen *et al.,* 2006). Takim (2012) reported that, the competition in mixtures becomes more severe with similar plants than with plants differing in growth habit. However, Lithourgidis *et al.* (2006) asserted that the effective use of fundamental resources in a crop scheme was partially dependent on the vital effectiveness of the system's component plants and partially on the impact of complementarity between plants. Complementarity and minimal competition for resources are building blocks that help to achieve efficient resource utilization. Malézieux *et al.* (2009) reported that, a factor that may be complementary at one stage of the growing cycle may become competitive at a later stage. Likewise, a competitive factor at one stage could become complementary at another. Therefore, Malézieux *et al.* (2009) concluded that, it was necessary to prolong complementarity for as long as possible, and that could be archived by manipulating inputs, planting dates, planting methods and arrangements.

2.9.5 Light interception in intercropping

The architecture of a given crop and the morphological structure of a given crop determine the level of interception of solar radiation. Sustainable use of growth factors such as light is key component of selecting components crops in an intercrop

(Eskandari, 2011). High light interception impedes the rate of photosynthesis in the plant and can eventually lead to significant reduction in growth parameters and yield (Nyasasi and Kisetu, 2014). In selecting crops or varieties for intercropping, low and high canopy plants are normally selected and plant together to improve radiation. Shorter plants such as groundnut are grown between longer plants like maize, millet etc. to improve light interception and distribution in between the crops (Seran and Brintha, 2010). One key element that affects yield is noted to be the amount of light that intercepts and possibly converted to yield parameters. Tsubo *et al. (*2005) indicated that, the light interception was maximized in maize-bean intercropping than maize grown as in monoculture. When light interception is managed well can lead to increase yield in intercropping.

According to Tsubo and Walker (2004), the effectiveness of radiation use of intercropped bean with maize was 77 % greater than that of sole cropped beans. High light interception was reported by Htet *et al.* (2017) in their findings realized of the effects of planting patterns on resource consumption of maize – soybean intercropping.

2.9.6 Water utilization in intercrop

The most significant factor in any crop production system is the availability of water to plants. Water plays critical from land preparation, planting, germination, morphological and physiological development of the crop until harvest (Eskandari, 2011). It is one of the key factors that determine crop output per unit area. Intercropping of two crop species especially, legumes and cereals has been found to utilize water efficiently than sole cropping by searching for large volumes of water through different soil horizons and depth due to varying root patterns of the intercrops (Alhassan and Egbe, 2014). Different root patterns in terms of size, length and pores of the root and root hairs enables intercropped species to exploit large volumes of water in the soil (Thobatsi, 2009). A main determinant of intercrop water use is the effectiveness of water use, which is defined as the yield per unit area divided by water use to yield the crop (Carlson, 2008). These include enhanced accessibility of water to crops, enhanced overall water removed from the soil in the form of evapotranspiration, enhanced transpiration without enhanced overall evapotranspiration, and enhanced effectiveness in water use. In general, the availability of water to crops can be increased by increasing the canopy cover, which prevents the soil from capping, resulting in enhanced infiltration and decreased soil erosion. Due to intercropping, the availability can also be improved by reducing weeds (Thobatsi, 2009). There is a huge potential to reduce evaporation through canopy cover. (Carlson, 2008). According to Liebenberg (1995), intercropping enhanced effectiveness in water use by more than 18% and in some instances by as much as 99%. Usually, the short season crops use water early in the season and get past their peak demand period before the onset of the peak demand period of the long season crops (Carlson, 2008).

2.9.7 Nutrients utilization in intercropping system

By increasing peanut and maize together, maize-based phytosiderphorus can mobilize Fe (III) and benefit from peanut plant iron nutrition (Li *et al*., 2003). Peanut intercropped with maize in all peanut intercropping system is known to improve iron (Fe) nutrition (Głowacka, 2013). In peanut plants, Fe nutrition is enhancement by intercropping with maize (Chu *et al*., 2000). According to Głowacka, (2013), the secretion of phytosiderophores from maize in the intercrop arrangement in peanut / maize intercropping may lead to the improvement of peanut Fe nutrition. Although Geiler

(2001) mentioned that soil pH had a major effect on nodulation and could cause deficiencies in certain essential nutrients such as P and Mo, intercropping also disclosed that the concentration of Fe and Zn in peanut crops increased considerably (Głowacka, 2013). In an intercrop, Li *et al*. (2001) stated greater acceptance of maize nitrogen in sole cultivation. The greater acquisition of N is often observed by a non-legume plant interspersed with a legume in the literature (Francis, 1986). This may be due to the effect of the contest. Intercropping, however, did not significantly influence the accomplishment of soybean nitrogen.

In other findings, the application of phosphorus (P) under intercropping significantly improve soybean phosphorus level (Li *et al.,* 2001). Legume- cereal intercropping reduces nitrate and potassium leaching in the soil (Askegaard and Eriksen, 2008) and not just as nitrogen fixing plant but also as an absorber of N, P and K from the soil minerals (Flores-sanchez *et al.,* 2013). These results make legumes a significant tool in crop systems where N and K are the main limiting factors for yields (Flores-Sanchez *et al.,* 2011). Rusinamhodzi *et al*. (2012) argues that micro-nutrient in-field deficiencies such as zinc, molybdenum and boron may bind leguminous development and limit the fixation of nitrogen. Nitrogen, phosphorus and potassium intake in maize can be significantly reduced due to intercropping compared to sole cropping. Nitrogen absorption in green gram was recorded as 284 kg ha^{-1} which has been significantly developed as intercrops with cowpea (239 kg ha^{-1}) and soybean (247 kg ha^{-1}). Nitrogen absorption in 1:1 row ratio (274 kg ha^{-1}) was maximum compared to 1:2 row ratio (251 kg ha^{-1}) (Kanakeri, 1991).

Crops require varying amounts of nutrients during their growth cycle. The uptake depends on how much distributed and concentrated the roots are in the soil (Rob *et al.*, 2015). Nutrient uptake is generally increased with enhanced soil root distribution and concentration. Nutrient effectiveness in intercropping systems happens in space (Eskandari, 2011). Nutrient uptake may be either temporary or spatial. In temporary nutrient uptake, distinct species in the intercrop have distinct requirements of a specific nutrient at distinct moments while in spatial nutrient uptake, nutrient requirements increase with growing root mass of the plant. Crop species with distinct root patterns and absorption of various growth nutrients improve efficient absorption of nitrogen (Thobatsi, 2009). This is due to the mobility status of nitrogen over other mineral components. The impact of fixing nitrogen is also a popular subject of studies. Many studies show that leguminous non-leguminous plants profit from nitrogen lately fixed by leguminous plants (Kermah *et al.*, 2017). Liebenberg (1997), stated that it is very unlikely that in that same season a non-legume would profit from nitrogen fixed by a legume unless the non-legume grows actively for a significantly longer moment than the legume.

2.10 Crop combinations in intercropping

The basic principle when growing two crops together normally is a deliberate attempt of choosing species that can minimize competition whiles maximizing cooperation or complementarity among themselves. To achieve this in principle, plant architecture, spatial arrangement, plant density and maturity days of the selected species are critical when selecting crops for intercropping (Preston, 2003). Various combinations has been identified for successful cooperation among crops grown in an intercrops (Mir *et al.*, 2016). Different planting arrangements include row intercropping, strip intercropping, relay intercropping and mixed intercropping. Row intercropping makes provision for regular row arrangement that allows component crops to assess growth resources without severe competition (Mir *et al.*, 2016). Strip intercropping reduces interspecific competition to the minimal whiles promoting high intraspecific competition among crops. In strip intercropping, crops are grown regular bands or strips which allow mechanization and other related operations. This type of combination has high potential for commercialization than row intercropping (Dolijanović *et al.,* 2009). In areas with bimodal rainfall, irrigation or long duration of rain of over six months or when using short to medium maturing varieties of crops, relay intercropping can be practice. This allows one crop to at least grow up to reproductive stage before the second crop is established. Late crops benefit from the remains of the older crop when it decomposes after harvest. In mixed intercropping, crops are planted haphazardly without definite row or strip arrangement. It is the most practice intercropping arrangement in history for smallholder farmers (Agegnehu *et al*., 2006). In this system of arrangement, common agronomic practice is so much difficult to practice compared to the other arrangements.

Planting crops with different maturity days give room for variation in growth resource needed per individual crop at a time. This consideration gives room for less competition for nutrients light water and space (Preston, 2003). Additionally, crop architecture is major consideration when selecting crops for intercropping. Provision are made in such way that, one crop takes sun light that otherwise might not have been taken by the other crop (Preston, 2003). For example, in a row spatial arrangement of maize-groundnut intercrop, maize is strategically planted to tap light without impeding the availability of the requirement of light for the groundnut. Plants are planted at optimum population to allow good cooperation. Normally, the planting rate in monoculture is reduce to a larger extent 80% to give space to the other crop to be planted.

In a nutshell, choice of crop combinations in an intercrop is as a virtue of plant competition, but it could be reduced by spatial arrangement, plant density, crop architecture and the plant ability to exploit soil nutrient (Chu *et al.*, 2004).

2.11 Assessing productivity of intercropping system

In evaluating the productivity of the intercropping scheme, various techniques and indices have been proposed (Preston, 2003). Several historical study works have recorded indices such as land equal ratio, competitive ratio, land equal coefficient, aggressiveness, financial advantage index, benefit cost ratio, etc. (Adekunle *et al.*, 2014). Normally, crops in the mixture are compare and measured against the counterparts in a monoculture (Dariush *et al.*, 2006). Land equivalent ratio is the most popular and most widely use method in assessing the productivity of intercrop against sole cropping (Preston, 2003). Other indices such as land equivalent ratio, aggressivity, monetary advantage index, competitive ratio, intercropping advantage etc. have been used extensively in assessing the economic and productivity of intercropping especially between two crop (Adekunle *et al.*, 2014). This study is therefore focusing on using some of these indices in assessing the agronomic and economic productivity of maize- groundnut row intercropping system in Northern Region of Ghana. Some of these indices are reviewed below.

2.11.1 Land equivalent ratio (LER)

Land equivalent ration is the total yield ratio from an intercrop to the ratio of total yield collected from the same plant species in the sole crop. In a nutshell, it is the total quantity of the intercrop yield as a fraction to that of the yield of the sole crop of the same species (Willey and Rao 1980).

Generally, in an intercropping scheme, sole crop legumes have greater yields compared to yields in intercropping. In most instances, however, it measures the soil productivity and demonstrates the benefit of mixed intercropping arrangement over sole cropping. According to Preston (2003), LER gives an indication of magnitude of sole cropping required to produce the same yield on a unit of intercropped land. Research has shown that, response of nitrogen to intercropping generally results in reduced LER values (Preston, 2003). Basically, measuring LER of 1.0 implies that there is no absolute economic benefit in intercropping a given crop over sole cropping and the vice versa (Legwaila et al., 2012). For instance, an LER of 1.34 indicates that if planted in pure stands, the yield produced in the total intercrop would have required 34 % more land, while an LER of 0. 25 indicates that the yield produced in the total intercrop was only 25 % of that of the same amount of land as pure stands planted (Brooker *et al.*, 2015).

2.11.2 Land equivalent coefficient

Land equivalent coefficient is use to indicate the yield advantage of the intercrop over the sole intercrop. Land equivalent coefficient is use to indicate the level cooperation between or among crops (Ghosh *et al.*, 2009). For any two crops the minimum value of land equivalent ratio to prove the interaction complementary and economic advantageous is 25 % (Agegnehu *et al.*, 2006). Nyasasi and Kisetu, (2014) reported 92

% land equivalent coefficient value in maize cowpea intercropping system. This signifies a yield advantage of the system. Mandal *et al*. (2014) reported 80 % and 85 % productivity advantage (LEC values in intercropping one row of maize followed by two rows of groundnut and two rows of maize followed by four rows of groundnut respectively when assessing when assessing efficiency of cereal legume intercropping system. In a study of castor bean-groundnut intercropping system with varying days of planting of groundnut in castor bean field, including castor planted the same day with groundnut, groundnut planted 10 days after castor, 15 days after caster, 20 days after castor and 25 days after castor land equivalent coefficient were 53 %, 67 %, 73 % ,71 % and 62 % respectively. Alhassan and Egbe (2014) also reported significant difference in land equivalent ratio between maize and Bambara groundnut.

2.11.3 Competitive ratio

Competitive ratio is the measures of the competitive ability of the two crop grown in the intercropping system over other (Cui *et al.*, 2017). It is a measure of the times by which one component crop is more competitive than the other and it is simply the land equivalent ratio of the individual crops taken into consideration the proportion of each crop in the intercrop (Takim, 2012). If competitive ratio is less than 1 there is positive interaction and the crops can be grown in an association and the vice-versa Cui *et al.* (2017) reported 0.92 competitive ratio for maize and 1.08 for soybean in 2 : 2 rows arrangement. Similarly, Eskandari (2011) reported significant difference in competitive ratio of wheat over bean is assessing the complementarity and nutrients consumption of wheat–beans intercropping system. In maize- cowpea intercropping system with spatial arrangement of 1:1, 1:2 and 2:1 various competitive ratio were 3.66, 2.47, 0.78 and

0.65,0.58 and 0.84 respectively for maize and cowpea (Takim, 2012). Egbe (2010) reported competitive ratio of soybean ranging from 0.76 to 1.15 and that of sorghum ranging from 1.23 to 0.76 in sorghum – soybean intercrop.

2.11.4 Aggressivity of intercrops

Aggressivity also measures the level of competition between or among crops (Alla *et al.*, 2014). It measures the competitive relationship among crops grown in the mixture. Aggressivity values are used to indicate the level of dominance of one crop in the association over the crop (Mandal *et al.*, 2014) . It measures the relative yield increase of one crop over the other (Egbe, 2010). The value for aggressivity would be zero if the two crops has the same competitive ability. However, any other circumstance the value is either positive or negative which symbolizes that a given crop is either dominant or dominated in the association (Kheroar *et al.*, 2013). Kheroar *et al.* (2013), findings revealed that maize was the dominant crop (positive aggressivity value) whiles groundnut was the dominated crop (negative aggressivity value) in maize –groundnut intercrop. Aggresivity values were reported consistently negative with a mean value of -0.25 for soybean in sorghum–soybean mixture (Egbe, 2010). In maize -groundnut mixture, maize consistently recorded positive aggressivity values ranging from 1.18 to 1.28 whiles groundnut where recording negative aggressivity values ranging from -1.18 to -1.2 (Mandal *et al.*, 2014). Row intercropping of castor bean and groundnut similarly gives positive AG values ranging from 1.55 to 2.37 and the vice-versa (Dutra *et al.*, 2015). Barley also dominated faba bean recording high positive aggressivity values whiles faba bean was the dominated crop recording negative AG values in evaluating the performance and land use efficiency of barley and faba bean mixed cropping system.

This observation has been reported in other association such as maize cowpea where by the maize dominated the cowpea (Takim, 2012). Similar results has been reported by (Alla *et al.*, 2014).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site

The study was conducted during 2017farming seasons at two different locations Vani and Zoggu at the East Gonja District and Savelugu-Nantong Municipal of the Northern Region of Ghana respectively. Vani is located between latitude E 955^{O} and longitude W 071^{O} while Zoggu can be found at latitude E940^{O} and longitude W 010^{O}. The field trial location was selected on the basis of common practices of maize –groundnut intercropping among farmers at the selected locations.

3.2 Research design and treatment

The experiment was conducted in randomized complete block design (RCBD) in three replications with each experimental unit measuring 10m × 5m ($50m^2$). The experiment consisted of six treatments combinations (Table 1) that were made up from different spatial row arrangements. Sanzal-sima (medium duration days) maize variety was intercropped with groundnut variety Samnut 22 (medium duration days). In addition, for each intercrop were sole cropping for maize and sole cropping for groundnut as control.

Table 1: List of treatments

	Treatment	Treatment Code
T1	One row maize followed by one row of groundnut	1RoM: 1RoG
T2	One row of maize followed by Two row of groundnut	1RoM: 2RoG
T3	Two rows of maize followed by one row groundnut	2RoM: 1RoG
T4	Two rows of maize followed by Two row of groundnut	2RoM: 2RoG
T5	Sole Maize	SM
T6	Sole Groundnut	SG

3.3 Planting

The two crop species were planted across each plot except the sole cropping systems. Planting method used was that use locally by the famers in the northern part of the country by the use of dibbler and a garden line to help get the crops in straight lines. At least three seed were planted per hole and later thinned to two per hole after the crop has germinated and emerged from the soil. Maize were planted at 80cm × 40cm for sole maize which gave31,250 plants/ha and 100cm × 40cm for the intercropping at plant population of 25, 000 /ha.

Two seeds of the groundnut were planted per hole and later thinned to one per hole after emergence. Planting was done at 80cm × 20cm for the sole groundnut at plant density of 62,500 plants /ha and 100cm × 20cm for the intercrop at a density of 50,000 plants/ha. Both crops were planted on the same day.

3.4 Fertilizer and weed managements

Two hands weeding with hoe were done at two and six weeks after planting. There was a third weeding which was done by ridging particularly for the maize to control lodging. N.P.K. at the rate of 250 kg ha^{-1} was applied to the maize two weeks after planting. The maize plants were top dressed with sulphate of ammonia (21%) at 125 kg ha^{-1} six weeks after planting. Side placement method of fertilizer application was used. No fertilizer was applied to the groundnut. This recommendation was based on common practice of the farmers at the location of the research.

3.5 Data collection

3.5.1 Growth parameters

Ten maize plants were tagged randomly in each plot. Data were collected on the plant height at 50% tasseling from all the ten plants and the mean per plot computed. Other data that were taken in relation to growth on the field were leaf area index of maize using the method of Mokhtarpour *et al.* (2010), with no measurement on the growth parameter of the groundnut.

3.5.2 Yield parameters

Grain yield were determined from each plot at harvest for both maize and groundnut. Maize grain yield was determined after harvesting, threshing, winnowing and weighing using electronic scale. For other parameters such as cob diameter and cob length,10 cobs were selected and measured by manual counting and measuring using a meter rule. For groundnut, 10 pods were selected at random and the pod diameter and pod length were measured after harvest. Kernel yield were also obtained after cracking the pods harvested from each plot. Grain and pod yield were measured using an electronic scale.

3.6 Computational statistics

3.6.1 Land equivalent ratio (LER)

Land equivalent ratio shows the effectiveness of intercropping over the pure stand. Land equivalent ratio more than 1 shows economic productivity of the intercrop over the pure stand and that it is advantageous to grow such crops in mixture than in pure stand and the vice –versa. In other to determine whether a given intercropping pattern is advantageous or more productive than the other, LER were calculated as;

$$\text{LER} = \frac{\text{Yim}}{\text{YM}} + \frac{\text{Yig}}{\text{YG}} \quad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Equation1}$$

(Willy and Rao, 1980)

Where Yim is the yield of maize in the intercrop

YM is the yield of maize in the sole cropping

Yig is the yield of groundnut in the intercrop

YG is the yield of groundnut in the sole cropping

3.6.2 Land equivalent coefficient (LEC)

Land equivalent coefficient measures the level of cooperation and complementarity between or among the component crops (Ghosh *et al.*, 2009). This was computed as

$$LEC = PLERm\ X\ PLERg \quad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Equation 2}$$

(Langat *et al.*, 2006)

Where, PLERm represents the partial land equivalent of maize and PLERg represents partial land equivalent of groundnut and it is usually expressed as a percentage. In an intercrop, any two crops in the mixture, the minimum land equivalent coefficient is 25%. This implies that yield and economic advantage is achieved only if the computed land equivalent ratio is 0.25 or 25 % and above (Agegnehu *et al.*, 2006)

3.7 Economic indices

3.7.1 Gross monetary returns (GMR)

This was determined using the prevailing farm gate price per given weight of each of the crops at the location of the experiment at harvest. All treatments were subjected to the same cost of production and management. This is because it provides the actual income that the farmer would receive after selling of the produce.

$GMR = unity\ price\ (\ Gh₵)\ x\ total\ yield\ (kilograms\ )$ ________________Equation 3

(Hugar and Palled, 2008)

3.7.2 Profitability

In orderto determine the actual amount of income a farmer may receive from any given pattern; net profit was calculated as:

$NP = Gross\ Monetary\ Returns - Total\ Production\ Cost$ ____________Equation 4

(Kermah *et al.*, 2017)

Taken into consideration the cost of major activity on the farm such as land preparation, planting, weed control, fertilizer management and harvesting. The Total Production Cost was obtained by summing the cost of this activities as at the time of the Research. All treatments were subjected to the same cost of production and management.

3.7.3 Monetary advantage index (MAI)

The MAI was calculated according to the formula.

$MAI = Value\ of\ combined\ intercrops\ x\ LER - 1$ ____________________ Equation 5

3.7.4 Benefit cost ratio

In other to determine the cost effectiveness of each of the pattern of intercropping, benefit cost ratio was calculated using the formula below:

$BCR = \frac{Gross\ Monetary\ Returns}{Total\ Cost\ of\ Production}$ ____________________ Equation 6

(Mondal *et al.*, 2012)

3.8 Data analysis

Research data were entered and exported to excel. Data were then subjected to analysis of variance (ANOVA) using GenStat statistical package (version 12.0) and the difference in means among various spatial arrangements were separated using least significant difference at 5 % level of probability.

CHAPTER FOUR

4.0 RESULTS

4.1 Effects of spatial arrangement on plant height of maize

The effect of spatial arrangement for plant height at Vani varied significantly(*P=0.032*). The sole maize at Vani recorded the highest height at tasseling. This was followed by the 1M: 1G at the same location. The 1M:2G recorded the lowest plant height at Vani. 1M:1G and 2M:2G recorded similar height. All spatial arrangement was significantly different (Figure 1).

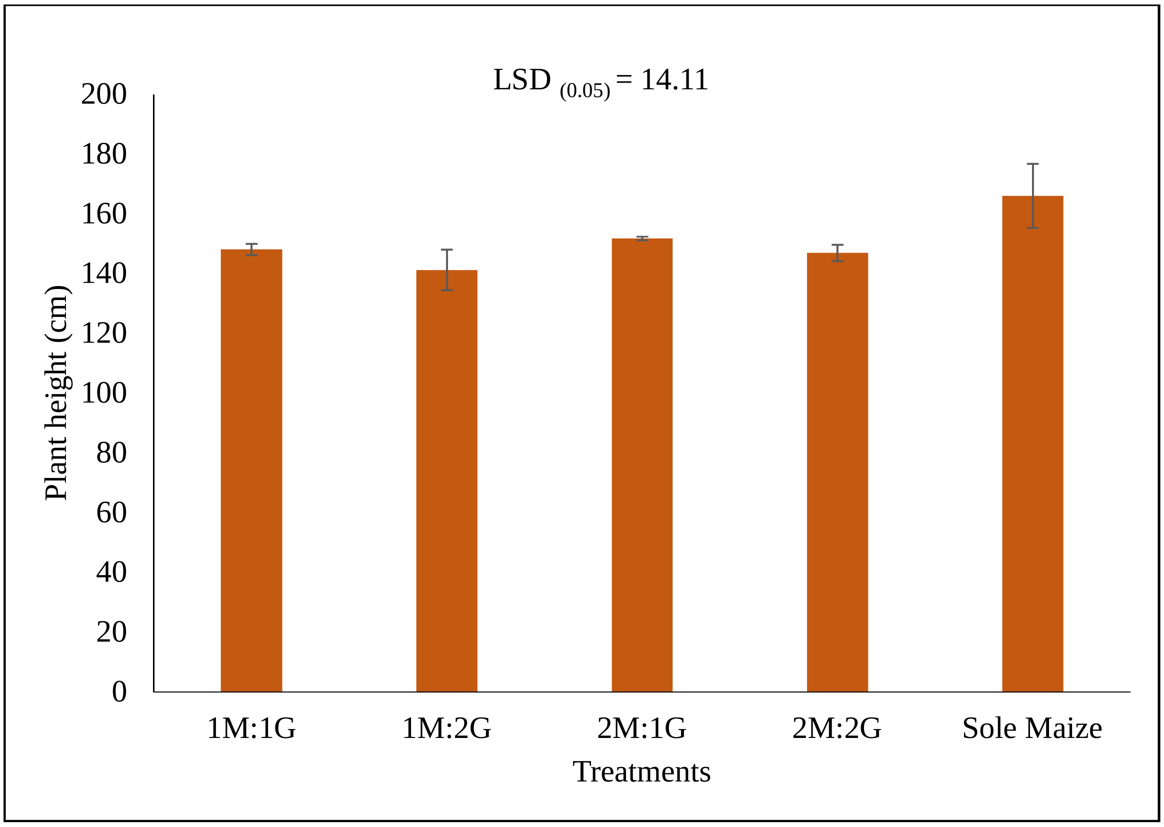

Figure 1: Effects of spatial arrangement on plant height of maize at Vani. Error bars represent standard error of means (SEM)

The effect of spatial arrangement for plant height at Zoggu was not significantly different (*P=0.583*). The sole maize at Zoggu recorded the highest height at tasseling but was not significantly different from all other treatments. All other treatments performed closely similar in terms of plant height at tasseling (Figure 2).

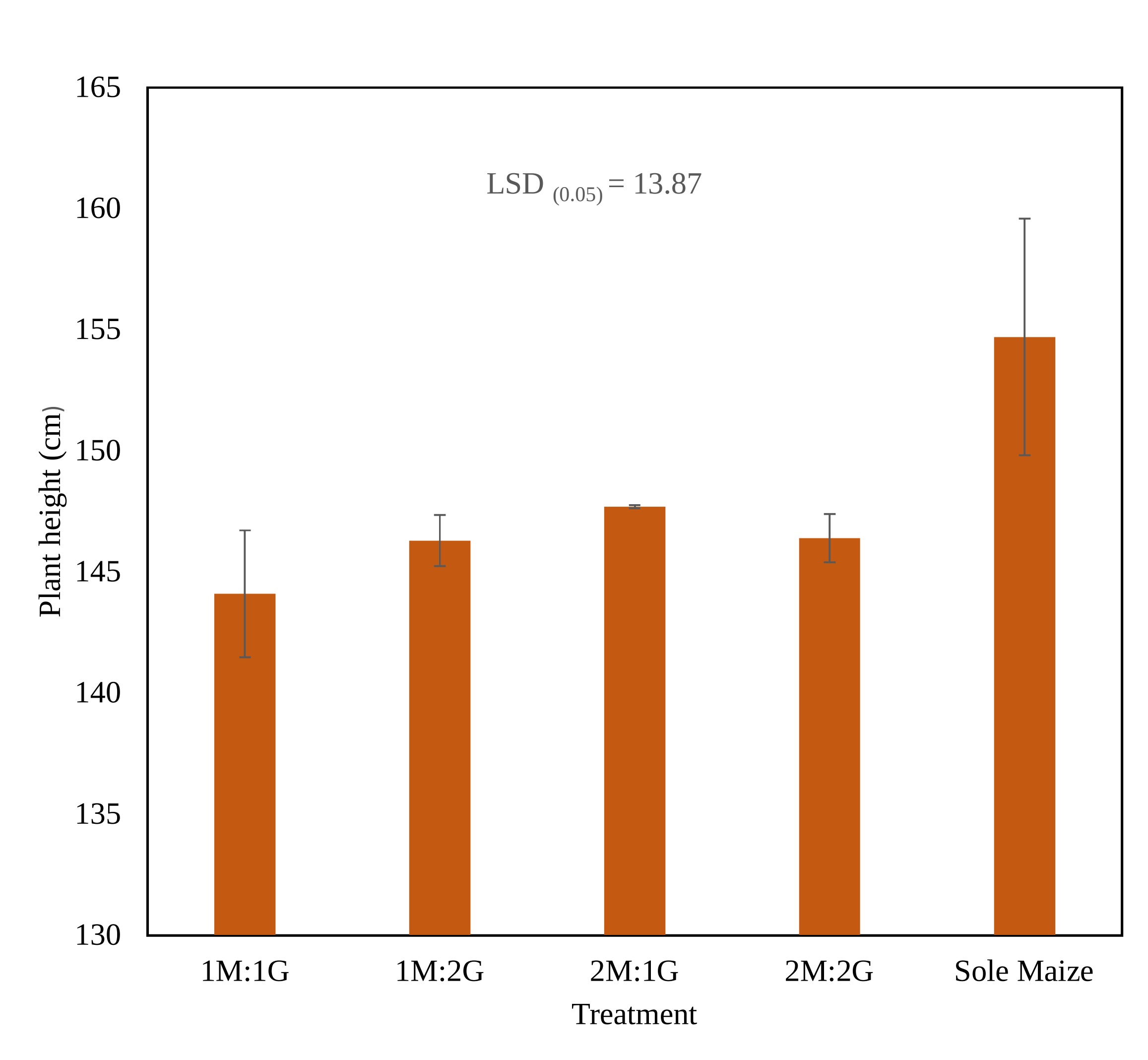

Figure 2: Effects of spatial arrangement on plant height of maize at Zoggu. Error bars represent SEM

4.0 Effects of spatial arrangement on maize cob length and weight

Cob length was not significantly influenced by spatial arrangements at Vani (*P=0.351)* though sole maize gave the longest cob (Table 2). All other treatments performed closely similar compared to the sole maize.

No significant difference was observed among treatments at Zoggu *(P= 0.370)* in terms of cob length. However, the one row of maize followed by two rows of groundnut recorded the highest cob length.

Table 2: Effects of spatial arrangement on cob length of maize

Location	Spatial Arrangement	Cob Length (cm)
Vani	1RoM: 1RoG	14.00
	1RoM: 2RoG	14.87
	2RoM: 1RoG	14.73
	2RoM: 2RoG	14.60
	SM	15.53
LSD		1.581
CV (%)		5.7
Zoggu	1RoM: 1RoG	12.77
	1RoM: 2RoG	14.60
	2RoM: 1RoG	13.63
	2RoM: 2RoG	13.27
	SM	13.90
LSD		2.020
CV (%)		7.9

4.3 Effects of spatial arrangement on cob weight

There was no significant difference among treatments (*P=0.837 and P=0.295* respectively for Vani and Zoggu) in terms of cob weight (Table 4). Sole maize recorded the highest cob weight at Vani. However, at Zoggu one row of maize followed by 2 rows of groundnut recorded the highest cob weight.

Table 3: Effects of spatial arrangement on cob weight of maize

Location	Spatial Arrangement	Cob Weight (g)
Vani	1RoM : 1RoG	142.1
	1RoM : 2RoG	130.5
	2RoM : 1RoG	133.0
	2RoM : 2RoG	136.4
	SM	143.1
LSD		1.581
CV (%)		5.7
Zoggu	1RoM : 1RoG	99.7
	1RoM : 2RoG	130.2
	2RoM : 1RoG	109.1
	2RoM : 2RoG	118.9
	SM	116.3
LSD		30.37
CV (%)		11.8

4.4 Effects of spatial arrangement on yield of maize

There were highly significant (*P= 0.001*) differences among the treatments for total grain yield at Vani. Sole maize recorded the highest performance in terms of grain yield followed by 1M: 1G. In between sole maize and 1M: 1G, there were not significant difference (Figure 3). At Zoggu there were significant differences (*P= 0.001*) with sole maize still recording the highest total grain yield followed by 1M:1G and 2M: 2G.

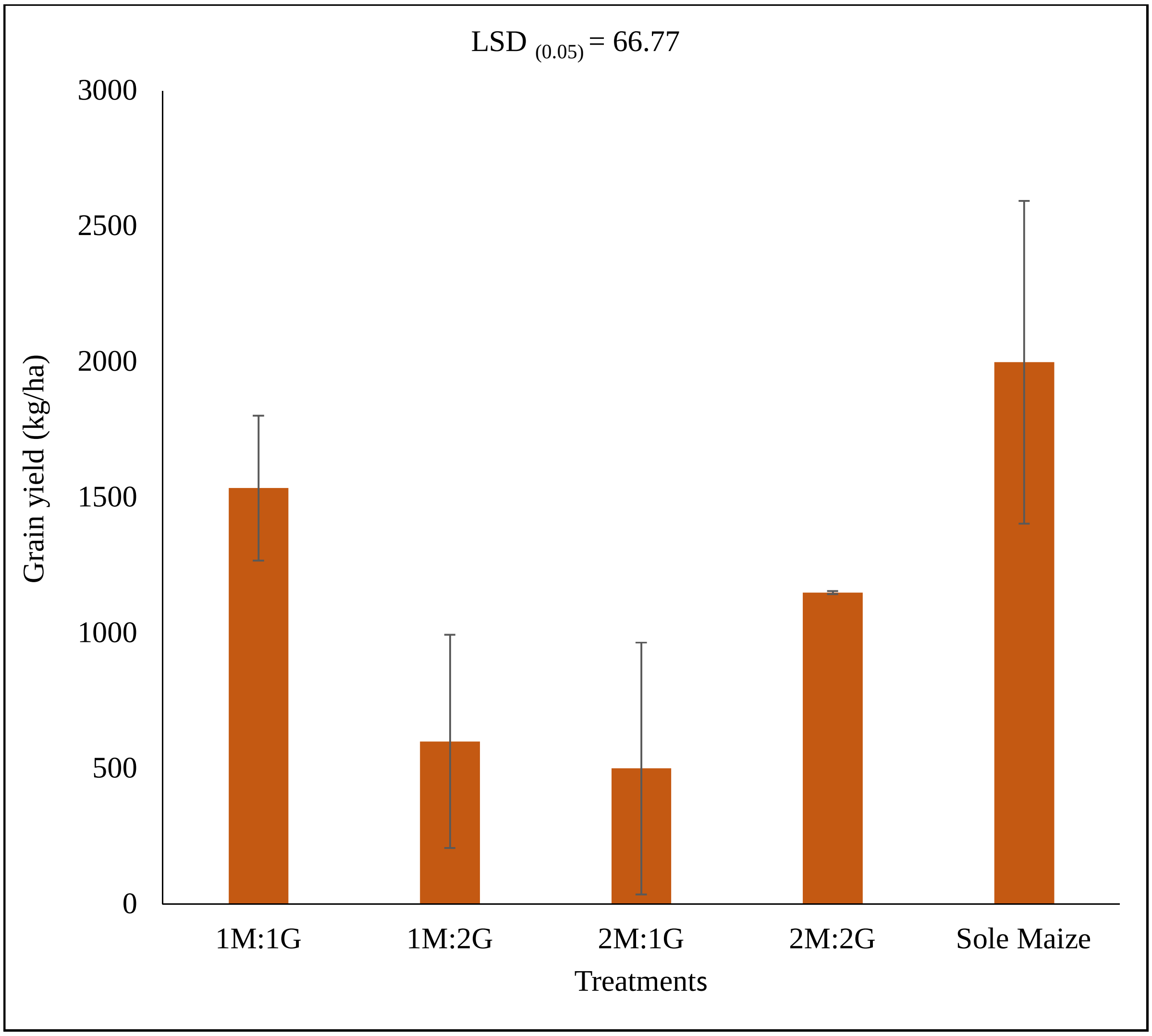

Figure 3: Effects of spatial arrangement on yield of maize at Vani. Error bars represent (SEM).

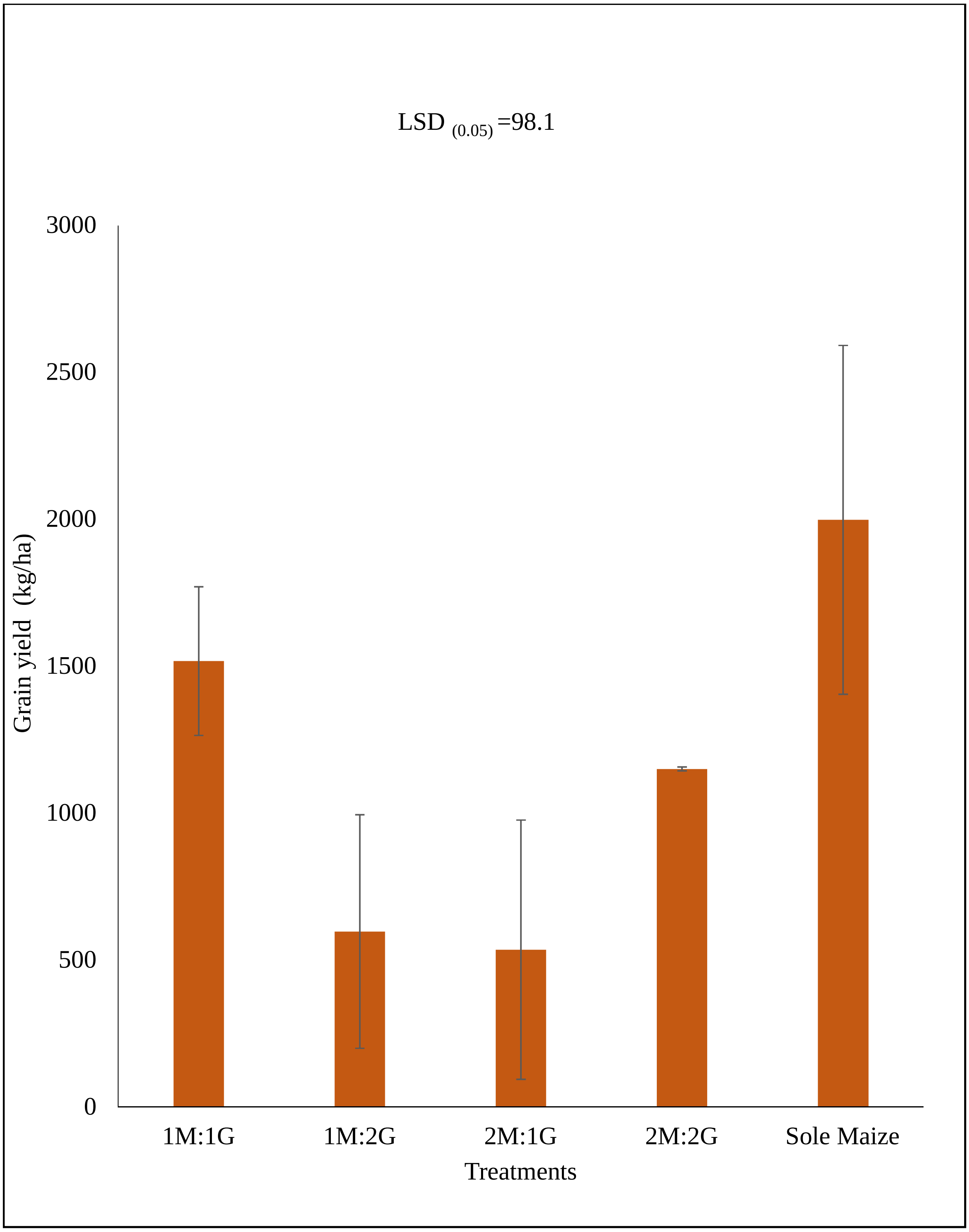

Figure 4: Effects of spatial arrangement on yield of maize at Zoggu. Error bars represent (SEM)

4.5 Effects of spatial arrangement on pod length of groundnut

The variation among treatments for pod length was not significant *(P = 0.398)*. 2RoM: 2RoG recorded highest pod length followed by 1RoM: 2RoG and 2RoM: 1RoG. Sole maize recorded the lowest pod length at Vani.

At Zoggu however, SM recorded the highest pod length though there was not significant difference *(P=0.458)* among treatments. 1RoM: 2RoG and 2RoM: 1RoG recorded almost the same pod length above 2RoM: 2RoG. 1RoM: 1RoM recorded the lowest pod length at Zoggu (Table 4).

Table 4: Effects of spatial arrangement on length of groundnut

location	spatial arrangement	pod Length (cm)
Vani	1RoM : 1RoG	2.9
	1RoM : 2RoG	2.90
	2RoM : 1RoG	2.90
	2RoM : 2RoG	3.03
	SG	2.85
LSD		0.2027
CV (%)		3.7
Zoggu	1RoM : 1RoG	2.13
	1RoM : 2RoG	2.82
	2RoM : 1RoG	2.83
	2RoM : 2RoG	2.70
	SM	3.00
LSD		1.087
CV (%)		21.4

4.6 Effects of spatial arrangement on pod diameter of groundnut

The variation among treatments in terms of pod diameter was not significantly different *(P=0.420)* at Vani. 1RoM: 2RoG recorded the highest pod diameter at Vani followed by sole groundnut (SG). 2RoM: 1RoG recorded lowest pod diameter after 2RoM: 2RoG and 1RoM: 1RoG.

At Zoggu, no significant difference *(P=0.066)* were observed among the spatial arrangements. However, similar trend was recorded were sole groundnut (SG) recorded highest pod diameter followed closing by 2RoM:2RoG. 2RoM: 1RoG still recorded the lowest pod diameter at Zoggu

Table 5: Effects spatial arrangement on pod diameter of groundnut

location	spatial arrangement	pod diameter (cm)
Vani	1RoM : 1RoG	1.45
	1RoM : 2RoG	1.49
	2RoM : 1RoG	1.40
	2RoM : 2RoG	1.46
	SG	1.48
LSD		0.1072
CV (%)		3.9
Zoggu	1RoM : 1RoG	1.31
	1RoM : 2RoG	1.48
	2RoM : 1RoG	1.27
	2RoM : 2RoG	1.51
	SG	1.53
LSD		0.2116
CV (%)		7.9

4.7 Effects of spatial arrangement on yield of groundnut

There were significant differences among the treatments at both sites in terms of kernel yield*(P= 0.033 and <0.001)*at Zoggu and Vani respectively (Figure 5). Though sole groundnut gave the highest yield, all other treatments performed alike at both locations. The intercrops were not significantly different in kernel yield at both sites.

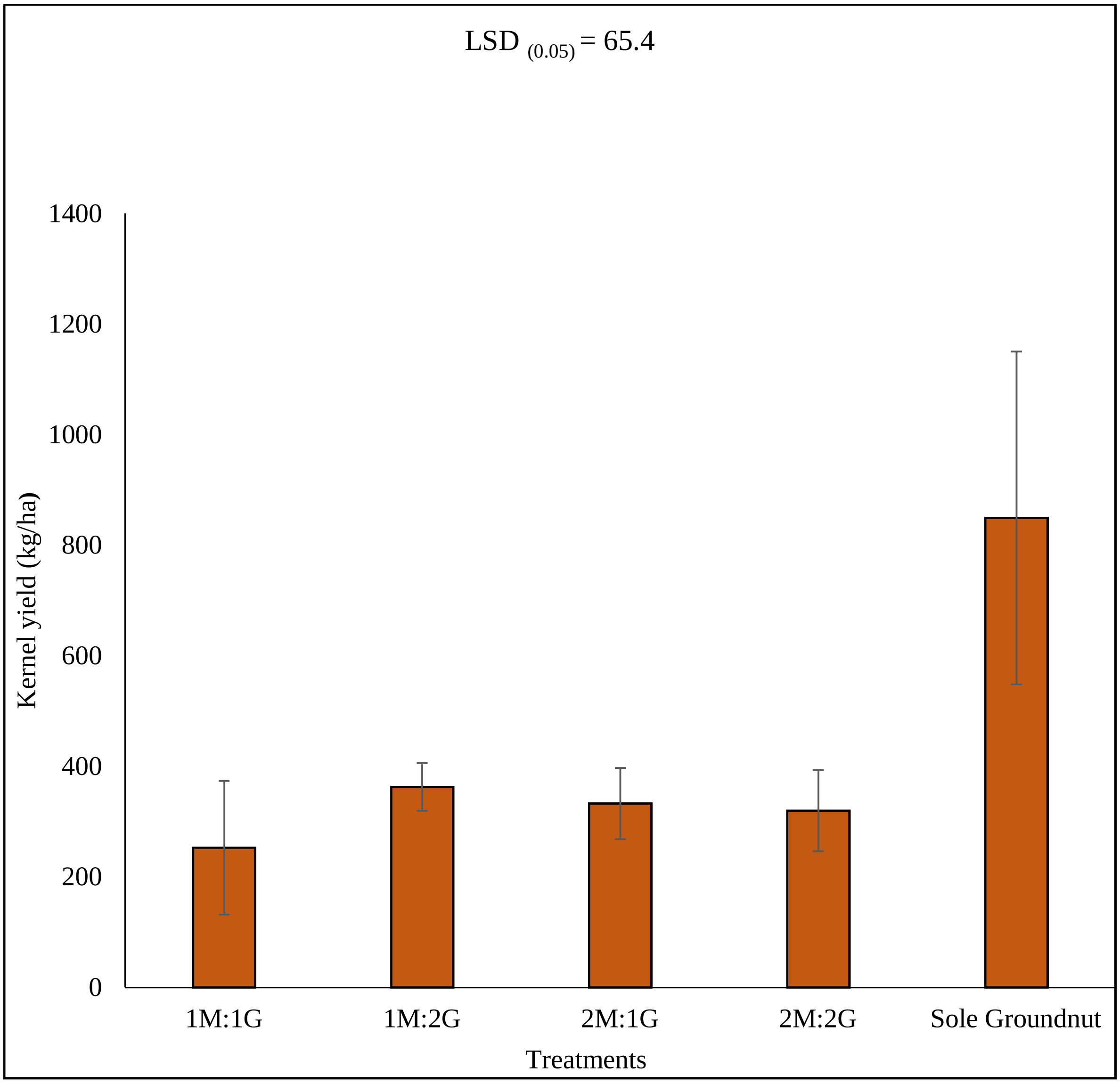

Figure 5: Effects of spatial arrangement on kernel yield of groundnut at Vani. Error bars represent (SEM)

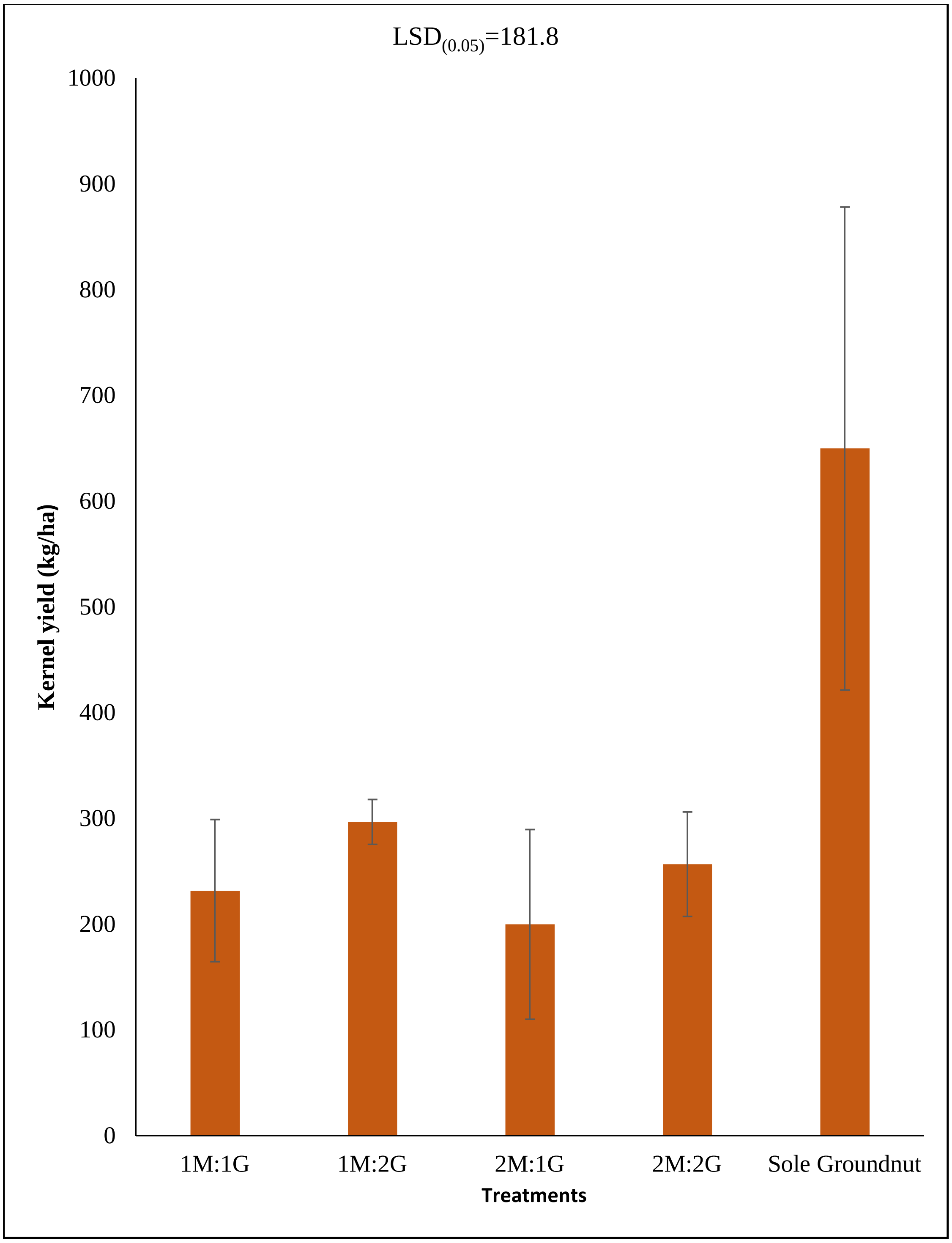

Figure 6: Effects of spatial arrangement on kernel yield of groundnut at Zoggu. Error bars represent (SEM)

4.8 Land equivalents ratio and land equivalents coefficient

Land equivalent ratio was calculated for maize/groundnut intercropping. At both locations, one row of maize followed by one row of groundnut recorded the highest land equivalent ratio (Table 6). Two rows of maize followed by two rows of groundnut performed similar to one row of maize followed by one row of groundnut. The 1RoM: 2RoG and 2RoM:1RoG combinations gave lesser land equivalent ratio Similar performance was recorded for land equivalent coefficient. In terms of land equivalent coefficient, one rows of maize followed by one row of groundnut gave better results than any of the spatial arrangements at both locations. It was only 1RoM:1RoG at Zoggu that recorded LEC value which was higher than the 0.25 bench mark for land equivalent coefficient (Table 7). The 1RoM:2RoG or 2RoM: 1RoM spatial arrangement gave the low LEC values at both locations (Table 6).

Table 6: Land equivalent ratio and land equivalents coefficient at Vani

location	spatial arrangement	land equivalent ratio	land equivalent coefficient
Vani	1RoM : 1RoG	1.07	0.23
	1RoM : 2RoG	0.73	0.13
	2RoM : 1RoG	0.25	0.10
	2RoM : 2RoG	0.95	0.22
	SM	_	_
	SG	_	_

Table 7: Land equivalent ratio and land equivalents coefficient at Zoggu

location	spatial arrangement	land equivalent	land equivalent coefficient
Vani	1RoM : 1RoG	1.12	0.27
	1RoM : 2RoG	0.76	0.14
	2RoM : 1RoG	0.58	0.08
	2RoM : 2RoG	0.97	0.23
	SM	_	_
	SG	_	_

4.9 Gross monetary returns and profitability

The gross monetary returns depend directly on yields and price paid for the product. At Vani, sole groundnut recorded higher monetary and profitability than the other spatial arrangements though one row of maize followed by one row of groundnut performed closely well (Table 8). It was that 1RoM:1RoG and 2RoM: 2RoG combinations gave GMR that were better than sole maize. The reverse trend was observed at Zoggu where 1RoM:1RoM gave the highest monetary returns and profitability.2RoM: 1RoG recorded the lowest gross monetary return and profitability at both locations.

Table 8: Gross monetary returns and profitability

Location	Treatments	Gross monetary returns (GH₵/ha)	Profitability (GH₵/ha)
Vani			
	1RoM: 1RoG	3312.85	1512.85
	1RoM: 2RoG	2352.00	552.00
	2RoM: 1RoG	2082.00	282.00
	2RoM: 2RoG	3002.75	1202.75
	SM	2997.30	1197.30
	SG	3400.00	1600.00
Zoggu			
	1RoM: 1RoG	3203.50	1403.50
	1RoM: 2RoG	2083.50	283.50
	2RoM: 1RoG	1602.50	-197.50
	2RoM: 2RoG	2753.00	953.00
	SM	3002.00	1185.00
	SG	2600.00	800.00

4.10 Monetary advantage index

The highest monetary advantage index (MAI) was recorded by 1RoM:1RoG at Vani (Table 10**)**. At the same location, sole groundnut (SG) recorded higher monetary advantage index (MAI) than sole maize (SM). The 2RoM: 2RoG or 1RoM:1RoG combinations of maize and groundnut were better than 2RoM: 1RoGor 1RoM: 2RoG combinations in monetary advantage index (MAI).

At Zoggu 1RoM: 1RoG recorded higher MAI than other combinations (Table 9). At that site sole maize outperformed sole groundnut in MAI. 2RoM: 2RoG also recorded higher MAI then sole groundnut. It is significant to note that 2RoM: 1RoG at both sites recorded low MAI

Table 9: Effects of spatial arrangement on monetary advantage index at Zoggu

Location	Treatment	MAI
Zoggu	1RoM: 1RoG	5700.34
	1RoM: 2RoG	2410.651
	2RoM: 1RoG	1425.67
	2RoM: 2RoG	4209.561
	SM	4989.01
	SG	3754.56

Table 10: Effects of spatial arrangement on monetary advantage index at Vani

Location	Treatments	MAI
Vani		
	1RoM: 1RoG	3543.75
	1RoM: 2RoG	1715.96
	2RoM: 1RoG	519.50
	2RoM: 2RoG	2851.61
	SM	2996.30
	SG	3399.00

4.11 Benefit cost ratio

The benefit cost ratio of sole groundnut (SG) at Vani was higher than the other combinations (Table 11). 1RoM: 1RoG combination recorded higher benefit cost ratio than all intercrops.

However, at Zoggu 1RoM: 1RoG combination gave higher BCR than all intercrops and monoculture. It is significant to note that 2RoM: 1RoG at both sites recorded low BCR

Table 11: Benefit cost ratio of maize-groundnut intercropping system

Location	Treatments	BCR
Vani	1RoM: 1RoG	1.84
	1RoM: 2RoG	1.31
	2RoM: 1RoG	1.16
	2RoM: 2RoG	1.67
	SM	1.67
	SG	1.89
Zoggu	1RoM: 1RoG	1.78
	1RoM: 2RoG	1.16
	2RoM: 1RoG	0.89
	2RoM: 2RoG	1.53
	SM	1.67
	SG	1.44

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effects of spatial arrangement on plant height of maize

The plant height of maize was affected by intercropping system at Vani. Sole maize grew taller than intercropped maize. This could be associated with competition between the two crops as a result of the spatial arrangement among the treatments. This implies that the row intercropping used poses a competitive threat to the cooperation. In maize- mung bean intercrop, maize did not record a significant reduction in height as a result of the spatial arrangement (Tohura, 2010). This finding contradicts the results at Vani where the maize plant height at tasseling was greater in the sole cropping than in the intercrop at both locations. This could probably be associated with high interspecific competition for available resources especially for water and space and soil nutrients between the component crops. Low intra competition made the sole maize to have grown vigorously higher than intercrops. Konlan *et al.*(2016) reported similar results in intercropping three groundnut varieties with maize in the Guinea Savanna Region of Ghana. Nyoki and Ndakidemi (2016) in their research with other legumes such as cowpea and lablab reported similar results such that, the sole maize was performing higher in terms of plant height than the maize-legume intercropped. Jaja and Ikechukwu (2018) reported higher plant height in sole maize than intercrop in assessing the effects of different rates of organic manure on maize and groundnut intercropping system.

5.2 Effects of spatial arrangement on cob weight and cob length of maize

Yield components of maize such as cob weight and cob length in the mixture were not affected. Though the monoculture performed better in terms of cob weight and cob length, this did not transform to any significant difference in terms of the two yields component. This means inter-specific competition among the component crops that lead to splitting of available resources between the component crops was minimal. Bhatnagar *et al.*(2007) in assessing the productivity and profitability of different legumes including groundnut reported in their findings that two rows of maize followed by two rows of groundnut did not affect cob length and weight.

5.3 Effects of spatial arrangement on pod diameter and pod length of groundnut

The result showed that, there were no variations in pod length of groundnut among the treatments. This situation might be due absence of intercrop competition for light, nutrients, moisture, and space. This corroborates with the findings of Islam *et al.* (2014) in assessing the effects of intercropping hybrid maize with sweet potato and Lemlem (2013) also reported similar results in assess the effects of intercropping on maize with cowpea and lablab. At Vani 1RoM: 2RoG recorded the higher pod diameter this could have been due to the available space for groundnut hence reduced inter competition for nutrients, water and light. Higher pod diameter in sole groundnut also confirmed this finding. This fall in line with Nyasasi and Kisetu (2014) findings in determining the land productivity of maize-cowpea intercrop.

5.4 Effects of spatial arrangement on yield of maize and groundnut

It was noted that, maize recorded lower yield in all its respective intercrops compared to the monoculture in the experiment. The lower grain yield might have been due to lower plant population of maize and competition for nutrients moisture and space. However, additional yield from groundnut also gave extra yield and income to the farmer.

The yield reduction of maize was more when intercropped with two 2 rows of groundnut and one row of groundnut. Alom *et al.*(2009) observed high yield of maize in monoculture compare to the intercrop in maize–groundnut system. Similar finding have been reported by (Egbe, 2010) in other legumes such as soybean.

The yield of groundnut was significantly influenced by the intercrop. The highest kernel yield was recorded in monoculture groundnut. These kernel yield differences in the intercropping mixtures were mainly due to the differential plant population per unit area and interspecific competition. The kernel yield of groundnut in intercropping situation was considerably reduced to about half of the monoculture. This corroborates with the findings of Bhatnagar *et al.*(2007) and Islam *et al.*(2014) that differences in yield of intercrop in spatial arrangement between two crops are mainly due to variation in plant population. However, Mandal *et al.*(2014) have reported higher yield of groundnut in one row of maize followed by two rows of groundnut than the monoculture.

Among the intercropping treatments, one row of maize followed by two rows of groundnut had higher kernel yield though the difference was not significant. This is also in conformity with the findings of Mandal *et al.*,(2014) reported higher yield of groundnut in 1:2 ratio combination in evaluating the productivity of maize- groundnut intercropping system.

5.5 Land equivalent ratio and land equivalent coefficient

Land equivalent ratio values greater than one indicates yield advantages of intercropping over monoculture. LER less than1indicates that more land is needed in the intercrop to equal the productivity of the monoculture (Willey, 1979).

The LERs of Vani ranged from 0.25 to 1.07 and that of Zoggu ranged from 0.58 to 1.12. It appears that intercrop design that allows equal number of rows of component crops to follow each other either as singly or double rows look good. In this study one row of maize followed one row of groundnut was 7 % better than monoculture situation and revealed relative advantage of the intercrop over the monoculture. The other intercrop combinations shows disadvantage over the monoculture Similar findings were reported by Konlan *et al.* (2014) who reported LER of ranging from 0.9 to 1.12 in assessing the effects of maize –groundnut intercropping

For any two-crop mixture, the minimum expected land equivalent coefficient (LEC) is 25 %, that is, a yield advantage is obtained if LEC value exceeds 0.25 (Alhassan and Egbe, 2014).One row of maize followed by one row of groundnut at Zoggu recorded 27 % LEC over all other combinations. Mandal *et al.* (2014) reported higher LEC of 85 % in two rows maize followed by 2 rows of groundnut.

5.6 Economic indices

5.6.1 Gross monetary returns

Higher gross monetary returns were obtained by monoculture groundnut at Vani. This finding disagrees with Matusso and Mugwe (2013) report where sole soybean gave less income compared with one row of maize followed by one row of soybean. However, at Zoggu, one row of maize followed by one row of groundnut recorded higher gross monetary returns. This was due to high maize yields in sole maize that brought about the higher income and higher unit price of groundnut of groundnut. This findings perfectly agreed with Matusso and Mugwe (2013) where the proportion of one row of maize followed by one row of soybean in cereal-legume intercropping gave a higher gross monetary returns to the farmers than the component crop grown in monoculture.

5.6.2 Profitability

Higher profitability was obtained by monoculture groundnut at Vani due to high yield and price value of a unit of groundnut. Among the combinations at both sites, 1RoM: 1RoG recorded high value for profitability. This finding corroborate with Bhatnagar *et al*. (2007) who reported high profitability in 2 : 2 or 1:1 ratio arrangement than sole maize and groundnut. This was due to high maize yields in sole maize that brought about the higher income and higher unit price of groundnut.

5.6.3 Monetary advantage index

All intercrop combinations gave positive monetary advantage index which indicates yield advantage. 1RoM: 1RoG recorded higher positive MAI at both site among the intercrop combinations. This was in line with (Khonde *et al.*, 2018) findings which reported higher positive MAI in maize soybean intercrop. Earlier, Kheroar *et al.* (2013) also reported high positive MAI in maize- groundnut intercropping with 1 : 1 ratio combination.

5.6.4 Benefit cost ratio

Sole groundnut showed higher benefit cost ratio than any of the intercrops at Vani. This was due to high demand and high price of groundnut at the time of harvest which brings in more income to the farmer. The intercrop combination, one row of maize followed by one row of groundnut performed very well and was the best among the intercrops. All intercrops have BCR more than 1 which indicate economic benefit in practicing the pattern. In maize- mung bean intercrop, Tohura (2010) reported high BCR above one in maize-mung bean intercropping system.

One row of maize followed by one row of groundnut gave high benefit cost ratio at Zoggu. The 50 : 50 combinations appears to compete well with the monoculture.

The results also suggest the possibility of obtaining a reasonable good yield and profitable economic return from intercropping maize with groundnut having the row arrangement of two row of maize in between two rows of groundnut. Mondal *et al.* (2012) reported higher BCR in two rows of carrot intercropped with two rows of groundnut.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Intercropping maize with groundnut does not affect cob length and cob weight of maize. Similarly, pod length and pod diameter of groundnut were not affected by the spatial arrangements. For plant height it was not conclusive as the two sites gave different outcome. Yield of both maize and groundnut were adversely affected by the intercropping at both Vani and Zoggu and this was expected due to land available to the intercrop and inter-competition for nutrients and light compare with monoculture situation.

Land equivalent ratio (LER) indicates that one row of maize followed by one row of groundnut could give additional 7 % and 12 % yield advantage over other monoculture at Vani and Zoggu respectively.

It was only 1RoM: 1RoG at Zoggu that the land equivalent coefficient exceeded the minimum 25 % required for economic advantage in intercropping system. The 1RoM: 1RoG and 2RoM: 2RoG maize – groundnut intercropping system recorded 23 % instead of 25 %.

High gross monetary returns and profitability were realized from the sole groundnut. 1RoM: 1RoG and 2RoM: 2RoG were similar to sole cropping in gross monetary returns and profitability at the two sites.

High positive monetary advantage index was achieved at Vani by practicing sole cropping of groundnut. 1RoM: 1RoG spatial arrangement recorded the best monetary advantage index among the combinations.

1RoG and 2RoM: 2RoG spatial arrangement of maize and groundnut were similar to sole groundnut and maize in terms of benefit cost ratio

Although maize in monoculture produced higher grain yield than their intercrops, one row of maize followed by one row of groundnut gave high benefit cost ratio than other spatial arrangements at both locations except sole groundnut at Vani was the only treatment that gave yield advantage which was higher than the monoculture.

One row of maize followed by one row of groundnut gives additional advantage in terms of yield, monetary advantage index, and benefits cost ratio for groundnut and maize production.

It can be concluded that having equal rows of maize and groundnut following each other is the best intercropping system for maize and groundnut.

6.2 Recommendations

In groundnut and maize intercropping system it is recommended that farmers should adopt one row of maize followed by one row of groundnut or two rows of maize followed by two rows of groundnut maize – groundnut intercropping system for high economic profitability for high economic profitability.

Further studies should be done on other types of intercropping such as relay–intercropping, mixed intercropping and strip inter cropping rather than row intercropping. This is due to the fact that there could be more relative advantage of those types as compared to the row–intercropping system.

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APPENDICES

Appendix 1: Analysis of variance for plant height of maize at 50% tasseling at vani (experiment 1)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	263.3	131.7	0.98	
Rep.*Units* stratum					
Trt	4	391.9	98.0	0.73	0.583
Residual	23	3104.0	135.0		
Total	29	3759.3			

Appendix 2: Analysis of variance for plant height of maize at 50% tasseling at Zoggu (experiment 2)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	110.73	55.36	0.99	
Rep.*Units* stratum					
Trt	4	1039.59	259.90	4.62	0.032
Residual	8	449.59	56.20		
Total	14	1599.91			

Appendix 3: Analysis of variance for cob length of maize at experiment 1 (Vani)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	1.1573	0.5787	0.82	
Rep.*Units* stratum					
Trt	4	3.6373	0.9093	1.29	0.351
Residual	8	5.6427	0.7053		
Total	14	10.4373			

Appendix 4: Analysis of variance for cob length of maize at experiment 2 (Zoggu)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	5.929	2.965	2.57	
Rep.*Units* stratum					
Trt	4	5.673	1.418	1.23	0.370
Residual	8	9.211	1.151		
Total	14	20.813			

Appendix 5: Analysis of variance for cob weight at experiment 1 (Vani)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	207.1	103.5	0.40	
Rep.*Units* stratum					
Trt	4	364.4	91.1	0.35	0.837
Residual	8	2081.0	260.1		
Total	14	2652.5			

Appendix 6: Analysis of variance for cob weight at experiment 2 (Zoggu)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	545.4	272.7	1.04	
Rep.*Units* stratum					
Trt	4	1545.5	386.4	1.48	0.295
Residual	8	2090.8	261.4		
Total	14	4181.7			

Appendix 7: Analysis of variance for maize grain yield at experiment 1(Vani)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	6764	3382	2.69	
Rep.*Units* stratum					
Treatment	4	4774990	1193748	949.22	<.001
Residual	8	10061	1258		
Total	14	4791815			

Appendix 8: Analysis of variance for maize grain yield at experiment 2(Zoggu)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	3577	1788	0.66	
Rep.*Units* stratum					
Treatment	4	4613470	1153367	424.74	<.001
Residual	8	21724	2715		
Total	14	4638770			

Appendix 9: Analysis of variance for pod diameter of groundnut for experiment 1 (Vani)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.002613	0.001307	0.40	
Rep.*Units* stratum					
Trt	4	0.014240	0.003560	1.10	0.420
Residual	8	0.025920	0.003240		
Total	14	0.042773			

Appendix 10 : Analysis of Variance for pod diameter of groundnut for experiment 2 (Zoggu)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.00316	0.00158	0.13	
Rep.*Units* stratum					
Trt	4	0.17224	0.04306	3.41	0.066
Residual	8	0.10104	0.01263		
Total	14	0.27644			

Appendix 11: Analysis of variance for pod length of groundnut for experiment 1 (Vani)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.00912	0.00456	0.39	
Rep.*Units* stratum					
Trt	4	0.05349	0.01337	1.15	0.398
Residual	8	0.09275	0.01159		
Total	14	0.15536			

Appendix 12:Analysis of variance for pod length of groundnut for experiment 2 (Zoggu)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.4750	0.2375	0.71	
Rep.*Units* stratum					
Trt	4	1.3435	0.3359	1.01	0.458
Residual	8	2.6681	0.3335		
Total	14	4.4866			

Appendix 13: Analysis of variance for kernel yield of groundnut for experiment 1 (Vani)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	1720	860	0.13	
Rep.*Units* stratum					
Trt	4	699960	174990	27.30	<.001
Residual	8	51280	6410		
Total	14	752960			

Appendix 14: Analysis of variance for kernel yield of groundnut for experiment 2 (Zoggu)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	50770	25385	2.72	
Rep.*Units* stratum					
Trt	4	406240	101560	10.89	0.003
Residual	8	74580	9322		
Total	14	531590			