AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT (AAMUSTED)

MAMPONG-ASHANTI

Effect of intercropping different varieties of groundnuts (*Arachis hypogaea* L.) with maize (*Zea mays* L.) on growth, yield, and productivity (LER) in the forest-Savannah transition zone of Ghana.

ISAAC NTEKOR

MASTER OF PHILOSOPHY (AGRONOMY)

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A THESIS IN THE DEPARTMENT OF CROP AND SOIL SCIENCES EDUCATION, FACULTY OF AGRICULTURE EDUCATION, SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF PHILOSOPHY (AGRONOMY)

OCTOBER, 2023

DECLARATION

STUDENT'S DECLARATION

I, Isaac Ntekor declare that except for references to the works of other researchers which have been duly cited and acknowledged, this research is the result of my own effort and that no part or whole has b been presented for another degree elsewhere.

Signature…………………………………….

Date………………………..………………

SUPERVISORS' DECLARATION

We hereby declare that this work has been supervised according to the guidelines for the Supervision of the postgraduate thesis as laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development

Prof. (Mrs.) Margaret Esi Essilfie (Principal Supervisor)

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Date…………………………….

Prof. Harrison K. Dapaah (Co-Supervisor)

Signature…………………………

Date…………………………….

DEDICATION

This thesis is dedicated to the Almighty God and the unwavering support, love, and encouragement of my parents, Mr. and Mrs. Ntekor, for their sacrifices, endless patience, and belief in my abilities.

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LIST OF ABBREVIATIONS

LER	Land equivalent ratio
SP	Spatial arrangement
VC	Varietal combination
HSD	Honestly Significant Difference
CV	Coefficient of variation
DAP	Days after planting
HI	Harvest index
CCL	Chlorophyll content of leaf
FAW	Fall armyworm
SSA	Sub-Saharan Africa
1M	1-Row maize
2M	2-Rows maize
3M	3-Rows maize
1G	1-Row groundnut
2G	2-Rows groundnut
3G	3-Rows groundnut
CSIR-CRI	Council for Scientific and Industrial Research of Crop Research Institute
DUS	Distinctness Uniformity and Stability
VCU	Value for Cultivation and Use
DSW	Dry shoot weight

ABSTRACT

Two field experiments were conducted during the minor rainy season, from August to December 2021 and the major rainy season, from March to July 2022 to determine the effect of intercropping different varieties of groundnut with maize on growth, yield, and productivity. A 3 x 3 factorial experiment trial in Randomized Complete Block Design (RCBD) plus four sole crops with four replications was used. Factors studied were; (A) three varietal combinations [(i) Opeaburo + Yenyawoso, (ii) Opeaburo + Dehye, and (iii) Opeaburo + Oboshie)] and (B) three spatial arrangements; [(i) SP1 = 1-row maize alternating with 1-row groundnut, (ii) SP2 = 1-row maize alternating with 2 rows groundnut, and (iii) SP3 = 1-row maize alternating with 3 rows groundnut)] plus four sole crops. The results showed that Yenyawoso intercropped with Opeaburo at SP2 and SP3 emerged and flowered earlier and had a higher percentage plant establishment. Dehye intercropped with Opeaburo at SP2 and SP3 resulted in higher plant height and increased branching. Oboshie intercropped with SP2 and SP3 had higher leaf chlorophyll content and dry shoot weight. Oboshie intercropped with Opeaburo at SP2 and SP3 and Yenyawoso intercropped with Opeaburo at SP2 and SP3 enhanced 100-seed weight, pod yield, seed yield, harvest index (HI), shelling percentage (%), and LER of the groundnuts.

For maize, Opeaburo intercropped with Dehye at SP1 and intercropped with Yenyawoso at SP2 had higher plant establishment for both seasons. Opeaburo intercropped with Yenyawoso, Oboshie, and Dehye at SP2 and SP3 had higher plant height, leaf chlorophyll content, and dry shoot weight. Opeaburo intercroped with Oboshie at SP2 and SP3 and intercropped with Yenyawoso at SP2 and SP3 enhanced stover weight, cob diameter and length, 100-seed weight, grain yield, harvest index (HI), shelling percentage (%), and LER of the maize crop.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Maize (*Zea mays* L.) is one of the most important cereal crops used in the human diet in large parts of the world and is also an important feed component for livestock (Human *et al*., 2019). It is regarded as the third most important cereal in the world after wheat and rice in the area cultivated and total production (Oladejo & Adetunji, 2012). According to Kaoema (2020), for the past three years in Ghana, the total maize production in Ghana has been estimated as 2,303 – 2,759 MT in 2018 – 2019 (FAO, 2020).

Dapaah *et al*. (2014) reported that groundnut is an important cash crop grown in Ghana by smallholder farmers in sole stands or mixed with other crops because of its massive protein content (22 – 30 %) and edible oil content (38 – 50 %). It is an increasingly popular and valuable food, feed, and cash crop in Ghana, notably in the Guinea savanna and forest-savanna transition agro-ecological zones (Breisinger *et al*., 2010). The crop has high commercial and nutritional values because of its high protein, fatty acid, vitamins, oil, carbohydrates, and minerals content. As stated by Janila & Mula (2015), groundnuts are rich in essential nutrients which are potential to provide health benefits.

Intercropping is one of the oldest practices that has remained a dominant form of agriculture in many parts of the world (Brooker *et al*., 2015). According to Somefun (2020), intercropping refers to cropping methods that produce two or more crops concurrently or simultaneously on the same plot of land in order to maximize yield. Smallholder farmers in Africa have long used intercropping, which is now gaining popularity due to its potential for maximizing land usage while producing high yields with minimal inputs (such as nitrogen fertilizer) (Martin-Guay *et al*., 2018). Intercropping also reduces pests and diseases (Zhang *et al*., 2019) and in agricultural systems, it can boost soil organic matter and nitrogen retention (Cong *et al*., 2015). The most often grown intercrop in the world is a combination of cereals and legumes (Martin-Guay *et al*., 2018). According to Pelzer *et al*. (2014), the intercropping of cereal and legumes has been promoted specifically for the purpose of acquiring nitrogen (N). Both cereals and legumes absorb nitrogen (N) from the soil solution; however, only the legumes fix nitrogen (N) from the air through symbiosis with nitrogen-fixing bacteria in root nodules. Due to less competition for nitrogen (N) since legumes get some of their nitrogen from the air, cereals thrive better in a mixture with a legume than in a single stand at low soil nitrogen (N) supply. The core objective of intercropping cereal with legumes is to produce the best harvest possible on a particular piece of land while making effective use of resources, which is impossible with sole cropping (Ouma and Jeruto, 2010). Additionally, it increases the variety of crops produced, the amount of organic manure and feed available, soil fertility, soil cover, and physical support (Pawan *et al*., 2012a).

1.2 Problem Statement and Justification

Intercropping cereals and legumes is still a predominant cropping system among smallholder farmers in Ghana. In the Guinea and Sudan Savannah zones of Ghana, intercropping cowpea or groundnuts with sorghum, millet or maize is predominant, while in the humid zones (forest and forest savannah transition zones), intercropping maize with cowpea or groundnuts is dominant or common among farmers. Intercropping can provide higher yields with fewer inputs (such as nitrogen fertilizer) and has the potential to maximize land use and, therefore, has been utilized by smallholder farmers in Ghana and Africa (Li *et al*., 2020a). The maize-groundnut intercrops practiced by farmers in the transition zone have been characterized by low crop yields and overall productivity. This is because most farmers still use low-yielding varieties, especially the groundnuts and also with the row arrangements to be adopted. New varieties of groundnuts have been released by the CSIR-Crops Research Institute which have had limited testing in intercropping systems compared with sole cropping. Additionally, examining the varieties under different row arrangements might increase the overall performance and productivity of the intercrop systems. Intercropping can create a more diverse and stable ecosystem in your field, attracting natural predators and beneficial insects that feed on fall armyworm larvae and eggs. Fall armyworms tend to thrive in monoculture fields where a single crop dominates (Harrison *et al*., 2019).

Proper planting pattern is very important to increase crop yield (Gulluoglu *et al*., 2016). Again, research conducted by Olayinka (2017) indicated that growth characters such as the number of leaves and leaf area were improved in 3-rows of groundnut alternating with 1-row maize (3G:1M) and 3-rows of groundnut alternating with 2-rows maize (3G:2M) spatial arrangement compared to 3-rows of groundnut alternating with 3-rows maize (3G:3M) and their respective sole cropping. Improvement in yield was also seen in the intercrops compared to their soles. The 3-rows of groundnut alternating with 3-rows maize (3G: 3M) produced groundnut seeds with increased percentage ash, fibre, and crude protein compared to other spatial arrangements and sole groundnut. The results showed that 3 rows of groundnuts alternating with 1-row maize 3G: 1M and 3-rows of groundnuts alternating with 2-rows maize 3G: 2M could be considered as appropriate spatial arrangements for improving the growth and yield of the intercrop.

According to research done by Naaba (2017), a 2:2 intercrop configuration produced the highest grain yield of maize and Roselle leaf yield (1685.4 kg and 16981.3 kg/ha, respectively) when examining the effects of cropping systems and intercropping on the post-harvest quality of maize and roselle. The next-highest grain output was provided by a 1:2 intercrop system with Roselle and maize. However, the intercropping of two rows of roselle and two rows of maize generated the highest yield and the greatest amount of money. Intercrop patterns that generated 1:2 produced the least. Every intercropping arrangement conserves a sizeable percentage of the land that would otherwise be required by a monocropping plan to get the same outcomes.

A lot of research has been done on intercropping but limited attention has been given to the spatial arrangement, especially maize-groundnut intercrop in Ghana. Therefore, it is observed that systems of maize and groundnut intercropping with a good spatial arrangement will provide a variety of intercropping alternatives that will address issues with insect pest infestation and soil fertility, leading to high yields and profitability.

1.3 Objectives of the Study

The main objective of the study was to determine the effect of intercropping different varieties of groundnuts with maize on growth, yield, and productivity (LER) in the forest-Savanna transition zone of Ghana.

The specific objectives of the study were to:

i. evaluate the effect of different spatial arrangements and varietal combinations on phenology and growth of intercropping maize and groundnut.

ii. determine the effect of different spatial arrangements and varietal combinations on yield and yield components of maize intercropped with groundnut.

iii. evaluate the effect of different spatial arrangements and varietal combinations on land use efficiency (productivity) of maize and groundnut intercrop.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution

Maize's centre of origin is located in Mesoamerica, primarily in Mexico and the Caribbean (Larranaga *et al*., 2021). From 6,000 to 7,500 years ago, in the highlands of Mexico, maize was first domesticated. From 5200 to 3400 BC, there were wild maize cobs in Mexico, according to archeological data corroborated by radiocarbon dating. After that, the wild types of maize slowly disappeared in favor of more contemporary forms due to more intensive farming. The majority of pre-Columbian, Mesoamerican, South American, and Caribbean societies relied heavily on maize as their primary food source, and their way of life was centered on the cornfield.

The word "mahiz" in the Taino language of the Caribbean islands served as the source of the name "maize," which later became "maiz" in Spanish. As a result, Linnaeus added the name as it appears in the Zea botanical classification. Corn is the common name for maize in English-speaking nations. While "corn" is used to refer to any "cereal" in certain nations, in others it refers to the "local staple." The ear of maize is distinct from other cereals, and no wild relatives of maize were discovered that were morphologically similar. Because of this, understanding how it evolved has been a major scientific problem and a major area of research for both biologists and archaeologists. Following the discovery of the Americas by European explorers in the 15th century, the crop was first introduced there before spreading to Sub-Saharan Africa and the rest of the world (Fonseca *et al.*, 2015). Currently, the United States of America is the world's top producer of maize, followed by China, Brazil, Russia, and Europe (Logrieco *et al*., 2021) whereas Nigeria is the leading producer of maize in West Africa and the tenth-largest producer in the World (Bala *et al*., 2021).

Groundnut known as peanut (*Arachis hypogaea* L.) originated in South America. The Greek words "hypogaea," which means "subterranean chamber," and "arachos," which means "weed," are the origin of the English name "Arachis." This is a term used in botany to describe a weed that bears fruit below the soil's surface (Kandoliya *et al*., 2015). According to Prasad *et al.* (2010), when the Europeans came to South and Central America, groundnut agriculture was already well-established and was first mentioned in archaeological documents from Peru. In Mexico, there is archeological proof of their existence. Kolo (2021) also noted that Virginia groundnut genotypes and Peruvian runner genotypes spread globally after European contact. The Virginia type may have traveled from Spain to Mexico in the sixteenth century, then across the Pacific to AfricaPeruvian runner types were dispatched to Madagascar, South East Asia, China, and the Western Pacific. According to Hammons *et al*. (2016), the Portuguese brought the Spanish variety to the ancient world in the seventeenth century, and the slave trade brought the Virginia varieties to South East USA. The varieties they discovered and their locations largely lend support to the hypotheses about dispersal presented above. According to a report by UDEH (2018), the Portuguese were in charge of bringing it from Brazil to West Africa in the sixteenth century.

2.2 Botany

Maize (*Zea mays*) is an annual grass of the Poaceae family that is cultivated as a staple meal worldwide (Kumar, 2022). As stated by Burroughs *et al*. (2023), *Zea mays*, a monocotyledonous plant, is a member of the Gramineae family and Maydeae tribe. A grass between two and three meters high, maize has a single, solid stem (stalk) that is 3 to 4 cm in diameter and has distinct nodes and internodes. There are between 15 and 20 internodes. These start short and quite thick, but they get longer and thinner as they get closer to the terminal male inflorescence. The nodes give rise to the leaves, which grow alternately on the stalk's opposite sides. In warm soil, it takes 4 days for plants to emerge; in cool soil, it takes 20 days. The plumule penetrates the seed coat 1-

2 days after planting in most warm soils, while the radicle appears 2-3 days after planting. The styles, known as silks, arise from the husks at the top of the ear and are long and unbranched with short protrusions known as trichomes (Kumar, 2022). Two sperm nuclei move through the pollen tube that forms inside the silk after the pollen has dropped on receptive silk, causing the grain to germinate. One nucleus fertilizes the haploid egg to create a diploid embryo when it reaches the ovule, while the second nucleus fuses with the diploid central cell to create a triploid endosperm. The pericarp is created by the fusion of the ovary wall and ovule coat (hull, seed-coat). The embryo, endosperm, and pericarp make up the maize kernel, which can vary in color, texture, and chemical makeup (10–13% of the grain).

Although red, purple, and brown can also appear in some landraces, yellow and white are the most typical hues for kernels. According to how tough the endosperm is, commercial maize is separated into the flint, dent, flour, sweet, and pop varieties (Burroughs *et al*., 2023). Anemophilous maize pollen is carried by the wind. Due to its rapid settling velocity, most pollen settles within a few meters of the tassel in calm conditions; yet, in strong winds, pollen can travel up to 500 meters. Pollen sheds throughout a number of days. It is very vulnerable to both dry air and high temperatures. While the silks are receptive for a much longer period, it is only viable under perfect conditions for 24 hours.

Groundnut (*Arachis hypogaea* L.) is a member of the Leguminosae family and the Papilionoideae subfamily (Sharma *et al*., 2017). According to Bitew *et al*. (2021), the botanical name of groundnut comes from the Greek words Arachis, which means "legume," and hypogaea, which means "below ground," and refers to the development of pods in the soil. It is cultivated for its edible seeds, which are high in protein and fat and go by the names peanut, earthnut, or goober. Every Arachis species is geocarpic, just like the West African Bambara groundnut. The plant is grown in warm temperate and tropical climates all over the world, as well. It does this by opening its fruits underground (Somefun *et al*., 2020). Groundnut is an annual plant. The plant, like other legumes, enriches the soil with nitrogen by using bacteria that fix nitrogen, making it an especially beneficial crop for improving the soil. Groundnuts can either have a spreading form that is 30-45 cm high with long branches that lie near the soil or an upright shrubby plant that is 45-60 cm high with short branches. The pinnately compound leaves on the robust, hairy stems have two pairs of leaflets each. Golden-yellow petals of 10 mm in size are present on the blooms, which are produced in the axils of the leaves. The oblong pods often include two or three seeds and are 25 to 50 mm in length with rounded edges. The unusual behavior of groundnut legumes to ripen underground is known as geocarpy (Belel *et al*., 2014).

After pollination and the withering of the flower, an unusual stalk-like structure called a peg grows from the base of the flower toward the soil. The fertilized ovules are carried downward in the sturdy tip of the peg until the tip is well below the soil surface, at which point the peg tip starts to develop into the characteristic pod. The pegs sometimes reach down 10 cm or more before their tips can develop fruits. These unusual fruits appear to function as roots to some degree, absorbing mineral nutrients directly from the soil. The pods may not develop properly unless the soil around them is well supplied with available calcium, regardless of the nutrients available to the roots.

2.3 Varieties

Maize and groundnut varieties vary from one another in several ways, and each one has its adaptation and yield potential. Improved cultivars with the appropriate agronomic strengths for your region produce great yields (Adu1 *et al*., 2014). For instance, a variety that matures quickly under drought conditions may produce good yields in regions with limited rainfall, especially in the Sudan savannah zone. In the Forest and Transitional zones, a late-maturing cultivar that is resistant to common pests and diseases may produce good yields.

According to Kumari & Sasidharan (2021), groundnut comes with two distinct botanical types for cultivation namely:

Virginia type: This is a late-maturing variety. The plants' secondary and tertiary branches are covered in pods, and the seeds exhibit noticeable new dormancy with alternating branching patterns. It seems dense and bushy and has several apical meristems.

Spanish Valencia: This cultivar matures quickly. The plant is often upright, the pods are grouped towards the plant's base, and the seeds have little new dormancy.

Groundnut is a strictly annual legume that grows to a maximum height of 60 cm. Four to six weeks after sowing, it begins to bloom with yellow flowers. After fertilization, the ovary produces a peg that develops into a pod containing one to six seeds that are protected by a thick fibrous shell. According to Siyamfinya (2014), a mature pod has a beak, a mesocarp, and an endocarp covering one to seven seeds. The pods are cylindrical and have a minor constriction between the seeds.

Meanwhile, some recommended varieties of maize and groundnut released by CSIR - Crops Research Institute and grown in Ghana and their characteristics are presented in Tables 2.1 and 2.2 respectively.

Table 2. 1: Agronomic Characteristics of Some Recommended Maize Varieties for Cultivation in Ghana

S/N.	Variety of Maize	Grain Colour	Yield Potential (ton/ha.)	Maturity Days	Distinctness Uniformity and Stability (DUS)	Value for Cultivation and Use (VCU)	Preferred Ecology
1.	CSIR-CRI Opeaburo	White	7.5 tons/ha	110 – 115 days	Top cross hybrid; Days to 50% silk: 56; Plant height (cm): 180; Ear height (cm): 90; Tassel colour: Cream with purple shade; Silk colour: Cream purple; Stem colour: Green with purple shade; Cob length (cm): 16.7; Cob diameter (cm): 4.9.	Moderately tolerant to drought; Very good for domestic purposes; Moisture %: 11.1; Protein %: 9.5; Fibre %: 1.4; Fat%: 4.8; Carbohydrate%:74.6	Forest and Forest Transition
2.	CSIR-Abontem	Yellow	4.7 tons/ha	75 – 80 days	Days to 50% silk: 54; Plant height (cm): 162; Ear height (cm): 82; Tassel colour: cream purple shade; Silk colour: purple; Cob length (cm): 15.5; Cob diameter (cm): 4.4; Kernel type: Flint/dent	OPV, QPM yellow. Good for poultry and livestock	Most suitable for Guinea and Sudan savannah Zones

S/N.	Variety of Maize	Grain Colour	Yield Potential (ton/ha.)	Maturity Days	Distinctness Uniformity and Stability (DUS)	Value for Cultivation and Use (VCU)	Preferred Ecology
3.	CSIR-Omankwa	White	5.0 tons/ha	90 days	Days to 50% silk: 54; Plant height (cm): 182; Ear height (cm): 91; Tassel colour: purple shade; Silk colour: purple; Cob length (cm): 15.7; Cob diameter (cm): 4.5; Kernel type: Flint/dent	QPM white.	Most suitable for coastal savannah zone
4.	Obatanpa	White	4.6 tons/ha	110 days	Days to 50% silk: 55; Plant height (cm): 175; Tassel colour: cream purple; Silk colour: cream purple; Stem colour: Cob length (cm): 15.2; Cob diameter (cm): 4.8; Kernel type: dent	Quality Protein Maize (QPM). Excellent for enhanced nutrition and health of humans, poultry, and livestock	All agro-ecologies in Ghana

(Source: Catalogue of Crop Varieties Released & Registered in Ghana, 2019) – CSIR-CRI)

Table 2. 2:Agronomic Characteristics of Some Recommended Groundnut Varieties for Cultivation in Ghana

S/N.	Variety of Groundnut	Grain Color	Yield Potential (ton/ha.)	Maturity Days	Distinctness Uniformity and Stability (DUS)	Value for Cultivation and Use (VCU)	Preferred Ecology
1.	Yenyawoso	Dark Red	2.7 tons/ha	90 days (early maturity)	Growth habit: Semi-erect; Leaf shape: Obovate; Leaf colour: Light green; Resistant to rust; Days to 50% flowering: 23; Pod length:3.0 cm; Pod diameter:1.3 cm; Seeds/pod:2	% Moisture 5.6; % Protein 29.85; % Fat 49.92; % Fibre 5.28; % Carbohydrate 6.92; Iron 3.17 (mg/100g); Calcium 513.02 (mg/100g); Oil content: 50%; 1000 seed weight: 416g	Savannah, forest-savannah transition, semi-deciduous forest
2.	Oboshie	Brown	2.6 tons/ha	105 – 110 days (late maturity)	Growth habit: Semi-erect; Leaf colour: Light green; Days to 50% flowering: 26; Pod length: 3.98cm; Seed length: 2.09; seed diameter:1.20cm; Seeds/pod: 2	Good flavour; Sweet taste; Iron: 3.62(mg/100g); Calcium 448.9(mg/100g); Moisture: 5.59; % Protein: 34.13; % Fat: 46.49; % Fibre: 4.54; % Carbohydrate: 6.78; %; 1000 seed weight: 856 g	Savannah, forest-savannah transition, semi-deciduous forest

S/N.	Variety of Groundnut	Grain Color	Yield Potential (ton/ha.)	Maturity Days	Distinctness Uniformity and Stability (DUS)	Value for Cultivation and Use (VCU)	Preferred Ecology
3.	Crops – Dehyee	Brown	2.9 tons/ha	85-90 days (early maturity)	Growth habit: Semi-erect; Leaflet colour: Light green; Pod Kernel Number: Medium (Mostly 3); Pod length: 22.30mm; Kernel size: Medium; 1000 Kernel weight: 447.00g.	% Moisture: 5.82%; Protein: 35.37%; Fat: 50.53%; Fibre: 2.35%; Carbohydrate: 3.69; Tolerant to Aflatoxins; High Oil content	Savannah, forest-savannah transition, semi-deciduous forest
4.	Obolo	Tan	2.7 tons/ha		Growth habit: semi-erect; Leaf colour-Light green; Days to 50% flowering: 25; Pod diameter:1.8 cm; Pod length: 3.8 cm; Seeds/pod: 2; Seed length; 1.9cm	Iron 5.11 (mg/100g); Calcium384.77(mg/100g); % Moisture 5.3; % Protein 28.6; % Fat 48.06; % Carbohydrate 8.3; 1000 seed weight -808g	Savannah, forest-savannah transition, semi-deciduous forest

(Source: Catalogue of Crop Varieties Released & Registered, 2019) – CSIR-CRI)

2.4 Nutritional Value and Uses

The high nutritional value of maize grains comes from their 72% carbohydrate, 10% protein, 4.8% oil, 8.5% fiber, 3.0% sugar, and 1.7% ash content (Kumari *et al*., 2017). In both irrigated and rainfed agricultural systems, *Zea mays* is the most significant cereal fodder and grain crop in the semi-arid and arid tropical regions (Halli & Angadi, 2020). The quality of maize protein depends upon its agronomic practices and genotype as well and it is not of good quality as compared to other cereal grains like rice, wheat, barley, etc. (Loskutov & Khlestkina, 2021). Recent research has shown that with genetic modification, the quality of maize protein can be improved (Hu *et al*., 2022). The opaque-2 gene in maize helps reduce the concentration of zein by up to 30% (Sultana *et al*., 2019) and improves the quality of protein maize (QPM). The protein content of maize helps in the growth and maintenance of tissues, formation of essential body compounds, transport of nutrients, regulation of water balance, and the like.

The main portion of maize grain is starch which provides more than 70% weight of its cereal kernel (Impa *et al.,* 2020). According to Cai & Shi (2010), starch in maize is composed of two glucose polymers mainly amylose which contributes to 30% of its starch content, and the rest of the content is made from amylose pectin (70%). Waxy maize is composed of 100% amylopectin content (Cai & Shi, 2010). Due to the pectin content, maize has a branch-type structure making the monosaccharide present in maize glucose and fructose, and the disaccharide as sucrose in a small amount.

Maize is also enriched with B-complex vitamins that play a vital role in growth, healthy skin, heart, hair, brain, and digestion. Maize contains fat-soluble vitamins that are comprised of provitamin A, carotenoids, lutein, which have a unique role in preventing both aging and cancer. These fat-soluble vitamins (A, D, E, K) act as antioxidants that help in protection against different types of cancer. The content of fat-soluble vitamins depends upon the genotype of maize. Yellow maize is enriched with different types of carotenoid pigment due to its genotype, while white maize is deficient in carotenoid content due to the absence of this genotype.

Groundnut seeds (kernels) are the most important product that is a rich source of nutrition and provides several health benefits (Akram *et al*., 2018). Additionally, it is among the most significant oilseed plants on the planet. Depending on the kind, groundnut seeds range from 40 to 50 percent fat, 20 to 50 percent protein, and 10 to 20 percent carbohydrates (Okello *et al*., 2010). Although groundnut oil contains seven fatty acids, palmitic (7–12%), oleic (40–50%), and linoleic (25–35%) combined account for about 90% of the total fatty acids (Bakal & Arioglu, 2019). The seeds are a good source of bioactive polyphenols, flavonoids, and isoflavones as well as minerals including calcium, phosphorus, iron, and zinc. The B-complex vitamins, such as thiamin, pantothenic acid, riboflavin, foliate, and niacin, are also included. They also comprise vitamin E. Following oil extraction, groundnut meal offers cattle and poultry a highly protein-rich feed.

The main components of groundnuts are crude protein (45.6%), sugar (32.50%), fat (2.5%), fiber (8.3%), and ash (5.0%). It also contains large amounts of the amino acids lysine, methionine, cysteine, threonine, and arginine. According to Abadya *et al*. (2021), groundnut haulms (the above-ground vegetative section), a good source of nutrient-rich cow feed, include a range of nutrients, including crude fiber (22–38%), protein (8–15%), lipids (1-3%), minerals (9–17%), and carbohydrates (38–45%). It is prepared as fresh or dried hay or silage, or as cow feed. When fed to animals, groundnut haulms have a nutrient digestibility of about 53% and a crude protein digestion of 88% (Pasupuleti *et al*., 2013). According to Ahmed *et al*. (2021), the green haulm of groundnuts provides good fodder, and the lower-grade oil from the feed is also used to make soap and lubricants. Groundnut oil is a component of cosmetic products such as face powder, shaving cream, shampoo, and paint. The leftover material from oil extraction is a high-protein diet for animals. Additionally, groundnuts can be utilized to make peanut milk, peanut protein, cake, and flour for human consumption.

2.5 Economic Importance

Maize is the most significant cereal crop in the region and is extensively relied upon by more than 1.2 billion people in SSA and Latin America (Badu-Apraku & Fakorede, 2017). More than 300 million Africans depend on maize as the main staple food crop (Badu-Apraku & Fakorede, 2017). The entire crop can be used to produce both food and non-food products. In Africa, 30–50% of low-income households' spending is on maize. Folberth *et al.* (2014) indicated that over 20% of total calorie intake in sub-Saharan Africa (SSA) comes from maize. However, several African countries depend on maize as a staple food crop and have adopted agricultural policies to maintain a steady supply of the commodity through increased production and productivity of the crop.

It is stapled human food, feed for livestock, fermentation, and many industrial uses. Research conducted by Sasank *et al.* (2020) indicated that maize has an abundant starch (65%). About 35% of production is consumed by humans, 25% by poultry and cattle feed, and 15% by food processing. In the new millennium, it is an alternate crop to rice and wheat. Maize is very important because of a good source of minerals, vitamins, fiber, and oil present in maize (rich in embryo). Small-scale farmers are engaged in maize farming, because of its high nutritional value and affordable source of vitamins and minerals for people living in rural areas.

Groundnut is a significant legume crop used for its oil, food, and feed that is grown in over 100 countries and occupies 24 million acres of land globally. (Lokossou *et al.*, 2022). In the last decade, global groundnut production increased marginally. Were *et al*. (2019) reported that 95% of the world's groundnut production is done in Asia and Africa, where resource-poor farmers grow the crop in rain-fed conditions with few inputs. Through the use of energy- and protein-rich groundnut kernels and the provision of nourishing fodder (haulms) for cattle, the groundnut is a cash crop that supports the farmer's income and way of life. The groundnut kernels are full of elements that can improve health, including vitamins, minerals, and mono-unsaturated fatty acids. Bioactive polyphenols, flavonoids, and isoflavones can be found in groundnuts. Due to their great nutritional value, groundnuts and goods made from them can be marketed as nutritious foods to help the underprivileged combat their lack of energy, protein, and micronutrients. Thousands of malnourished children's lives have been saved by the use of groundnuts as a therapeutic diet (Javed *et al*., 2021).

A report by Nalluri *et al*. (2017) indicated that more than 60% of the world's groundnut production is crushed to extract oil for use in food and industry, while 40% is used for food and other purposes (such as seed for planting the crop the following season). Because of its high smoking point, groundnut oil is a great cooking medium (Nandini *et al*., 2021). The cake left over after oil extraction is utilized in the production of enhanced, readily digestible meals for youngsters and the elderly. The groundnut seed can be used to manufacture flour for baked goods and confections as well as consumed raw (unheated), boiled, and roasted. The fertilizer and feed industries employ groundnut shells as fuel, filler, or in the production of particle boardsHaulms made of groundnuts are a wholesome source of feed for animals. When fed to cattle, groundnut meal has an approximate 53% digestibility of minerals and an approximate 88% digestibility of crude protein. Because it is a legume, groundnut improves soil fertility and health by burying nitrogen and organic matter.

2.6 Production Estimate

Maize production in Africa was around 75 million tons in 2018, representing 7.5% of world maize production. By 2020, farms cultivated maize were estimated at 216 million (216M) globally (Erenstein *et al*., 2021). According to Erenstein *et al*. (2021), maize farms vary substantially by region, with East Asia and Pacific (EAP) farms growing nearly half of the maize in 2020, 44% in Latin America and the Caribbean (LAC), and 43% in Sub- Saharan African (SSA). Over half (56.5%) of the global maize farms are located in East Asia and the Pacific (EAP) primarily in China (110 M). Nearly a quarter (22%) of global maize farms are located in Sub- Saharan Africa (SSA), and 12% in South Asia (SA). Overall, 28 countries were estimated to have over one million (1 M) maize farms in 2020 with China contributing to 60% of global maize farms (Erenstein *et al*., 2021).

In Africa, maize accounts for roughly 24% of farmland, with an average production of 2 tons per hectare per year (Sang, 2021). Nigeria, with more than 33 million tons produced, is the biggest producer in Africa, followed by South Africa, Egypt, and Ethiopia (Italia *et al.*, 2022). Africa imports 28% of its required maize grain from countries outside the continent (Italia *et al*., 2022) as most of the maize production in Africa is done under rain-fed conditions since irregular rainfalls can cause shortages and famines during occasional droughts. According to Abdullahi *et al*. (2020), the total maize harvest in Africa was estimated at 40 million hectares, with Nigeria being the top producer (16 %) followed by Tanzania. Worldwide consumption of maize is estimated to be more than 116 million tons with 30% and 21% of the consumption occurring globally and in SSA, respectively. Around 14 countries in SSA consume 85–95% of maize as their staple food (Matumba *et al*., 2015). Depending on the country, there are several ways to process and prepare maize. Eastern, Southern, and Western Africa all make porridge out of ground maize. In order to bridge the gap when the grain supply is insufficient, green (fresh) maize is boiled or roasted on its cob throughout all of Africa.

In 2014, 42.32 million tons of in-shell groundnuts were produced globally across 25,70 million acres of groundnut cultivation (FAOSTAT, 2015). The top four countries that grow groundnuts are China (22%), India (19%), Nigeria (11%), and the USA (2%). About 60% of the world's manufacturing is made in China (42%) and India (18%), with Nigeria (7.7%), the USA (4.3%), and Indonesia (1.8%) following (Rathnakumar *et al*., 2013). Together, Africa and Asia account for 95% of the world's groundnut area and 91% of its output, with 12.40 million hectares and 11.54 million tons of production, respectively. According to Venkataravana *et al*. (2020), China is the largest producer as well as consumer of groundnut in the world with 171.50 Mt in 2017-18 followed by India with 91.79 Mt whilst Nigeria leads Africa with 24.20 Mt. The production of groundnut in Africa covers 31.3% of land area and 18.6% production (Essilfie *et al*., 2020). In Ghana, it is a cash crop with about 90% of smallholder farming households involved in its production and about 85% of its total production from the Northern part of the country (MoFA, 2016). Groundnut production has increased by 2.67% year since 1980, primarily due to increases in yield (1.74%) and cultivated area (0.93%) (FAOSTAT, 2015). China was the world's top producer of groundnut oil in 2015–16 with 2.74 million tons produced. Groundnuts are grown in more than 100 countries all over the world in a variety of agroecological conditions. The majority of the world's groundnut production is produced in rising Asia and Africa, where most of the cultivation is restricted. African Americans made up 51.01 percent of the population in 2014, compared to 19.71% and 27.68 percent in 1990.

2.7 Climatic and Soil Requirements

2.7.1 Climatic Requirements

Maize can be grown over a wide environmental range. It is essentially a warm-climate crop with sufficient rainfall needs. The majority of the crop is grown in humid subtropical and warmer temperate climates. The lowest seasonal rainfall in the maize area is 200 mm. Available evidence indicates that maize as a purely rainfed crop may be risky in regions with a mean annual rainfall of 400 mm and that even in areas receiving 600 mm of rain, irrigation appears to be necessary for high yield. Soil temperature of 26 °C to 30 °C is optimum for both germination and seedling growth. The minimum temperature for germination is 10°C. Girijesh *et al.* (2011) consider that the ideal temperature for maize germination is 21 °C. Emergence is normally reduced below 13 °C and fails below 10 °C. For uniformity of the initial stand, a minimum temperature of 17 °C to 20 °C is necessary (Hacisalihoglu *et al.,* 2018). In higher altitudes as in northern Europe, North America, etc. where maize is sown in spring, low soil temperatures prevent early seeding. Earlier germination may subject the crop to freezing temperatures besides hastening flowering leading to reduced crop duration. Too late sowing encourages pest and disease problems. Hence, there is a need for day-neutral spring maize in higher altitudes (Degani & Dor, 2021). The range of temperature for maize growth is from 9 °C to 46 °C with an optimum of around 34 °C (Singh *et al.,* 2018). All these values maximum, minimum, and optimum are 4 °C to 6 °C higher than those of wheat or barley. When mean daily temperatures are below 20 °C, crop duration will be extended by 10-20 days depending on the variety. Maize is more resistant to drought. The crop can recover from early-season drought. Maize is sensitive to freezing temperatures (Grotjahn, 2021) except in a very early stage and can recover from the effects of frost if it occurs when the plant is less than 15 cm in height. Very young seedlings are less susceptible to high temperatures. From the findings of Grotjahn (2021), maize can recover from early adverse climatic conditions during early-stage hence, early sowing of maize with the onset of rains, even at the risk of early drought due to the late onset of regular rains is recommended.

In the reproductive phase, temperatures above 32 °C as well as frost can reduce yield. Soil moisture stress before silking, during silking, and after silking reduces grain yield. The optimum temperature at tasseling is 21 °C to 30 °C (Waqas *et al.*, 2021). High temperature promotes respiration meanwhile, an important effect of temperature is that high temperature, particularly at night, shortens the grain-filling period thereby reducing the yield. High temperature increases the rate of grain filling but greatly reduces the duration of the grain-filling period, whereas low temperatures cause an inverse response. The grain yield of maize, like other small grains, is higher at lower temperatures because of an increase in the length of the grain-filling period and greater partitioning of photosynthesis of dry matter to grain (Liu *et al*., 2015).

Groundnut can be grown in a variety of temperate and humid climates, however, the semi-arid tropics produce the most (Ijaz *et al*., 2021). As stated by (Singh, 2011), the ideal temperature is in the 20–30 °C range. Below 16 °C and above 32 °C are the only temperatures where productivity is possible (Prasad *et al*., 2010). Depending on the cultivar, groundnuts need between 1800 and 2400 degree-days of thermal time, or at a base temperature of 10 °C. The crop can also be cultivated in areas with 200 to 1000 mm of rainfall each year. In order to produce at its best, groundnut likes clear days with lots of sunlight, which are influenced by day duration and light intensity (Mohammed, 2019b). It is a day-neutral plant, and temperature determines when it will flower. The post-flowering period is when flowers create pegs and pods as well as absorb distribution, therefore photoperiod is crucial for reproductive effectiveness. At the expense of reproductive growth, long days favor vegetative growth (Naawe & Angyiereyiri, 2020). When the photoperiod lengthens from 13 to 16 hours each day during the post-flowering period, reproductive development is constrained. High temperatures and long days diminish the effectiveness of reproduction. As the timing of flowering is affected by photoperiod, some cultivars are also sensitive to it.

2.7.2 Soil Requirement

Maize is nutrient intensive and requires adequate supplies of all nutrients for all growth stages. Fertile, well-drained, well-aerated, and good-textured soil can supply these nutrients. However, soil pH determines the availability of nutrients in the soil. pH is the level of acidity or alkalinity of the soil. Maize crops grow best at a soil pH of between 5.5 and 7.3, with pH 6.0–6.5 being optimal. In this range, nitrogen, potassium, phosphorus, calcium, and magnesium are readily available. As stated by Sardans & Peñuelas (2021), nitrogen helps in the establishment of healthy leaves, phosphorus for root formation, and potassium for fruiting while secondary nutrients such as calcium and magnesium among others are critical for crop physiological functions. Soil testing helps establish the available nutrients and the remedial steps that need to be undertaken in case of deficiencies (Shukla & Behra, 2019). Fertile soil should be well prepared for sowing. The correct tillage method ensures ample availability of all plant nutrients, water retention, and reduced incidences of pests and diseases. With a pH range of 5.0 to 7.0, maize grows well in a variety of soil types. Planting maize in deep, fine-textured, well-aerated, well-drained loamy soils that are rich in organic matter produces high yields (Elmahdi, 2016). As stated by Asekabta (2018) deep, well-drained, silty loams with high to moderate organic matter and nutrient content and a pH of 5.5-8.0 are often necessary for maize to grow as productively as possible. The crop is very sensitive to waterlogging and since it is mainly grown during the rainy season, care should be taken to ensure that water does not stagnate on the soil surface for more than 4-5 hours. Loamy or silty loam soil or silty clay loam soil having fairly permeable subsoil is an ideal soil type. Research conducted by Wang *et al.* (2020) stated that maize plants, particularly at the seedling stage, are susceptible to salinity. Soil salinity can have a marked influence on the uptake of nutrients but decreased dry matter production probably due to decreased soil water and increased toxicity of sodium chloride and sulphate in the soil solution.

Li *et al.* (2018) also indicated that maize is also sensitive to waterlogging. However, the provision of adequate drainage is essential for economic production. Light soils facilitate drainage but have relatively poor water-holding capacity. On the contrary, heavy soils with good water retentivity have relatively poor drainage. Hence, soils ideally suited for maize crops should have adequate water-holding capacity and also good drainage. Therefore, the ideal soil type for maize production is neither clayey nor sandy with an exchangeable capacity of around 20 milli-equivalent/100 g, base saturation of 70-90%, bulk density of about 1.3 g/cc, and water-holding capacity of about 16 cm/m depth (Rugimbana, 2019).

Groundnut needs very good soil for its pod formation since the pegs develop under the soil. According to Prasad *et al*. (2010), well-drained, light-colored sand, loamy sand, or sandy loam are the ideal soil types for growing groundnuts. Prasad *et al*. (2010), again cited that, these light-textured soils made it easier for pegs to penetrate and for pods to grow. Additionally, this makes harvesting simpler and reduces pod losses while harvesting. The clean, shining appearance of the pods and their higher market value contribute to an increase in the quality of the crop from light-textured soils. Good yields of groundnut are produced in soils with a pH of 6.0 to 6.5 (Wijanarko & Rahmianna, 2020). Although groundnut is thought to be tolerant of acidic soils, certain cultivars thrive on soils that are slightly alkaline and have a pH of up to 8.0 because they are better at fixing nitrogen.

2.8 Propagation

Maize is best grown in warm, tropical, and sub-tropical regions as it requires warm soils to develop optimally. One of the most important requirements for growing maize is high-quality soil that is deep, fertile, and well-draining with a pH between 6.0 and 6.8. Maize plants are very heavy feeders (Behera *et al*., 2021) and even the most fertile of soils may need to be supplemented with nutrients as the plants develop, particularly nitrogen. Maize also requires plenty of space as it grows and is pollinated by wind. It should be planted where it will receive full sunlight for most of the day and be provided with ample moisture. Planting dates for maize depend on the variety being grown. Soil can be brought up to temperature faster by laying black plastic mulches approximately 1 week before planting. Seeds should be sown about 2.5 cm deep and 30 - 40 cm apart allowing 60 - 80 cm between rows. Maize should be planted in blocks (numerous rows) rather than in a single long row as it is wind pollinated and pollen can transfer between plants much more efficiently.

Shelled seeds are desirable for sowing since unshelled nuts may contain diseased nuts or have a tendency to speed up the rotting of the seeds in the pods. Five to seven days after planting, germination occurs. The effects of moisture stress are more acute in larger seeds. Two to three seeds are generally used per hole when planting the nuts. Research conducted by Okello *et al*. (2013) revealed that pests including squirrels, mice, rats, lizards, termites, and birds can be prevented from harming or taking the seeds from the soil after planting by applying an insecticide or fungicide seed dressing. For bunch varieties, Mohammed (2019) suggested that on flat or elevated beds, it is advised to space items 30 x 30 cm and 30 × 45 cm apart.

Mohammed (2019) indicated that the goal should be to use a spatial layout that will result at least 120,000 plants per hectare in commercial plantings. Mohammed (2019a) asserts that local varieties, which are primarily runners, should have broader spacing. Typically, it has been advised to use 90 cm x 20 cm for spreading and 60 cm x 10 cm for bunch types (Mohammed, 2019b). When to plant depends on both the cultivar and the area. The best time to sow should be chosen so that the plant's cycle and other important environmental factors, such as the chance of rainfall distribution, are as closely matched as feasible. Sowing in the Ashanti and Bono regions of southern and central Ghana begins in March or April during the main season and in September or October during the minor season, according to research by Ayivor *et al*. (2017). In May or June, sowing gets under way in the Northern and Upper Regions. Sowing early in the planting season often produces higher yields and successfully fights rosette disease.

2.9 Agronomic Practices

2.9.1 Pest and Diseases Control

In Ghana, stem borers, cutworms, grasshoppers, weevils, termites, fall armyworms, and larger grain borers are the main pests of maize. Among the most common diseases affecting maize are rust, smuts, bacterial blight, and maize streak. Knowing the pests and diseases that are prevalent in the region where the crop will be cultivated and choosing plant varieties that are resistant to them are some helpful management strategies for managing pests and diseases in maize. After the seeds have emerged, start checking the field for pest infestation. Then, periodically check their numbers to see if they are causing enough financial harm to warrant management. Additionally, planting early can help you avoid the heavy insect impact that late crops face (Adu1 *et al*., 2014).

2.9.2 Fall armyworm (Spodoptera frugiperda) and its effect on Maize growth and yield

A single, or a small collection of irregularly shaped holes in the foliage; intense larval feeding results in skeletonized leaves; on the leaves, there may be egg clusters of 50–150 eggs. The egg clusters are covered in a whitish scale that gives them a cottony or fuzzy appearance. Young larvae are pale green to yellow, while older larvae are typically darker green with a dark and light line running along the side of their body and a pink or yellow underside. Leaf damage is usually characterized by ragged feeding in the upper leaves. Leaf damage is usually scattered in rows across the leaf. Younger larvae usually eat tissue from one side, leaving the other side intact. Deep feeding may destroy maize tassels. Caterpillars enter through the side of the ear and feed on the developing kernel

The most important pest of maize is the Fall Armyworm (FAW), *Spodoptera frugiperda* (Lepidoptera: Noctuidae). According to Sisay *et al*. (2018), it is considered a native pest in tropical and sub-tropical Americas. On the African continent, FAW is among the most destructive invasive pests. It is a sporadic pest with a diverse host range challenging the food security of over 300 million people by causing severe damage to the world's 1st rank cereal crop maize. FAW is becoming tolerant to many insecticide use strategies and has difficulty in finding and surveying field infestation with simple protocols (Chhetri & Acharya, 2019). The larvae eat in large numbers on the leaves, stems, and reproductive organs of plants. They range in color from light green to dark brown and have longitudinal stripes. More than 350 plant species are affected by the pest, which severely damages crops like maize, rice, sorghum, sugarcane, etc. The host crop most susceptible to FAW is maize, a high-priority food crop across many sub-Saharan countries.

Annual loss from FAW was estimated at up to 17.7 million t of maize from 12 African countries, enough to feed tens of millions of people and representing an economic loss of up to US$4.6 billion (Kamara *et al*., 2020). In Nigeria, FAW was first reported in Oyo and Ogun states in 2016. Currently, the pest is present in all the states of the country. Losses up to 100% have been recorded in some farmers' fields. The pest is very difficult to control, and management in maize fields necessitates the frequent application of insecticides and sometimes the use of multiple types and formulations of chemicals. The eggs measure 0.4 mm in diameter and 0.3 mm in height. When they are laid, they are creamy or pale yellow, but before they hatch, they turn light brown. In most times, masses of 150–200 eggs are laid 2-4 layers deep on the surface of the leaf. Egg masses may be laid on the undersides too, or on top of the leaves.

While there are pesticides available for commercial management, many of those that are available for home gardens do not adequately control armyworm larvae. Biological control is achieved by natural enemies that parasitize the armyworm larvae, as well as by applying *Bacillus thuringiensis.*

2.9.3 Diseases and Pests of Groundnut

According to Gantait & Mondal (2018), there are viral and fungal groundnut diseases in West Africa, though bacterial wilt and nematode infestation are significant in some areas. Groundnut rosette disease, early and late leaf spot, stem rot, seed rots, mycotoxin infection, leaf rust, pod rot, southern blight, seedling infections, and groundnut rust were among the diseases mentioned by Motagi *et al*. (2022). Some of the suggested disease control techniques include the use of resistant cultivars, deep plowing, crop rotation to prevent disease buildup in the soil, early planting, removal of weeds that serve as alternate hosts, improved drainage to slow the spread of diseases in the soil, removal, and burning of affected plants, and seed dressing with the appropriate fungicides by Joshi *et al.* (2020). Additionally, a wide variety of insect pests attack groundnuts. The main pests that affect groundnut include leaf-eating caterpillars, thrips, stalk borers, leaf-eating ants, flea beetles, aphids, and leaf miners.

2.9.4 Weed Management in Maize and Groundnut

Weeds compete with maize for space, nutrients, water in the soil, light, and nutrients, which reduces yields, lowers grain quality, and raises production costs. Weeds often harbor insects and diseases, which further increases production costs (Adu1 *et al.*, 2014). Weeds must never coexist with maize plants before they are controlled because maize is most susceptible to weed competition during its early growth stage. As indicated by Adu1 *et al*. (2014), during the crucial 2 to 4 weeks following planting, weeding significantly improves grain production. This promotes quick growth and increases the established maize plants' competitiveness. Following ground preparation, planting right away can assist in lessening weed competition. Row planting also makes weed control easier. Herbicides can be used judiciously to manage weeds in situations when weed pressure is high and timeliness is essential for hand weeding to be effective. Herbicide use has advantages over manual weed management since it is quicker, less expensive, and less tedious. On the other hand, whether there are broadleaved or grassy weeds, which are more prevalent, determines the type of herbicide employed (Adu1 *et al.*, 2014).

Weeds could be eliminated using post-emergence herbicides like Glyphosate and Paraquat before the area is prepared for planting. In contrast to Paraquat, such as Gramazone, which can be mixed with Pendimenthalin at the recommended rate and administered immediately after planting, Glyphosate (Round-up, Sunphosate, Sarosate) is often applied 1-2 weeks before planting. Pendimenthalin kills pre-emerging weeds, but Paraquat kills any live weeds in the field. Again, 2-3 days after planting, selective pre-emergence herbicides such as Atrazine can be used at the recommended rate to prevent maize and weed seedling emergence. Highly effective land preparation increases the herbicides' efficacy. The herbicide needs moisture to become active. Herbicides effectively manage annual grasses and broadleaf weeds; however, to effectively control perennial weeds or weeds that emerge after the application of herbicides, hoe weeding is frequently required. The quantity of herbicide to be used, the manner and timing of application, the meteorological circumstances, the type of weeds, etc. all play a role in how successfully herbicides are utilized. Use integrated weed management techniques that include mechanical, chemical, and cultural treatments for the best weed control and highest grain yields (Adu1 *et al*., 2014). According to Dalorima *et al*. (2014), maintaining weed-free groundnut was the crop's top goal after emergence since young groundnut was extremely susceptible to weed competition and had a fast fall in output. According to Isah *et al*. (2020), weeds could decrease yield by 18–70%. Therefore, it should be highlighted that weeding should be done between two and three weeks after planting, while the weeds are still delicate. As recommended by Johnson III (2019), repeated weeding is advised but one must be cautious while weeding near the pegs to prevent damage. Mechanical weed management techniques can range from straightforward hand pulling to using hand-hoes, animals, and tractor-drawn cultivators. Arpitha *et al*. (2021) also observed that weed control is crucial for groundnut production during the first five weeks following emergence. Zhang *et al*. (2021) suggested that, in the ideal situation, weeding should cease after flowering and the start of pegging. In some places, it may be appropriate to employ pre-emergence herbicides. Pre-emergence weedicides, like the semizine-based herbicide Gesatop, have been utilized to manage both grasses and broad-leaved weeds in groundnut.

2.9.5 Harvesting

As soon as the grain is dry and the moisture content is 15% or less, maize should be harvested (Adu1 *et al*., 2014). Birds, storage bugs, and illnesses will nest and cause damage if harvesting is delayed. In dry savannah regions, the grains may be harvested after they have dried out on the field. When the cobs begin to fall, the crop is ready to be harvested if left to dry on the field. Typically, when maize reaches maturity, it may be raining in the forest and forest-savannah transition zones. Maize should be taken out of the field early in such circumstances (ideally after two to three days without rain) and dried in the sun or in specialized drying cribs. To promote even drying, the grains should be frequently moved across the drying surface (Adu1 *et al*., 2014).

Groundnut pods are developed underground and at times becomes difficult to define maturity (Liew *et al*., 2021). Depending on the variety, groundnuts can mature in 90 days for early-maturing varieties to 150 days for late-maturing varieties, according to research by Arioglu *et al*. (2018). Care should be given while choosing pods for maturity testing because flowering lasts for extended periods of time. In actuality, plants are ready for harvest when the interior hull color is dark, the seeds are simple to separate, and the leaves turn yellow and start to fall. The right time to harvest groundnuts is crucial since an early harvest reduces production and crop quality, whereas a delayed harvest results in pods remaining in the soil and becoming more susceptible to diseases and post-harvest losses. In underdeveloped nations, harvesting is typically done by pulling or excavating the plant using modest machineries or animal-drawn equipment.

2.10 Intercropping System

According to Abobatta (2018), agriculture faces several difficulties, including managing water resources and preserving soil fertility. Intercropping systems can be used to improve soil and water conservation and boost crop yields to solve these issues. As stated by Tang *et al*. (2021), intercropping is the practice of growing two or more crop species simultaneously on the same field. Smallholder farmers in Africa have long used intercropping, which is now gaining popularity due to its potential for maximizing land usage while producing high yields with minimal inputs (such as nitrogen fertilizer). (Martin-Guay *et al*., 2018). Intercropping also reduces pests and diseases (Zhang *et al*., 2019) and in agricultural systems, it can boost soil organic matter and nitrogen retention (Cong *et al*., 2015). Therefore, intercropping contributes to the sustainable intensification of agriculture (Tang *et al*., 2021). The most often grown intercrop in the world is a combination of cereals and legumes (Martin-Guay *et al*., 2018).

According to Pelzer *et al*. (2014), intercropping of cereal and legumes has been promoted specifically for the acquisition of nitrogen (N). While both the cereal and the legumes acquire nitrogen (N) from the soil solution, only the legume fixes nitrogen (N) from the air through symbiosis with nitrogen-fixing bacteria in root nodules. Due to less competition for nitrogen (N) since legumes get some of their nitrogen from the air, cereals thrive better in a mixture with a legume than in a solitary stand at low soil nitrogen (N) supply. A wide variety of crops, including cereals (maize, sorghum, rice, and millet), legumes (cowpea, soy beans, groundnuts/peanuts), and vegetables, can be interplanted (Roselle, tomatoes, pepper, and okra).

2.10.1 Principles of Intercropping

According to Gebru (2015), there are numerous intercropping principles, some of which include:

- The component crops should be complementary to each other.
- To enable the component crop to grow quickly, the main crop should have a longer lifespan and slower growth habits.
- The intercrop system's component crops ought to require comparable agronomic procedures. It is possible to intercrop crops from various families, particularly upright and creeping crops. It is advisable to intercrop crops that can withstand erosion with crops that cannot.
- Component crops with various rooting depths and rooting patterns are appropriate.

2.10.2 Types of Intercropping

Various publications have identified different intercropping practices that are used all over the world. According to Ouma & Jeruto (2010b), there are four primary spatial layouts of intercropping. These include:

- **Strip Intercropping:** This is the practice of planting multiple crops in rows that are evenly spaced to enable farming activities and sufficiently close enough to allow for crop interactions (Gou *et al.*, 2017).
- **Row Intercropping**: This is the practice of cultivating many crops in a distinct row (Streit *et al.*, 2019).
- **Mixed Intercropping:** In this situation, multiple crops are planted side by side with no particular arrangement (Granzow *et al.*, 2017).
- **Relay Intercropping**: This intercropping strategy allows for the growth of a second crop when the first crop is almost ready for reproduction(Ouma & Jeruto, 2010b).

2.10.3 Maize intercropping with groundnut

The instantaneous release of groundnut to fix nitrogen has a stimulating effect on maize. This suggests that leguminous nodules only become active during the flowering stages, releasing nitrogen that has been absorbed directly from the soil and incorporated into the maize plants' structure. As a result, some allo-chemicals from leguminous plants are released, enhancing the growth and yield characteristics of the linked maize crop (Mohammed, 2019b). The difference between the groundnut intercropping systems and the single groundnut system may be due to the above-ground competition for light in combinations of maize and groundnut (Zhang *et al.*, 2020). According to decades of scientific research, groundnut-maize intercropping systems should, as a matter of principle, be based on the current varieties of maize and groundnut, which should only be evaluated and distributed to farmers based on their capacity to meet the requirements of the current intercropping systems. Because of the shadowing effect of the maize crops, the intercropped groundnut's decreased leaf area indices were likely due to less photosynthesis (WANG *et al*., 2021).

2.10.4 Advantages of Maize and Groundnut Intercrop

In rain-fed agriculture where resources are scarce, intercropping is common because it allows one crop to benefit from a resource that the others are not fully utilizing. Getahun *et al*. (2018) noted that intercropping provides smallholder farmers with enormous benefits in their low-input and high-risk settings. Bitew *et al*. (2021) noted that farmers' preference for a combination of cereals and legumes is likely due to the potential of legumes to reduce soil erosion and increase soil fertility. As stated by Mugwe & Otieno (2020), accessibility, enhancing profit, reducing risk, maintaining soil quality, and enhancing soil fertility are a few of the key reasons smallholder farmers intercrop their farm crops. Additionally, they can yield more stable yields, larger returns from intercrops than from single crops, and better nutrient utilization (Layek *et al*., 2018). The importance of intercropping cereals (maize) and legumes (groundnut) intercrop includes the following:

2.10.5 Biodiversity and stability

Growing two or more crops simultaneously enhances the farm's biodiversity, which translates to more food and stability and spreads risk (Pawan *et al*., 2012b). The most important feature is that both crops can compensate if one crop fails or gets worse; if crops grow independently, this compensation will not be possible.

2.10.6 Increased yield

There is an inefficient use of nutrients and water when two or more crops with varying rates of nutrient and water uptake are planted together, the cumulative effects of the intercrop can result in larger yields than the yield of the single crop (Pawan *et al*., 2012b).

2.10.7 Soil fertility maintenance

The enhancement and preservation of soil fertility is a significant advantage of intercropping. This is accomplished by cultivating legumes alongside vegetables and cereals or tubers. Decomposing roots and dropped leaves after the intercrop is harvested supply nitrogen and other nutrients for the following crop (Pawan *et al*., 2012b). Research conducted by Nyoki & Ndakidemi (2016) stated that intercropping is acknowledged to increase soil fertility better than monoculture owing to biological nitrogen fixation. Dahmardeh *et al*. (2010) also indicated that through the combination of cereal and legumes, the soil is considerably improved since the legumes fix atmospheric nitrogen both while growing and after they have broken down. Kermah *et al.* (2017) that when the residual legumes are ploughed back into the soil the next season, their effects are higher.

2.10.8 Intercrop as insurance against crop failure

Due to its stability compared to solitary cropping, intercropping is one method of maintaining food security among farm households in underdeveloped nations. Literature demonstrates that intercropping is thought to be more stable for a specific disaster created because it partially restores the diversity that is lost under mono-cropping (Lithourgidis *et al.*, 2011a). Concerning crop failure, intercropping offers a high level of certainty, particularly during extreme weather conditions. More insurance provides farmers with financial security, making the scheme especially ideal for labor-intensive small farms (Lithourgidis *et al*., 2011b).

2.10.9 Pest and disease management

The capacity to control diseases and pests more cheaply, effectively, and sustainably is essential to any agricultural production enterprise. A pest or disease can wipe out all crops, especially in a monoculture agricultural production system, having a significant financial impact on the farmer (Matusso *et al*., 2014). According to reports, solitary maize had higher pest and disease infestations than maize intercropped with soybean, and sole maize had more maize stem borers than maize intercropped with groundnut. Matusso *et al.* (2014) again noted that the infestation of sole maize was higher than that of soybean intercropped with maize.

2.10.10 Erosion control

The soil surface is protected from the direct effect of rains, wind, or flowing water when cereals are intercropped with foliar legumes like cowpea, groundnut, etc. It has been reported by Sharma *et al*. (2020) that, as a cover crop, maize-cowpea intercropping is well known for preventing soil erosion. The growth of the legumes covers the soil pores, reducing surface drainage (Sharma *et al.*, 2020). When long-lived crops like maize, sorghum, millet, and pigeon peas are planted, they act as windbreaks to stop wind erosion. (Mir *et al.*, 2016). Again, for short plants, tall plants serve as windbreaks to protect them from mechanical harm.

2.10.11 Disadvantages of intercropping

Intercropping with intense competition may lower the output of the component crops (Ahmed *et al*., 2020). Average growth rates, growth durations, and distance from the roots of the various crops are what determine the degree of competition where component crops are planted in certain rows. A cereal-legume intercrop typically has a better growth rate, greater height, and a more consistent fibrous root system, giving it a competitive advantage. A common component of the majority of tropical intercropping systems has been identified as maize (Mlango, 2018). Dwivedi *et al*. (2016) noted an increase in the size of all of its morphological components as well as an increase in cell division and expansion as a result of nitrogen impacts on maize growth. A study by Kumari *et al*. (2019) stated that because of the intercropping of legumes, maize yields were reduced. Zhan *et al.* (2020) noted that maize production was unaffected by the way that legumes and maize were planted. Mohammed (2019) reported that intercropping obstructs maize tasseling and silking. When maize and cowpea were interplanted, it was found that the length of the ear, cob length, dry cob weight, dry grain yield, and dry total plant biomass of maize were all significantly decreased (Egbe *et al*., 2010).

2.10.12 Intercropping inhibits mechanization

Although intercropping has several advantages, including increasing a farmer's revenue, improving soil fertility, and managing pests and diseases, the practice has recently been on the decline due to mechanization in agriculture. Commercial farmers with huge expanses of land, typically in monoculture, as opposed to small land sizes, as in intercropping, are the primary target market for agricultural machinery for applying fertilizer and controlling weeds, including pesticides and harvesting equipment (Lithourgidis *et al*., 2011b).

2.10.13 Shading effect in intercropping system

When one crop is overgrown and blocks the other crop's access to light, it can become a pest. By covering the other crop in the relationship, legumes can readily turn into a weed pest and reduce productivity (Alla *et al.*, 2014).

2.10.14 Interception of light in intercropping

The amount of solar radiation absorbed by a particular crop depends on its morphological composition. One of the most important elements in choosing the crops for an intercrop is the sustainable use of growth factors like sunshine (Eskandari, 2011a). Excessive light absorption reduces the pace of photosynthesis in the plant, which could eventually cause a significant decrease in growth parameters and output (Nyasasi and Kisetu, 2014). When selecting crops or kinds for intercropping, low and high-canopy plants are often chosen and planted together to enhance radiation. According to Nassary *et al*. (2019), shorter plants like peanuts are grown between longer plants like maize, millet, etc. to maximize light absorption and dispersion across the crops. The amount of light that is intercepted and potentially translated into yield parameters is one important factor that influences yield. Li *et al.* (2019) indicated that in contrast to maize cultivated as a monoculture, the light interception was maximized in maize-bean intercropping. When light interception is properly handled, intercropping yields can be increased. The author was also aware of how the maize-soybean intercropping affected the resource consumption of planting patterns.

2.10.15 Use of water in intercrop

Any crop production system's most important component is the water supply that is available to the plants. Water is essential for the preparation of the soil, planting, germination, and physiological and morphological growth of the crop till harvest (Eskandari, 2011b). It is a crucial element in determining agricultural output per unit area. Due to the diverse root systems of the intercrops, it has been discovered that intercropping two crop species, particularly legumes and cereals, uses water more effectively than sole cropping by looking for significant volumes of water through various soil layers and depths (Alhassan and Egbe, 2014). Varying root patterns, as measured by root length, root pores, and root hairs, enable intercropped species to utilize a large quantity of soil water (Mohammed, 2019b). Increasing the canopy cover makes more water available to crops because it keeps the soil from capping, which improves infiltration and reduces soil erosion.

2.10.16 Utilization of nutrients in the intercropping system

Głowacka (2013) stated that groundnut intercropped with maize improves iron (Fe) nutrition. As noted by Głowacka (2013), the secretion of phytosiderophores from maize in the intercrop arrangement in groundnut and maize intercropping may promote peanut Fe nutrition. In an intercrop, Belel (2014) stated increased adoption of nitrogen in maize agriculture when used alone. A non-legume plant is frequently seen in the literature combined with a legume, showing the increased accumulation of N (Mohammed, 2019b). Reduced nitrate and potassium leaching in the soil is a result of legume-cereal intercropping. (Ding, 2021) and not only as a plant that fixes nitrogen, but also as an absorber of N, P, and K from the minerals in the soil (Flores-Sanchez, 2013). These results demonstrate the value of legumes as a tool in agricultural settings where the main yield-limiting factors are N and K (Flores-Sanchez, 2011). Rusinamhodzi *et al.* (2012) indicated that micronutrient deficits in the field, such as those in zinc, molybdenum, and boron, may hinder the growth of legumes and restrict the fixation of nitrogen. When compared to sole cropping, intercropping can dramatically lower the amount of nitrogen, phosphorus, and potassium that maize consumes. The uptake is influenced by how evenly spaced and densely packed the roots are in the soil. In intercropping systems, nutrient efficiency occurs in space (Eskandari, 2011b). Both temporal and spatial nutrient absorption are possible. When it comes to temporary nutrient uptake, different species in the intercrop have different nutrient needs at different times, however when it comes to spatial nutrient uptake, nutrient needs rise along with the plant's expanding root mass. The efficient absorption of nitrogen is improved in crop species with distinctive root structures and absorption of various growth nutrients. This is because nitrogen is more mobile than other mineral components. According to Kermah *et al*. (2017), numerous studies demonstrate that nitrogen recently fixed by leguminous plants benefits both leguminous and non-leguminous plants.

2.11 Effect of Different Spatial Arrangement and Varietal Combinations on Yield of Maize and Groundnut (Legume) Intercropping System

The intercropping system is an important agricultural practice that involves growing two or more crops together in the same field (Maitra and Gitari, 2020), which can potentially lead to increased productivity and resource utilization. Understanding the impact of different spatial arrangements and varietal combinations on yield is crucial for optimizing intercropping strategies. Different spatial arrangements, such as row arrangements, strip cropping, or mixed cropping, influenced the yield of both maize and groundnut crops (Homulle *et al*., 2021). The spatial arrangement affected the availability of resources, light interception, and nutrient uptake by the crops, thus influencing their growth and yield. The choice of varietal combinations also played a crucial role in determining the overall yield of the intercropping system. The interaction between different maize and groundnut varieties influenced the competitive interactions, resource partitioning, and complementarity between the crops. Certain combinations of varieties were found to have a synergistic effect, resulting in higher overall yields compared to others. A study by Abdul Rahman *et al*. (2021), revealed that specific spatial arrangements, such as strip cropping or mixed cropping, combined with certain varietal combinations, resulted in higher grain yields for both maize and groundnut.

These combinations effectively utilized available resources, reduced competition between the crops, and enhanced resource complementarity. It is worth noting that the optimal spatial arrangement and varietal combination may vary depending on environmental conditions, crop management practices, and specific crop cultivars. According to Bugilla *et al*. (2023), the highest groundnut pod yields of 1815.00 kg/ha and 2359.00 kg/ha were recorded by the 0WAP × 1M2G treatment, whereas the highest seed yields of groundnut (404 kg/ha and 637 kg/ha) for major and minor rainy seasons respectively were produced by 1WAP × 2M.

Konlan & Kombiok (2013) reported that the highest groundnut and maize yields in the sintercrop in both years were obtained respectively from 2 rows of groundnut + 1 row of maize and 1 row of groundnut + 2 rows maize. The 1-row maize + 2 rows maize and 1-row groundnut + 2 rows maize intercropping arrangement was therefore the most advantageous in both years, achieving land equivalent ratio values greater than 1. Olayinka (2017) indicated that growth characters such as the number of leaves and leaf area were enhanced in 3G:1M and 3G:2M spatial arrangement when compared to 3G:3M and their respective sole cropping. Yield was also enhanced in the intercrop compared to their soles. The 3G:3M produced groundnut seeds with increased percentage ash, fibre, and crude protein with concomitant reduction of the fat and carbohydrate when compared to other spatial arrangements and sole groundnut. The results showed that 3G:1M and 3G:2M could be considered appropriate spatial arrangements for enhancing the growth and yield of the intercrop. Zea *et al*. (2016) revealed that in terms of the spatial arrangement, the grain yield of groundnut from the double row (1:2) performed better than the single row of groundnut (1:1) because of crop complementarities however about dry matter accumulation, the 1:2 spatial arrangement for the groundnut produced less than the 1:1, however, sole maize performed better than both spacings. In the case of the maize, sole maize produced the highest grain yield, dry matter accumulation, leaf area index, height at maturity, and harvest index.

2.12 Land equivalent ratio (LER)

Land equivalent ratio is the total yield ratio from an intercrop to the ratio of total yield collected from the same plant species in the sole crop. Ennin *et al*. (2001) also defined the Land equivalent ratio (LER) as the total land area required under sole cropping to give yields obtained in the intercropping. In a nutshell, the LER values for the intercrops were more than 1.0. This value implies that the intercrops had a yield advantage over the sole crops. The intercropping of the groundnut 1:2 spatial arrangement gave the highest LER of 3.39 and the 1:1 spatial arrangement gave 1.48. The results, therefore, suggest that in the groundnut-maize intercropping system both 1:2 spactial arrangement is best however this will depend largely on the crop interest of the farmer. It is the total quantity of the intercrop yield as a fraction of that of the yield of the sole crop of the same species (Layek *et al.*, 2018b). Generally, in an intercropping scheme, sole crop legumes have greater yields compared to yields in intercropping. In most instances, however, it measures soil productivity and demonstrates the benefit of mixed intercropping arrangement over sole cropping.

According to Mohammed (2019a), LER indicates the magnitude of sole cropping required to produce the same yield on a unit of intercropped land. Research has shown that the response of nitrogen to intercropping generally results in reduced LER values (Mohammed, 2019a). Measuring LER of 1.0 implies that there is no absolute economic benefit in intercropping a given crop over sole cropping and vice versa (Mohammed, 2019a). 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. Zea *et al*. (2016) stated that for land equivalent ratios (LER), the LER values for the intercrops were more than 1.0. This value implies that the intercrops had a yield advantage over the sole crops. The intercropping of the groundnut 1:2 spatial arrangement gave the highest LER of 3.39 and the 1:1 spatial arrangement gave 1.48. The results therefore suggest that in the groundnut-maize intercropping system both 1:2 spactial arrangement is best however this will depend largely on the crop interest of the farmer. According to Mei *et al.* (2021), when the land equality ratio (LER) equals 1, it indicates that the yield of intercrop and sole crops is the same. LER values greater than 1 suggest the usefulness of intercrop cultivation, while LER values less than 1 indicate the unprofitability of intercrop cultivation. Previous studies have reported physiological and morphological differences, as well as higher LER, in intercropping systems involving potatoes and beans (Nasrollahzadeh *et al*., 2012) and sunflower and beans (Hamzei and Babaei, 2017).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site/Location

Two field experiments were carried out from August to December, 2021 in the minor rainy season and March to July, 2022 in the major rainy season. The field research was conducted at the Research field of the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Mampong Campus. Mampong-Ashanti is located in the Forest-Savannah transitional zone of Ghan (Geodatos, 2020). The mean annual rainfall of Asante Mampong is approximately 1270 mm with a bimodal rainfall pattern. The major rains begin around early April and end in July whilst the minor rains start in September and end in November. There is a short dryness in August but the main dry season begins in December and ends in March. The area experiences a mean temperature of about 27 ^{o}C per annum with a temperature range normally from 22 ^{o}C to 30 ^{o}C (GSS, 2014). The soil at the experimental site is derived from the Voltaian sandstone and belongs to the Bediase Series of the Savannah Ochrosol class. It is classified as Chromic Luvisol in the FAO/UNESCO (2008) system of classification. It is deep red, sandy loam, and free from stones. It is well-drained and friable and also has good water-holding capacity, texture, and structure. It has a pH of about 6.5.

3.2 Experimental Design and Treatments

The experimental design used was a 3 x 3 factorial experiment arranged in a Randomized Complete Block Design (RCBD) and replicated four times. Sole crops of maize and groundnut varieties were added.

The factors studied were:

(A) – Varietal Combination of Maize and Groundnut: - (i) Opeaburo + Yenyawoso, (ii) Opeaburo + Dehye, and (iii) Opeaburo + Oboshie and

(B) – Spatial Arrangements: - (i) 1-row maize alternating with 1-row groundnut (SP1), (ii) 1-row maize alternating with 2 rows groundnut (SP2), and (iii) 1-row maize alternating with 3 rows groundnut (SP3).

Each plot size consisted of 4 sets each of the intercrop spatial arrangement, with row length of 5 m long. Therefore, the plot sizes were for the intercrops SP1 = 4 m wide x 5 m long, SP2 = 6 m wide x 5 m long, and SP3 = 8 m wide x 5 m long. The within row spacing for the intercrops was 40 cm for the maize and 20 cm for the groundnuts. The sole crops also consisted of 4 rows each per crop and 5 m length of row. The sole maize was planted at 80 cm x 40 cm, and the groundnut varieties at 50 cm x 20 cm. The maize and groundnuts had 2 plants/hill for the intercrops and sole crops.

Opeaburo maize variety and Yenyawoso, Dehye, and Oboshie groundnut varieties were developed and released by the Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI). The seeds were obtained from the CSIR-CRI. The Opeaburo maize variety is a white dent with a maturity period between 110 - 115 days. This variety of maize was selected for the study because it is drought and disease-resistant. It is a high-yielding variety with a yield potential of 7.5 t/ha. It is also very good for domestic purposes.

The Yenyawoso groundnut variety is early maturing with a maturity period of 85 - 90 days, Dehye is an early maturing variety with a maturity period between 85 – 90 days, and Oboshie is a late-maturing variety with a maturity period between 105 – 110 days. These three (3) varieties of groundnuts were also selected for the study because they are high-yielding varieties with the following yield potentials: Yenyawoso (2.7 t/ha), Dehye (2.9 t/ha), and Oboshie (2.6 t/ha). They are also drought-resistant and grow vigorously.

The row arrangements are shown in the plates below:

Plate 3:1-row maize alternating with 1-row groundnut (SP1)

Plate 3:2-row maize alternating with 2 rows of groundnut (SP2)

Plate 3:3-Row maize alternating with 3 rows of groundnut (SP3)

3.3 Land Preparation and Planting

The land was prepared in August 2021 by ploughing, harrowing, and later levelled. The land was demarcated into four replications. Both maize seeds and groundnut seeds were planted directly on the same day using three seeds per hole which were thinned to 2 seeds/hill two weeks after emergence. Maize seeds were planted on flat land, while groundnut seeds were planted on ridges. The same land preparation was done for the second field trial in March 2022 and planting.

3.4 Cultural Practices

3.4.1 Weed Control

Four (4) separate weedings were done with the aid of a hoe and a cutlass. The first weeding was done two weeks after seedling emergence. The second and third weeding were done 30 and 60 days after planting, respectively. Several weeding was done because of the frequent appearance of the nutgrass (*Cyperus rotundus*). The weeding was to ensure that the weeds do not compete with the crops for nutrients and soil water to ensure optimum yield.

3.4.2 Pest and Disease Control

Frequent visit to the experimental field was done to observe the incidence of pests such as stem borers, corn leaf aphid rodents, and fall armyworm on maize and diseases such as rust, early leaf spot, late leaf spot, and rosette on groundnut. Emaster (*Emamectin benzoate*) insecticide at a rate of 10-30 ml per acre was applied to control fall armyworm infestation two weeks after seedling emergence and any time the fall armyworm appeared on the field with the aid of a CP 15 knapsack sprayer. Incidence of diseases on groundnut was very minimal so no control measures were taken against it.

3.5 Data collected

3.5.1 Maize Data

3.5.1.1 Days to 50% Emergence

The days to 50% emergence for sole and intercrop maize was estimated as the number of days after sowing when 50% of the seedlings in the two central harvestable rows had emerged and the outcome was expressed as a percentage of the total number of seedlings expected to emerge.

3.5.1.2 Percentage Plant Establishment

The percentage plant establishment for both sole and intercrop maize was determined twenty-one (21) days after the sowing of seeds. This was done by counting the number of plants that had been established within the two central rows and the percentage plant establishment was estimated.

3.5.1.3 Days to 50% Tasseling

Days to 50% tasseling for both sole and intercrop maize was estimated by counting from the two rows the days after sowing when 50% or half of the plants had tasseled.

3.5.1.4 Days to 50% Silking

The days to 50% silking for both sole and intercrop was determined by counting from the two rows the days after sowing when 50% or half of the plants had silked.

3.5.1.5 Plant Height

The meter rule was used to determine the height of the maize plant from the plant's base to its flag leaf. Plant height was measured from five randomly selected and tagged plants in the two central rows for sole crops and intercrops, three (3) weeks after planting and every two-weeks interval, and their mean values were estimated.

3.5.1.6 Number of Leaves per plant

The number of leaves per plant of maize for both sole and intercrop from the five randomly selected and tagged plants in the two central harvestable rows was determined by counting the total number of leaves per plant for the tagged plants. This was done three (3) weeks after planting and every two weeks over the growing period and their mean values were estimated.

3.5.1.7 Dry Matter Accumulation

The dry matter of maize for both sole and intercrop was determined three (3) weeks after planting and every two weeks interval. Two plants were cut from the border of each plot of sole maize and intercrop and were chopped into smaller pieces for weighing. The fresh shoot weight was determined using the Westinghouse electronic weighing scale. A 200 g of fresh root and shoot was fetched from the bulk envelope and was oven-dried in the laboratory at 85 ^{o}C until the constant weight was attained and their means estimated.

3.5.1.8 Chlorophyll Content of Leaf (CCL)

A SPAD meter was used to measure the chlorophyll content of leaves of both sole and intercrop maize from the five (5) randomly selected and tagged plants in the two-central harvestable. The SPAD readings were taken on the 5th and 6th leaves from the base of each plant, thirty (30) days after planting and every two weeks interval, and their mean values were estimated.

3.5.1.9 Number of plants harvested

The total number of plants harvested from the two central rows for both sole and intercrop maize was counted and the means was estimated.

3.5.1.10 Number of lodged plants per plot

The total number of plants from the two central rows of both sole and intercrop maize that lodged at the base or stem was counted and the mean was estimated.

3.5.1.11 Stover weight per plant and per plot

The stalk of maize together with the cobs for the five tagged plants was harvested from the two central rows for both sole and intercrop maize and weighed in kilograms (kg) using the Westinghouse electronic weighing scale and recorded as the stover weight per plant whilst the remaining untagged plants from the harvestable area per plot were harvested and added to the tagged ones and weighed using the Westinghouse electronic weighing scale and were recorded as the stover weight per plot.

3.5.1.12 Dry matter accumulation at harvest

The dry matter accumulation of maize at harvest was determined after the plants had been harvested. Harvested plant shoot per plot was chopped into pieces and weighed using the Westinghouse electronic weighing scale and oven-dried in the laboratory at 85 °C until the constant temperature was attained and the mean recorded.

3.5.1.13 Number of cobs per plant and per plot

The total number of cobs harvested from the five randomly selected tagged plants from the two central harvested rows for both sole and intercrop maize was counted as the number of cobs per plant and the mean recorded whilst the remaining untagged plants from the harvestable area per plot were also harvested and the total number of cobs counted and added to the tagged ones and the mean recorded as cobs per plot.

3.5.1.14 Number of filled cobs per plot

The number of filled cobs per plot was estimated by counting the total number of cobs that were filled with grains and the mean estimated.

3.5.1.15 Cob diameter

The diameter of five cobs that were randomly selected at harvest from the two central harvestable rows was measured from the widest part using the Vernier caliper after de-husking and the mean was estimated.

3.5.1.16 Cob length

The length of five cobs that were randomly selected at harvest from the two central harvestable rows was measured using the metre rule after de-husking and the mean was estimated.

3.5.1.17 100-Seed weight

The 100-seed weight of maize was measured by randomly selecting one hundred seeds from each plot after shelling and their weigh taken using the Westinghouse electronic weighing scale and their means recorded.

3.5.1.18 Shelling percentage

All cobs from the two central rows per plot for sole and intercrop maize were weighed using a salter-suspended weigher (model number 235). Cobs were shelled and the grains were weighed using an electronic weighing scale. The cob weight and the grain weight were used to compute the shelling percentage as follows;

Shelling % = $\frac{Maize\ grain\ weight}{Weight\ of\ cobs}\ x\ 100\%$ (Ruswandi *et al.*, 2021).

3.5.1.19 Grain yield

The grain yield from the harvestable area per plot of both sole and intercrop maize was calculated and the results were then used to compute the yield per hectare. Thus, grain yield per hectare is given as;

Grain yield (kg) per hectare = $\frac{10000m^2\ x\ Q\ grain\ (kg)}{Harvest\ area\ (m^2)}$ (Makarova *et al.*, 2020).

3.5.1.20 Harvest index

The shoots of both sole and intercrop maize together with the cobs from the two central harvestable rows were weighed using a salter suspended weigher with model number 235. The cobs were then removed and weighed alone.

Thus, the Harvest index = $\frac{Grain\ weight}{Above\ ground\ biomass(stover+grain)}$ (Imran *et al.*, 2021).

3.5.2 Groundnuts Data

3.5.2.1 Days to 50% Emergence

Days to 50% emergence for both sole and intercrop groundnut was estimated as the number of days after sowing of seeds when 50% of the seedlings in the two central harvestable rows had emerged and the outcome was recorded as a percentage of the total.

3.5.2.2 Percentage Plant Establishment

The percentage plant establishment was determined at twenty-one (21) days after sowing of groundnut seeds for both sole and intercrop. This was done by counting the number of plants that had been established within the two central harvestable rows and the outcome was estimated as a percentage of the total.

3.5.2.3 Days to 50% Flowering

Days to 50% flowering of groundnut were assessed by counting from the two rows the days after flowering when 50% or half of the plants had flowered. This was done for both the sole and intercrop groundnut.

3.5.2.4 Plant Height

The plant height was determined from the base of the plant to the flag leaf using the meter rule. This was done for both sole and intercrop of groundnut from the five randomly selected and tagged plants in the two central rows, three weeks after planting and every two weeks interval, and their mean values were estimated.

3.5.2.5 Number of Branches per plant

The number of branches per plant for both sole and intercrop from the five randomly selected and tagged plants in the two central rows were determined three (3) weeks after planting and every two weeks interval. This was done by counting the total number of branches from each tagged plant and the mean estimated.

3.5.2.6 Dry Matter Accumulation

The dry matter of groundnut for both sole and intercrop was determined three (3) weeks after planting and every two weeks intervals through the growing season. Two plants were cut from the border of each plot of sole and intercrop groundnut. They were chopped into smaller pieces for weighing. The fresh shoot weight was determined using the Westinghouse electronic weighing scale. A 200 g of fresh root and shoot was fetched from the bulk envelope and was oven-dried in the laboratory at 85 ^{o}C until the constant weight was attained and their means estimated.

3.5.2.7 Chlorophyll Content of Leaves (CCL)

The chlorophyll content in groundnut was estimated by the SPAD meter for both sole and intercrop groundnut from the five (5) randomly selected plants from the two central rows. This was done by taking the chlorophyll content of two (2) leaves on the main stem from the five (5) tagged plants and their means estimated.

3.5.2.8 Number of plants harvested

The total number of plants harvested from the two central rows for both sole and intercrop groundnuts was counted and the means were estimated.

3.5.2.9 Biomass weight per plant and per plot

The biomass weight of the five tagged plants after harvested from the two central rows for both sole and intercrop groundnut was weighed in kilograms (kg) using the Westinghouse electronic weighing scale and recorded as the haulm or biomass weight per plant whilst the remaining untagged plants from the harvestable area per plot were harvested and added to the tagged ones and weighed together using the Westinghouse electronic weighing scale and the mean recorded.

3.5.2.10 Dry matter at harvest

The dry matter accumulation of groundnut at harvest was determined after the plants had been harvested. Harvested plant shoot per plot was chopped into pieces and weighed using the Westinghouse electronic weighing scale and oven-dried in the laboratory at 85 °C until the constant temperature was attained and the mean recorded.

3.5.2.11 Number of pods per plant and per plot

The total number of pods per plant for both sole and intercrop groundnut were counted from the five plants randomly selected and tagged from the two central harvestable rows and the mean was recorded whereas the number of pods per plot was estimated by adding pods from both tagged plants and the untagged plants from the harvestable rows and counted together and the mean estimated.

3.5.2.12 Number of seeds per pod

The number of seeds per pod of groundnut from ten (10) randomly selected pods from the cenral rows of both sole and intercrop groundnut were counted and their mean was recorded.

3.5.2.13 100-Seed weight

The 100-seed weight of groundnut was measured by randomly selecting a hundred seeds from each plot after shelling and their weigh taken using the Westinghouse electronic weighing scale and their means recorded.

3.5.2.14 Shelling percentage

All pods from the two central rows per plot for sole and intercrop groundnut were weighed using the Westinghouse electronic weighing scale. Pods were shelled and the grains were weighed using an electronic weighing scale. The pod weight and the grain weight were used to compute the shelling percentage as follows;

Shelling % = $\frac{Groundnut\ grain\ weight}{Weight\ of\ pods}\ x\ 100\%$ (Ruswandi *et al.*, 2021).

3.5.2.15 Grain yield

The grain yield from the harvestable area per plot of both sole and intercrop groundnut was calculated and the results were then used to compute the yield per hectare.

Thus, grain yield (kg) per hectare = $\frac{10000m^2\ x\ Q\ grain\ (kg)}{Harvest\ area\ (m^2)}$ (Makarova *et al.*, 2020).

3.5.2.16 Harvest index

The shoots of both sole and intercrop groundnut together with the pods from the two central harvestable rows were weighed using a salter suspended weigher with model number 235. The pods were then removed and weighed alone.

Thus, harvest index = $\frac{Grain\ weight}{Above\ ground\ biomass(stover+grain)}$ (Imran *et al.*, 2021).

3.6 Land equivalent ratio (LER)

Land equivalent ratio shows the effectiveness of intercropping over the pure stand. A land equivalent ratio of more than 1 shows the economic productivity of the intercrop over the pure stand and that it is advantageous to grow such crops in a 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 was calculated as;

LER = Σ (YI/YS) (Khademi *et al.*, 2023), where

Y = Yield of crop 1 in intercropping, and

Y = Yield of crop 1 in sole cropping

3.7 Data Analysis

Using Genstat 11th edition, analysis of variance (ANOVA) was used to analyse the data that were gathered. Tukey's Honestly Significant Difference (HSD) was used to separate treatment means at a 5% level of probability.

Correlation analysis covering growth and yield and yield components was also conducted.

CHAPTER FOUR

4.0 RESULTS

4.1 Climatic Conditions at the Experimental site

The total rainfall during the experiment for the 2021 minor raining season was 676.7 mm. The highest relative humidity (77%) was recorded in August and September and the least was recorded in December 2021 (58%). The mean maximum and minimum temperatures during the 2021 minor raining season were 31.9 ^{0}C and 23.06 ^{0}C, respectively (Table 4.1). The total rainfall during the 2022 major raining season was 694.6 mm. The highest relative humidity (74%) was recorded in June and July, while the least was recorded in April 2022 (66%) during the major raining season. The mean maximum and minimum temperatures during the 2022 major raining season were 26.76 ^{0}C and 23.44 ^{0}C, respectively (Table 4.2).

Table 4.1: Climatic data for 2021 Minor cropping season for Experiment one (1)

Month	**Total Rainfall (mm)**	**Relative Humidity (%)**	**Mean Temperature (℃)**	
			Max	**Min**
August, 2021	1695	77	29.7	22.7
September	225.1	77	30.3	23.2
October	208.7	72	32.1	22.3
November	73.4	68	33.1	23.4
December	0.0	58	34.3	23.7
Total	**676.7**			

(Ghana Meteorological Agency – Mampong Ashanti, 2021).

Table 4. 2: Climatic data for 2022 Major cropping season for Experiment Two (2)

Month	**Total Rainfall (mm)**	**Relative Humidity (%)**	**Mean Temperature (℃)**	
			Max	**Min**
March, 2022	109.2	67	34	23.9
April	79.6	66	33.1	23.5
May	147.8	71	32.7	23.8
June	149.0	74	31	23.3
July	203.6	74	30	22.7
Total	**694.6**			

(Ghana Meteorological Agency – Mampong Ashanti, 2022).

4.2 Influence of Variety and Spatial arrangement on Phenology of Groundnut and Maize

4.2.1 Groundnut

4.2.1.1 Days to 50% emergence

The results of days to 50% emergence of groundnut for the 2021 minor and 2022 major cropping seasons are shown in Table 4.3. There was a significant ($P \leq 0.05$) interactive effect in the days to 50% emergence between groundnut varieties for both the 2021 minor and 2022 major cropping seasons (Table 4.3). The days to 50% emergence ranged from 9 – 11 days for the minor season and 7 – 10 days for the major season. Generally, Yenyawoso emerged earlier than Dehye and Oboshie by 1 – 2 days across both seasons (Table 4.3). Generally, the groundnut varieties emerged earlier in the major season than the minor season by 1 – 2 days (Table 4.3). Spatial arrangement and varietal combination x spatial arrangement interactions did not influence the days to emergence of the groundnut varieties. Opeaburo + Yenyawoso x SP3 resulted in the earliest days to 50% emergence during the 2021 minor cropping period, while Opeaburo + Yenyawoso x SP2 resulted in the earliest days to 50% emergence during the 2022 major cropping season. Opeaburo + Oboshie x SP1 and Opeaburo + Oboshie x SP3 interactions had late days to 50% emergence for the 2021 minor and 2022 major cropping periods, respectively.

4.2.1.2 Percentage plant establishment

The results in Table 4.3 show the percentage plant establishment of groundnut for 2021 minor and 2022 major cropping seasons. Significantly ($P \leq 0.05$), differences existed in the percentage plant establishment among treatment means for both 2021 and 2022 cropping seasons of groundnut. Percentage plant establishment ranged from 51.9 – 73.9 % and 57.7 – 96.1 % for the minor and major seasons, respectively (Table 4.3). Generally, plant establishment was higher for Yenyawoso (73.9 – 94 %) than for Dehye (59.4 – 88.4 %) and Oboshie (51.9 – 64.8

%) in the intercrops for both seasons. Generally, plant establishement was higher during the 2022 major season (57.6 % - 96.1 %) than during the 2021 minor season (51.9 % - 73 %). There was no spatial arrangement or varietal combination x spatial arrangement interaction effects on percentag plant establishment in both seasons (Table 4.3). Opeaburo + Yenyawoso x SP2 and SP3 interactions had the highest percentage plant establishment in 2021 cropping season, while Opeaburo + Yenyawoso x SP2 interaction recorded the highest percentage plant establishment in the 2022 major cropping season (Table 4.3). Plots with solely Oboshie exhibited the lowest percentage plant establishment for both 2021 minor 2022 major cropping seasons. There was no spatial arrangement or varietal combination x spatial arrangement interaction effects on percentage plant establishment in both seasons (Table 4.3).

Table 4.3: Days to 50% emergence and percentage plant establishment of groundnut as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons

Treatment		**Days to 50% emergence**		**Percentage plant establishment (%)**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	10	7	72.44	89.81
	SP2	9	7	73.86	96.09
	SP3	9	7	73.86	93.75
Opeaburo + Dehye	SP1	11	9	59.38	88.35
	SP2	10	8	59.66	84.38
	SP3	10	9	62.78	87.22
Opeaburo + Oboshie	SP1	11	10	54.26	64.77
	SP2	11	10	54.55	57.67
	SP3	11	10	51.99	61.65
Sole Yenyawoso	-	10	7	73.01	85.23
Sole Dehye	-	10	9	58.24	84.44
Sole Oboshie	-	11	10	53.98	59.66
CV (%)		**7.0**	**5.4**	**11.18**	**15.7**

Variety =	*HSD=0.59***	*p=<.001*	*HSD=8.05***	*p=<.001*
Season =	*HSD=0.46***	*p=<.001*	*HSD=6.10***	*p=<.001*
Spatial arrangement =	*NS*		*NS*	
Season x variety =	*HSD=0.72***	*p=0.036*	*HSD=10.92***	*p=0.010*
Season x spatial arrangement =	*NS*		*NS*	
Variety x spatial arrangement =	*NS*		*NS*	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference, CV (%) = Coefficient of variation.

4.2.1.13 Days to 50% flowering

Table 4.4 shows results of days to 50% flowering of groundnut for 2021 minor and 2022 major cropping seasons.Yenyawoso flowered a few days ealier (27 – 28 dyas) than Dehye (30 – 31 days) and Oboshie (32 – 34 days) in the intercrops during both seasons. For the 2021 period, Opeaburo + Yenyawoso x SP1 interaction and sole Yenyawoso had the earliest days to 50% flowering of groundnut, while for the 2022 major season, Opeaburo x Yenyawoso x SP1, SP2, and SP3 interactions exhibited the earliest and same days to 50% flowering of groundnut. On the other hand, plots with Opeaburo + Oboshie x SP2 and Opeaburo + Oboshie x SP3 interactions, as well as Sole Oboshie, were late to flower for the 2021 minor and 2022 major cropping seasons. Days to 50% flowering was similar for both seasons. However, spatial arrangement and varietal combination x spatial arrangements interaction effects on days to 50% flowering were not significant (P>0.05) for both seasons.

Table 4.4: Days to 50 % flowering of groundnut as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Treatment		**Days to 50% flowering**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	27	28
	SP2	28	28
	SP3	28	28
Opeaburo + Dehye	SP1	30	30
	SP2	30	30
	SP3	31	30
Opeaburo + Oboshie	SP1	34	32
	SP2	33	32
	SP3	33	33
Sole Yenyawoso	-	27	28
Sole Dehye	-	30	30
Sole Oboshie	-	33	33
CV (%)		**2.4**	**2.7**
Variety =		*HSD=0.49***	*p=<.001*
Season =		*HSD=0.51***	*p=0.038*
Spatial arrangement =		*NS*	
Season x variety =		*HSD=0.72***	*p=0.008*
Season x spatial arrangement =		*NS*	
Variety x spatial arrangement =		*NS*	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference, CV (%) = Coefficient of variation.

4.2.2 Maize

4.2.2.1 Days to 50% emergence

The results for days to 50% emergence as affected by varietal combination, spatial arrangement or their interactions are shown in Table 4.5. Days to 50% emergence ranged from 5 – 6 days for the maize variety Opeaburo and did not differ among the varietal combinations, spatial arrangement, and varietal combination x spatial arrangement interactions (Table 4.5).

4.2.2.2 Percentage plant establishment

Table 4.5 shows the results of percentage plant establishment of maize. The percentage plant establishment of maize ranged from 76 – 92.5 % and 91.9 – 97.5 % for the minor and major seasons among the intercrops. The sole maize had 79 – 96.3% plant establishment (Table 4.5). Opeaburo + Dehye x SP1 recorded the highest percentage plant establishment for the 2021 period, which was significantly ($p \leq 0.05$) different from Opeaburo + Yenyawoso x SP2. Conversely, plots with Opeaburo + Yenyawoso x SP2 had the least percentage plant establishment for the 2021 minor cropping season. Percentage plant establishment did not differ among varietal combinations, spatial arrangement nor varietal combination x spatial arrangement interactions for both seasons. However, the percentage plant establishment was slightly higher in the 2022 major season than the 2021 minor season by about 5 – 15.4 % (Table 4.5).

Table 4.5: Days to 50 % emergence and percentage plant establishment of maize as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Treatment		**Days to 50% emergence**		**Percentage plant establishment (%)**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	6	5	82.50	96.25
	SP2	5	5	76.25	97.50
	SP3	5	5	91.88	96.88
Opeaburo + Dehye	SP1	6	5	92.50	97.50
	SP2	5	5	78.75	91.88
	SP3	6	5	85.00	96.88
Opeaburo + Oboshie	SP1	5	5	83.75	96.25
	SP2	5	5	81.25	95.62
	SP3	6	5	81.25	96.88
Sole Opeaburo	-	6	5	79.38	96.25
CV (%)		**9.0**	**9.3**	**11.1**	**4.0**
Variety =		*NS*		*NS*	
Season =		*HSD=0.22***	*p=<.001*	*HSD=3.23***	*p=<.001*
Spatial arrangement =		*NS*		*NS*	
Season x variety =		*NS*		*NS*	
Season x spatial arrangement =		*NS*		*NS*	
Variety x spatial arrangement =		*NS*		*NS*	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference, CV (%) = Coefficient of variation.

4.2.2.3 Days to 50% tasseling

The results for the days to 50% tasseling for the maize variety Opeaburo in intercrop and sole crop are shown in Table 4.6. There was a significant (P≤0.05) difference between the treatment means in both cropping seasons. The days to 50 % tasseling ranged from 52 – 54 % for both seasons. Opeaburo + Yenyawoso x SP2 interaction recorded the earliest days to 50% tasseling for 2021 cropping season, while Opeaburo + Oboshie x SP2 interaction obtained the earliest days to 50% tasseling for 2022 major cropping season. For the 2021 minor cropping season, plots with Opeaburo + Dehye x SP2, Opeaburo + Oboshie x SP1, and Opeaburo + Oboshie x SP2 interactions were late to tassel, while for the 2022 major cropping period, Opeaburo + Dehye x SP1 interaction was late to tassel. The days to 50% tasseling was not significantly different among the varietal combinations, spatial arrangements nor the varietal combination x spatial arrangement interactions for both seasons. Generally, tasseling did not differ between the two seasons either (Table 4.6).

4.2.2.4 Days to 50% silking

The results for the days to 50% silking for the maize variety Opeaburo in intercrop and sole crop are shown in Table 4.6. The days to 50% silking ranged from 57 – 60 days for both seasons. Opeaburo + Yenyawoso x SP2 interaction recorded the earliest days to 50% silking for the 2021 cropping period. The days to 50% silking was not significantly different among the varietal combinations, spatial arrangements nor the varietal combination x spatial arrangement interactions for both seasons. Generally, silking did not differ between the two seasons either (Table 4.6).

Table 4. 6: Days to 50% tasseling and days to 50% silking of maize as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Treatment		**Days to 50% tasseling**		**Days to 50% silking**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	52.75	53.50	58.25	58.75
	SP2	52.25	53.25	57.25	59.50
	SP3	52.75	52.75	57.50	58.75
Opeaburo + Dehye	SP1	53.00	54.25	58.25	59.25
	SP2	53.50	53.25	58.75	59.50
	SP3	53.25	53.25	58.25	58.75
Opeaburo + Oboshie	SP1	53.50	53.50	59.00	59.50
	SP2	53.50	52.50	59.50	58.50
	SP3	53.25	53.50	58.50	59.25
Sole Opeaburo	-	53.50	53.0	59.00	58.75
CV (%)		**1.1**	**1.5**	**1.7**	**1.2**

Variety =	*NS*	*NS*	
Season =	*NS*	*HSD=0.42***	*p=0.004*
Spatial arrangement =	*NS*	*NS*	
Season x variety =	*NS*	*HSD=0.86***	*p=0.046*
Season x spatial arrangement =	*NS*	*NS*	
Variety x spatial arrangement =	*NS*	*NS*	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference, CV (%) = Coefficient of variation.

4.3 Influence of Variety and Spatial arrangement on vegetative growth of Groundnut.

4.3.1 Plant height

Figures 4.1 and 4.2 shows result of plant height of groundnut varieties and their intercrops from 21 DAP to 77 DAP for for seasons. The plant height increased throughout the entire period from 21 DAP to 77 DAP for both seasons. Generally, Dehye and its intercrop showed the highest increase in plant height throughout the growing period followed by

Yenyawoso and its intercrop whereas Oboshie and its intercrop had the lowest trends in plant height among the groundnut varieties (Figures 4.1 and 4.2).

Results in Figures 4.3 and 4.4 show results of spatial arrangement for plant height of groundnut varieties for both 2021 minor and 2022 major cropping periods. Generally, no significant difference was observed among the spatial arrangements. However, the spatial arrangements showed an increase in plant height from 21 – 77 DAP with SP2 standing out in terms of plant height among the groundnut varieties and their intercrops for the spatial arrangement.

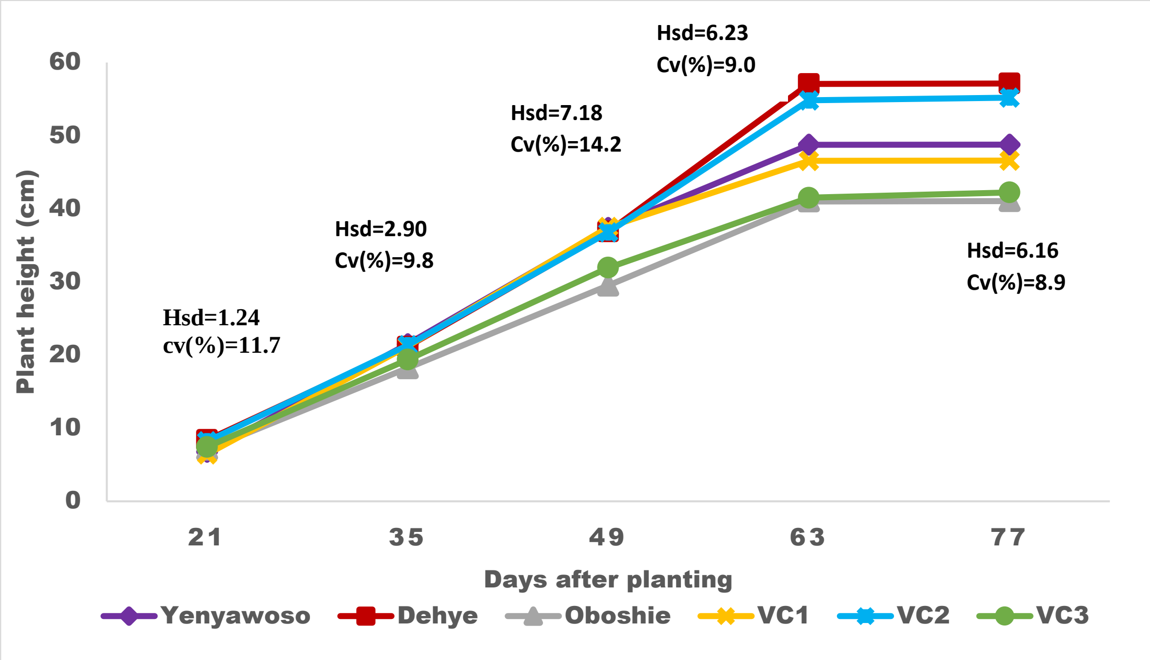

Figure 4.1: Plant height of groundnut as influenced by variety for 2021 minor cropping season.

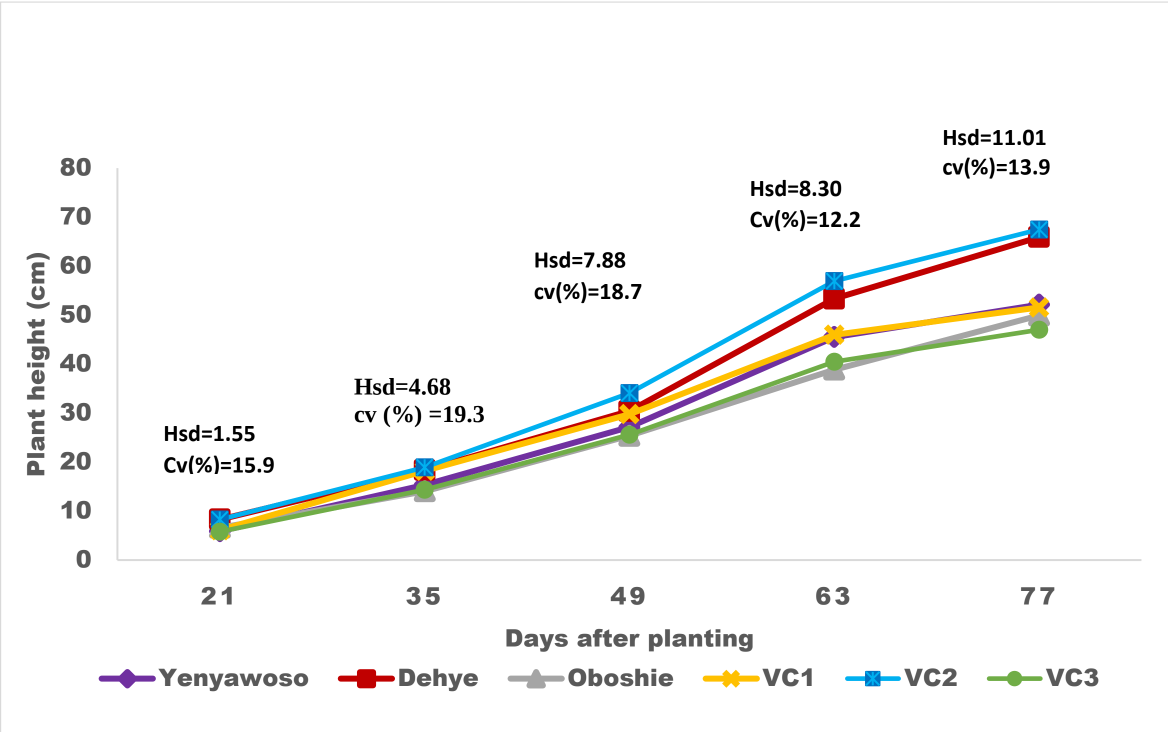

Figure 4.2: Plant height of groundnut as influenced by variety for 2022 major cropping season

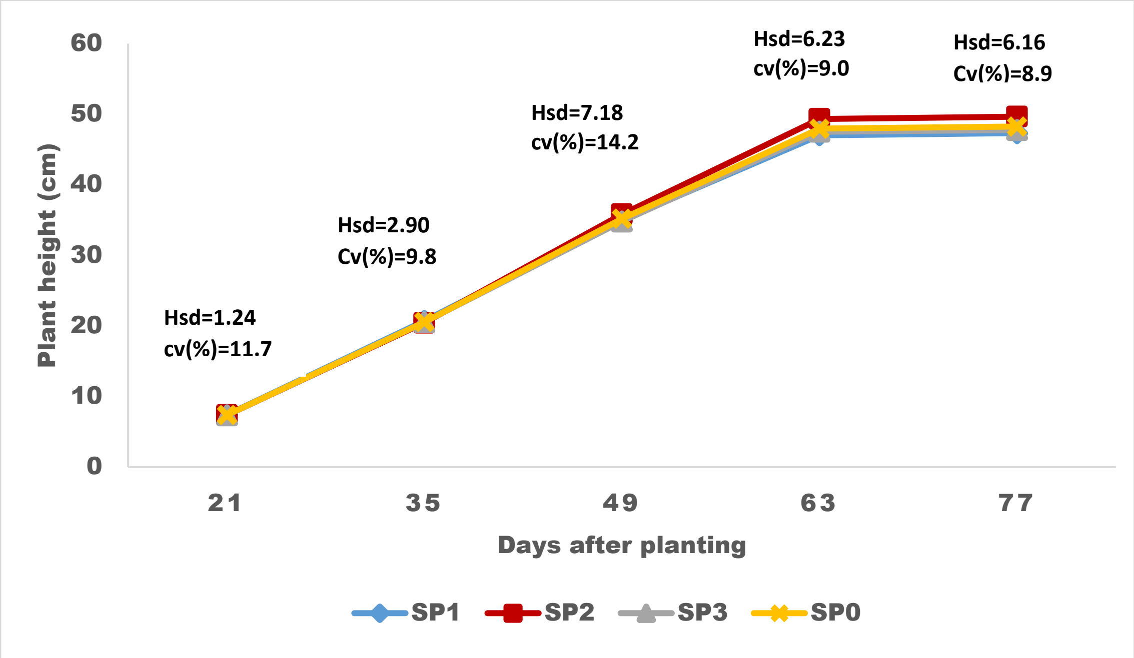

Figure 4.3: Plant height of groundnut as influenced by spatial arrangement for 2021minor cropping season.

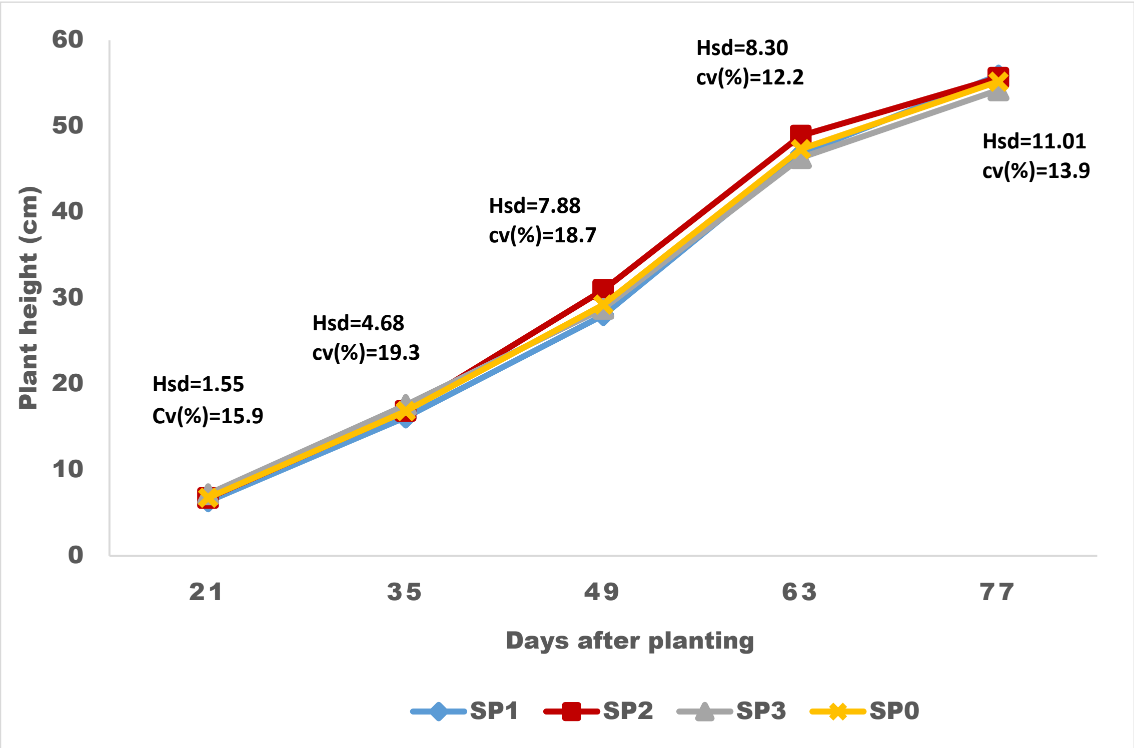

Figure 4.4:Plant height of groundnut as influenced by spatial arrangement for 2022 major cropping season.

4.3.2 Number of branches per plant

Figures 4.5 and 4.6 indicate the results of number of branches among groundnut varieties and their intercrops for both seasons. The number of branches per plant of groundnut increased from 21 DAP to 63 DAP for both seasons until 77 DAP where it remained constant. Generally, Oboshie variety and its intercrop had the highest increase in plants followed by Yenyawoso and Dehye throughout the growing period in both seasons.

Results in Figures 4.7 and 4.8 show results of spatial arrangement for the number of branches per plant of groundnut varieties for both seasons. Generally, the spatial arrangements showed an increase in the number of branches per plant of groundnut from 21 – 63 DAP until 77 DAP where it remained constant. SP2 had the greatest number of branches per plant in the 2021 minor season whereas, in the 2022 major season, SP3 had the greatest number of branches per plant among the groundnut varieties and their intercrops for the spatial arrangement.

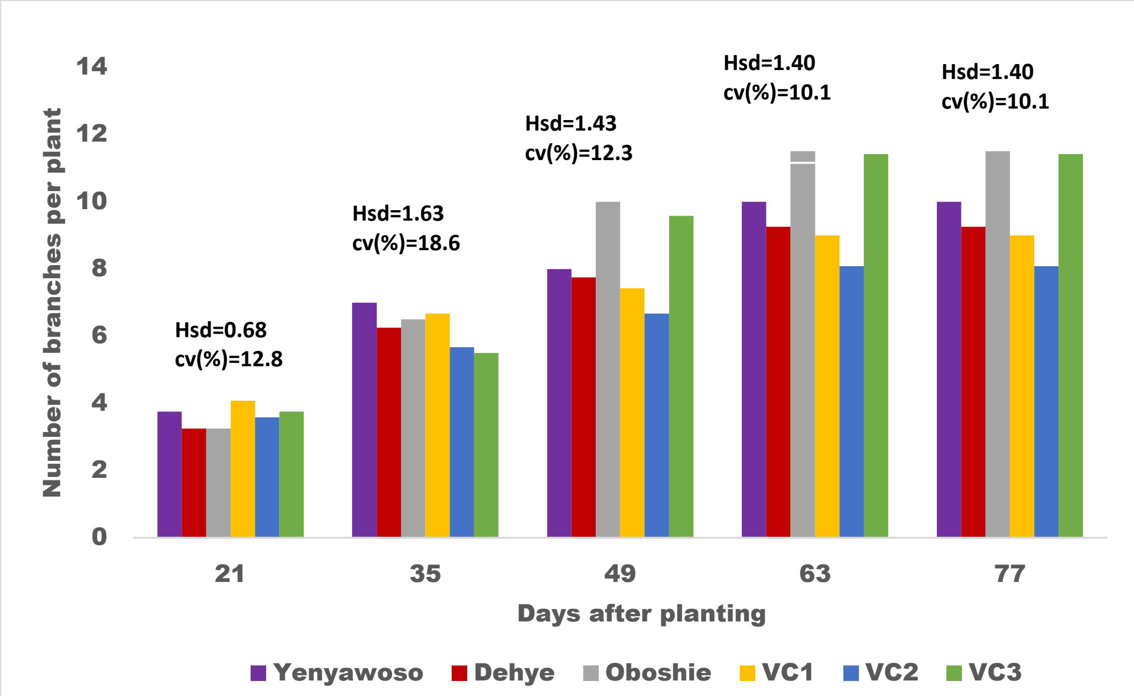

Figure 4.5: Number of branches of groundnut as influenced by variety for 2021 minor cropping season.

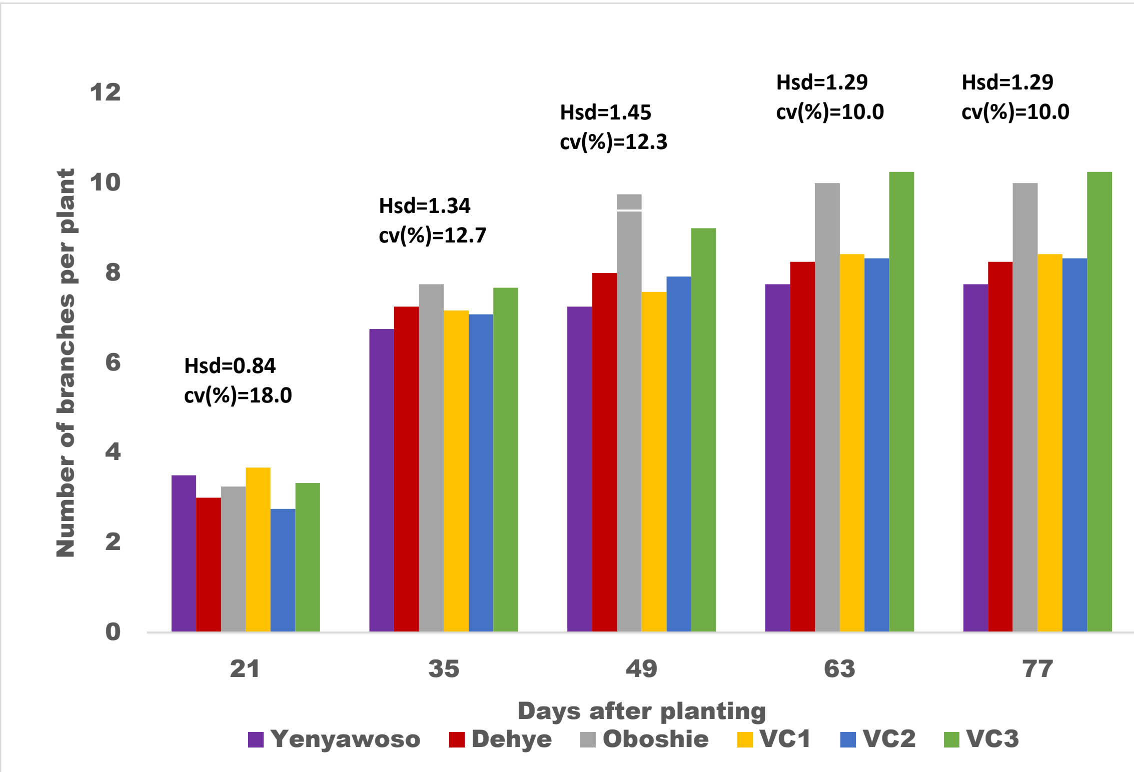

Figure 4.6: Number of branches of groundnut as influenced by variety for 2022 major cropping season.

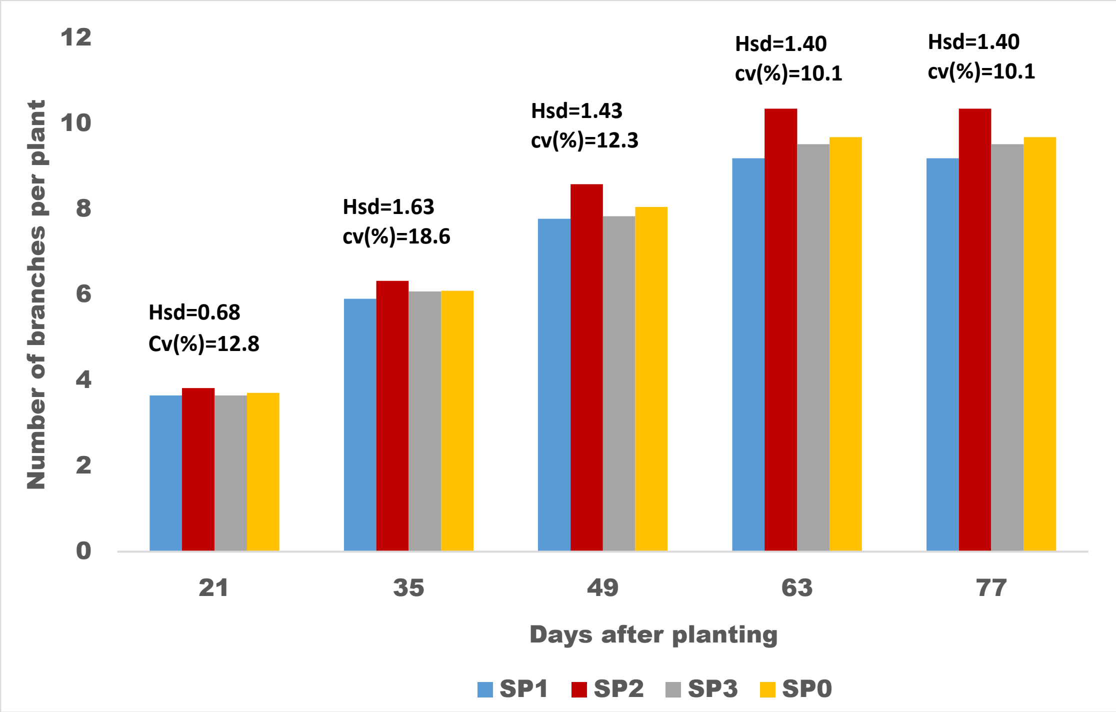

Figure 4.7: Number of branches of groundnut as influenced by spatial arrangement for 2021 minor cropping season.

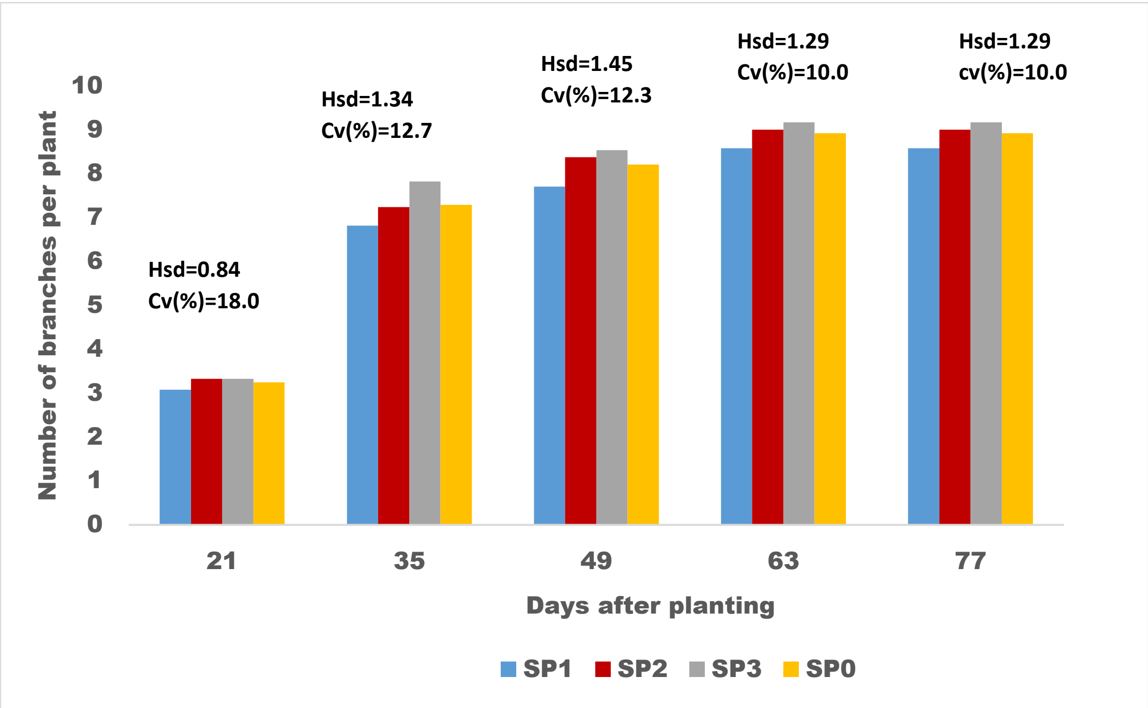

Figure 4.8: Number of branches of groundnut as influenced by spatial arrangement for 2022 major cropping season.

4.3.3 Chlorophyll content of leaf (CCL)

Results of the Chlorophyll content of leaf (CCL) among groundnut varieties and their intercrop are shown in Figures 4.9 and 4.10 in both 2021 minor and 2022 major cropping seasons. The 2021 minor season had an increase in Chlorophyll content of leaf (CCL) from 30 – 44 DAP until 58 – 72 DAP where it declined. For the 2022 major season, the Chlorophyll content of leaf (CCL) increased from 30 DAP to 58 DAP until 72 DAP where it declined (figures 4.9 and 4.10). Generally, Oboshie and its intercrop had the highest Chlorophyll content of leaf (CCL) for the groundnut varieties compared to Yenyawoso and Dehye.

Figures 4.11 and 4.12 are the results of spatial arrangements for the Chlorophyll content of leaf (CCL). There was a decreased trend in the Chlorophyll content of leaf from 30 DAP to 72 DAP for both cropping seasons. The spatial arrangements in the 2021 minor season did not differ compared to the 2022 major season where it differed significantly. Generally, SP1 and SP2 had the highest increase in Chlorophyll content of leaf for both seasons (Figures 4.11 and 4.12).

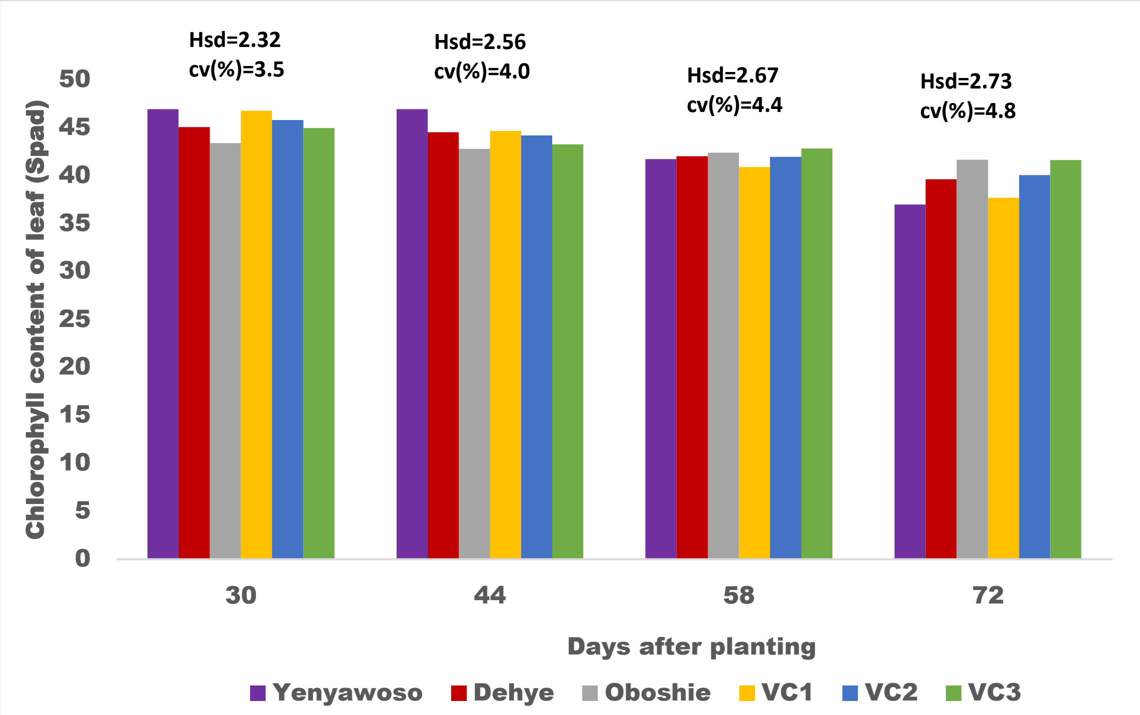

Figure 4.9: Chlorophyll content of leaf for groundnut as influenced by variety for 2021 minor cropping season.

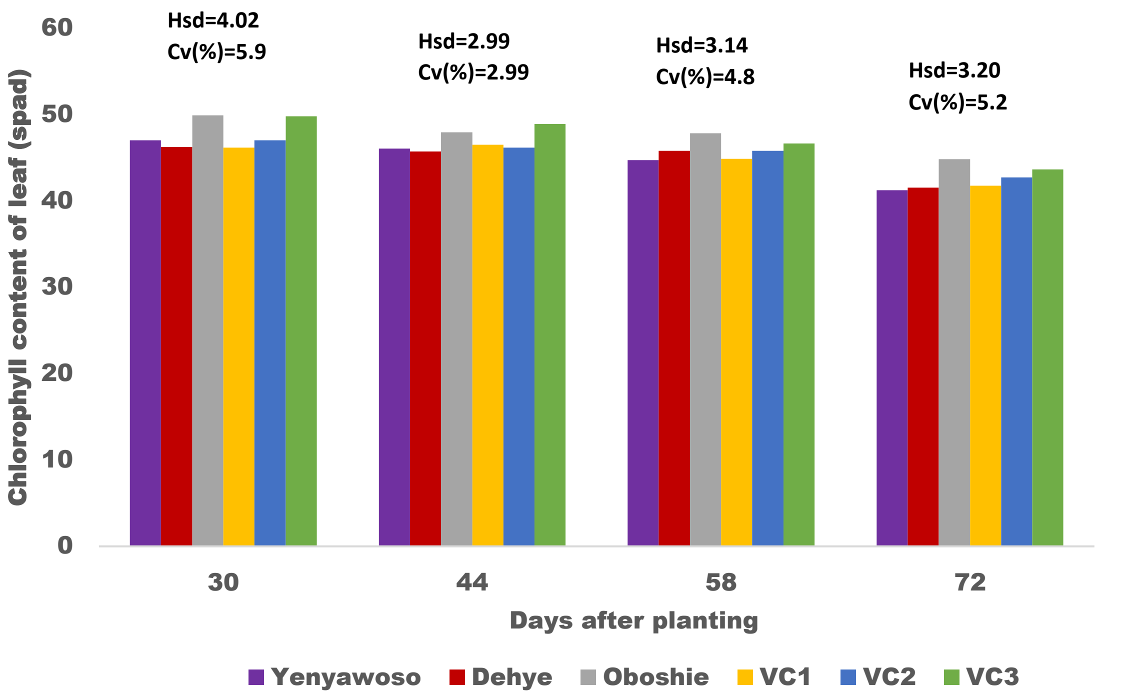

Figure 4.10: Chlorophyll content of leaf for groundnut as influenced by variety for 2022 major cropping season.

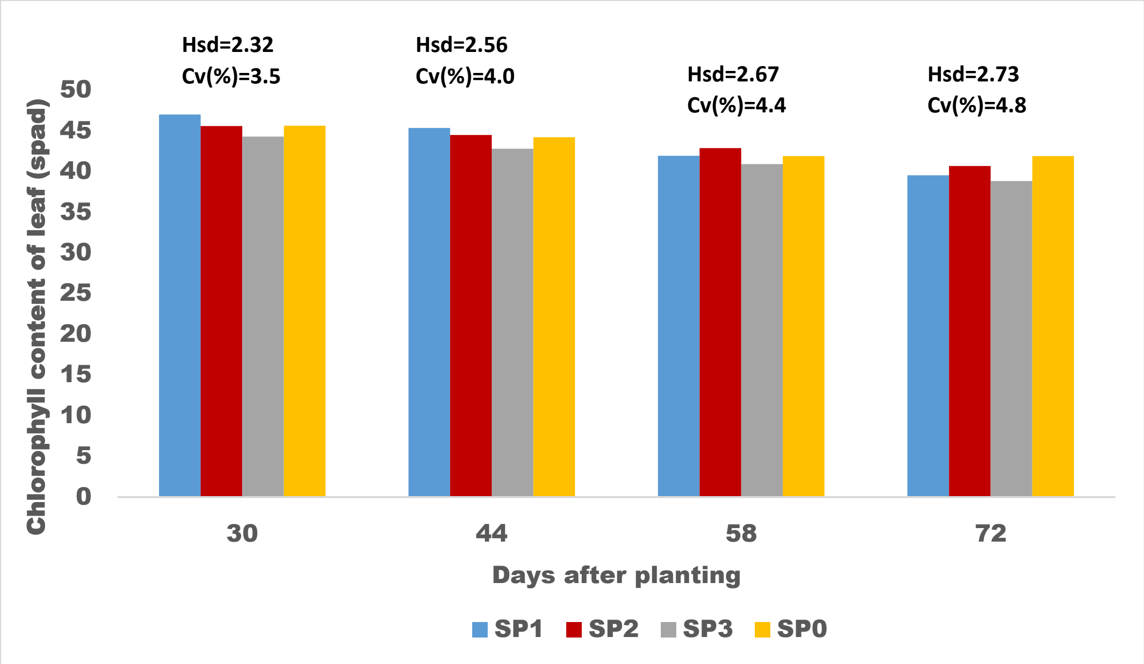

Figure 4.11: Chlorophyll content of leaf for groundnut as influenced by spatial arrangement for 2021 minor cropping season.

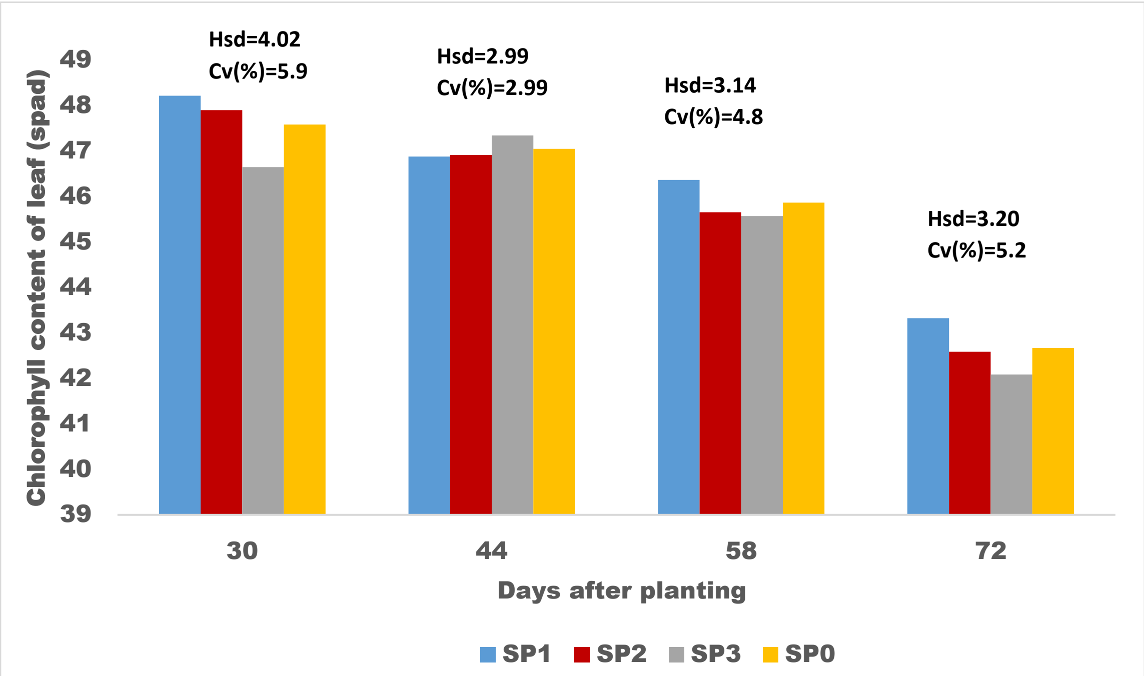

Figure 4.12:Chlorophyll content of leaf for groundnut as influenced by spatial arrangement for 2022 major cropping season.

4.3.4 Dry shoot weight (DSW)

Figures 4.14 and 4.15 are the results of dry shoot weight among groundnut varieties and their intercrops. Generally, there was an increase in dry shoot weight among the groundnut varieties and their intercrops from 21 – 49 DAP until 63 DAP where there was a decline for both seasons. Dehye and intercrop generally had the greatest dry shoot weight followed by Oboshie and Yenyawoso recording the least for both 2021 minor and 2022 major seasons (Figures 4.14 and 4.15).

Results of dry shoot weight of spatial arrangements among groundnut varieties and their intercrops are shown in Figures 4.15 and 4.16. Dry shoot weight showed an increasing trend from 21 DAP to 49 DAP until 63 DAP where it declined. Generally, SP2 showed the highest increase in dry shoot weight among the spatial arrangements (Figures 4.15 and 4.16).

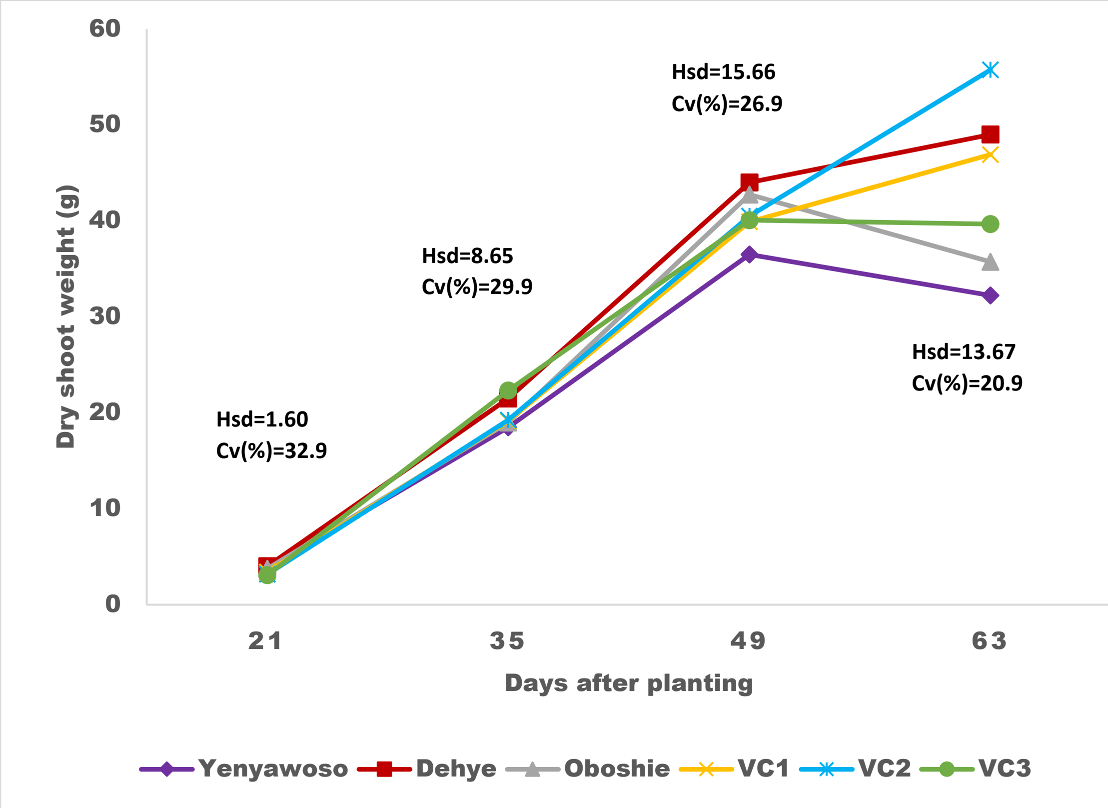

Figure 4.13: Dry shoot weight of groundnut as influenced by variety for 2021 minor cropping season.

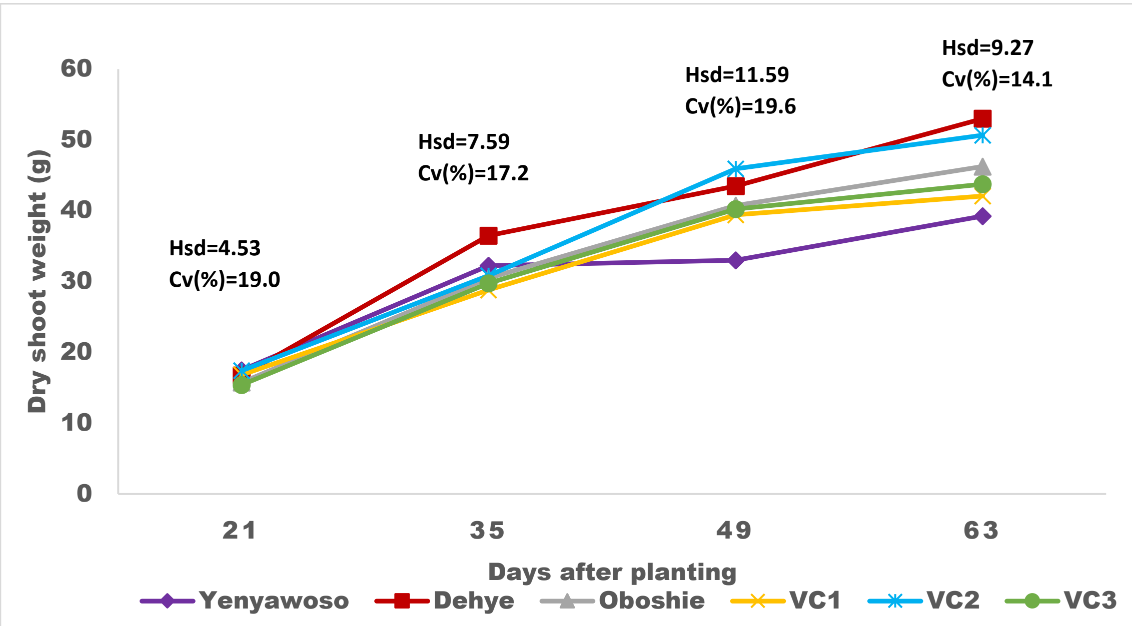

Figure 4. 14:Dry shoot weight of groundnut as influenced by variety for 2022 major cropping season.

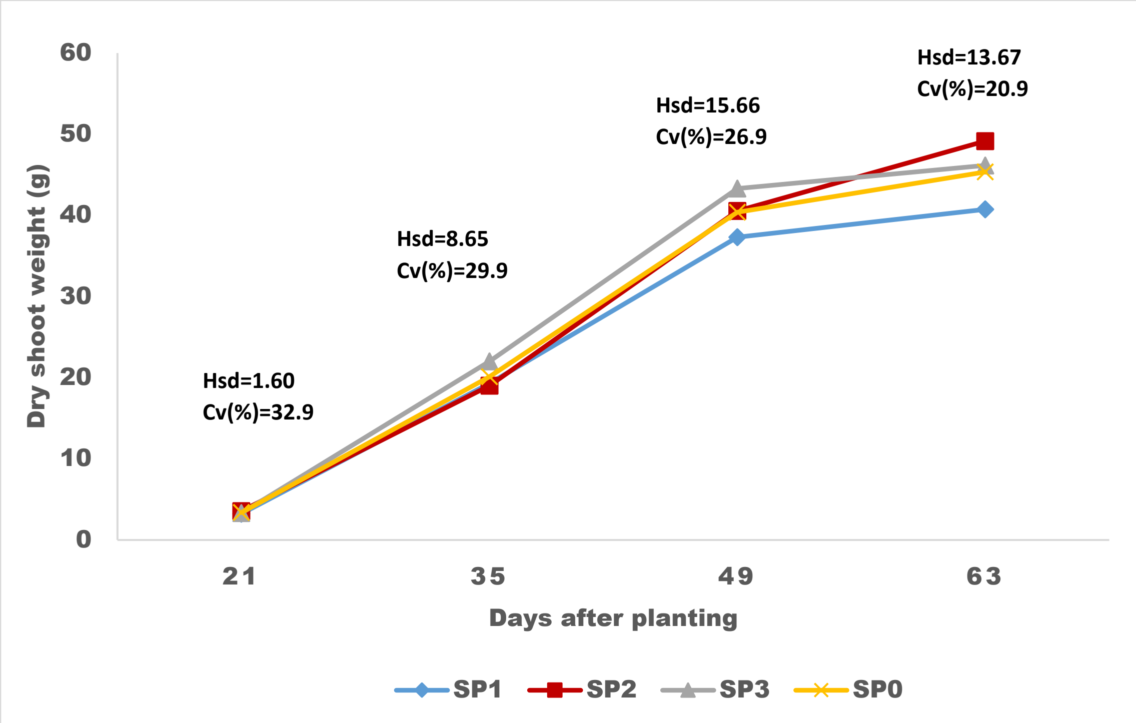

Figure 4.15: Dry shoot weight of groundnut as influenced by spatial arrangement for 2021 minor cropping season.

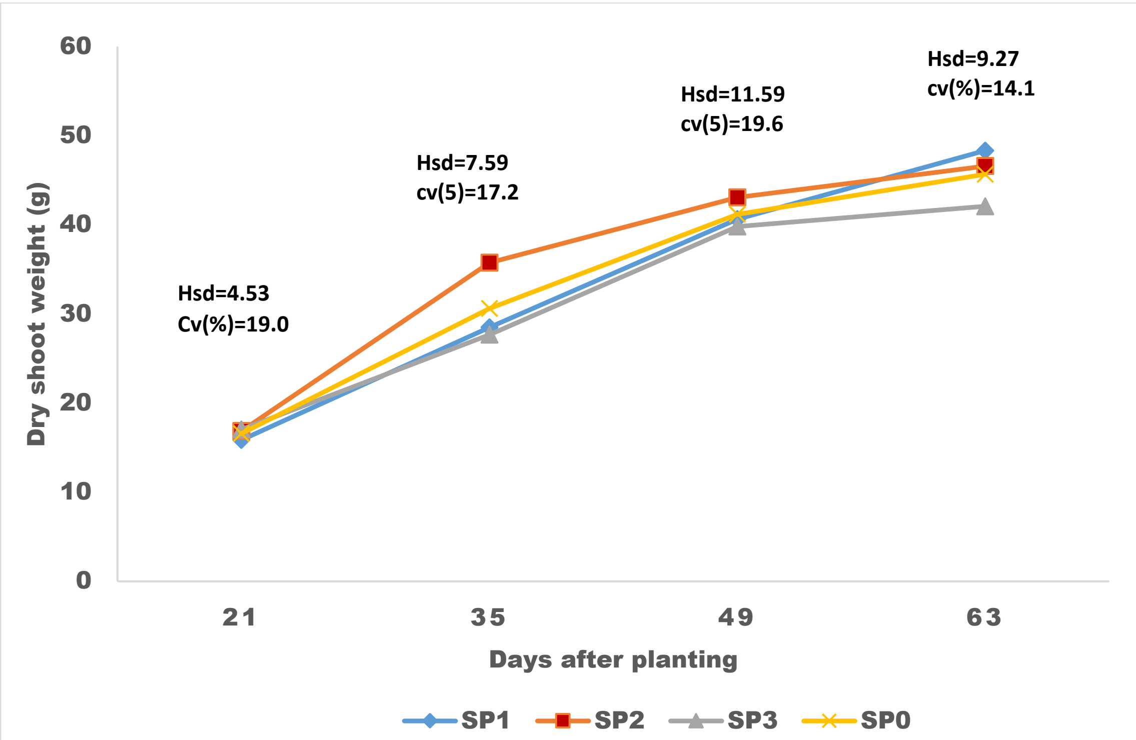

Figure 4.16: Dry shoot weight of groundnut as influenced by spatial arrangement for 2022 major cropping season.

4.4 Influence of Variety and Spatial arrangement on vegetative growth of maize.

4.4.1 Plant height

Results of plant height of maize and its intercrop are shown in figures 4.17 and 4.18 for both the 2021 minor and 2022 major cropping seasons. The plant height was taken from 21 – 77 DAP. The treatment means did not differ significantly. Plant height increased from 21 DAP – 63 DAP for both seasons until 77 DAP where it remained constant. For the 2021 minor season, plant height was higher in varietal combination 1 (VC1) whereas, in the 2022 major season, plant height was higher in sole Opeaburo. Plant height was lower in varietal combination 2 (VC2), figures 4.17 and 4.18.

Figures 4.19 and 20 show the results of spatial arrangements for the plant height of maize and its intercrop. There was an increase trend of maize plant height among the spatial arrangements from 21 DAP – 77 DAP for both seasons. Spatial arrangements 1 (SP1) and the sole plots (SP0) had the highest increase in plant height for both seasons.

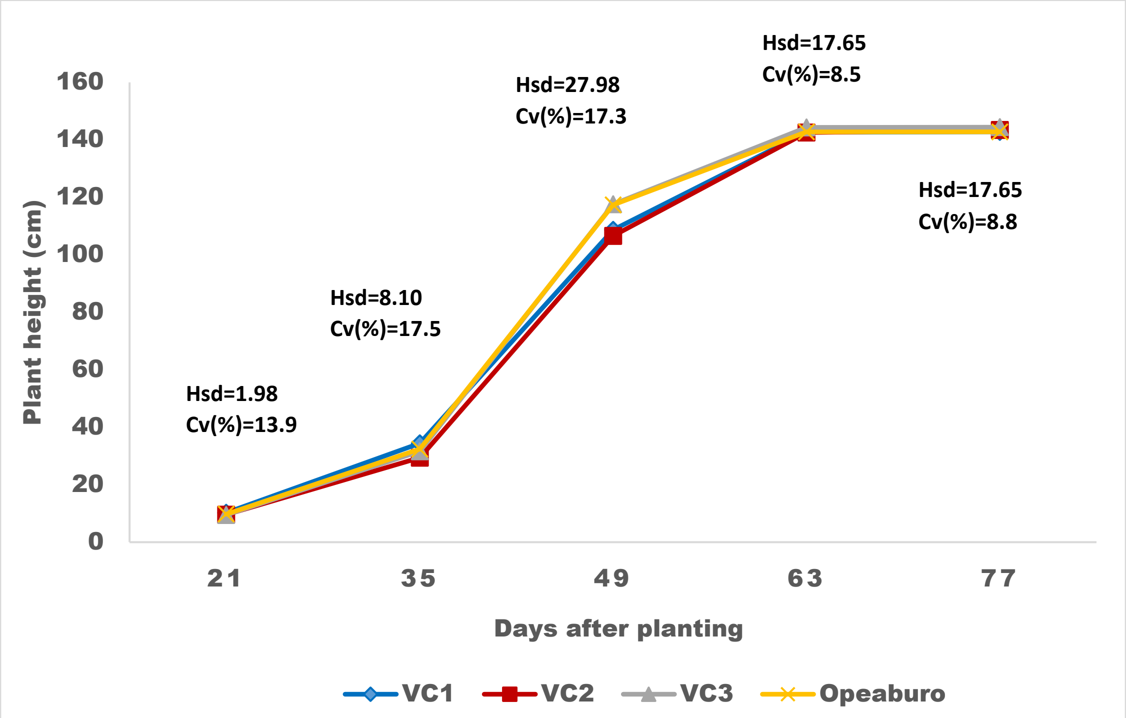

Figure 4.17:Plant height of maize as influenced by variety for 2021 minor cropping season.

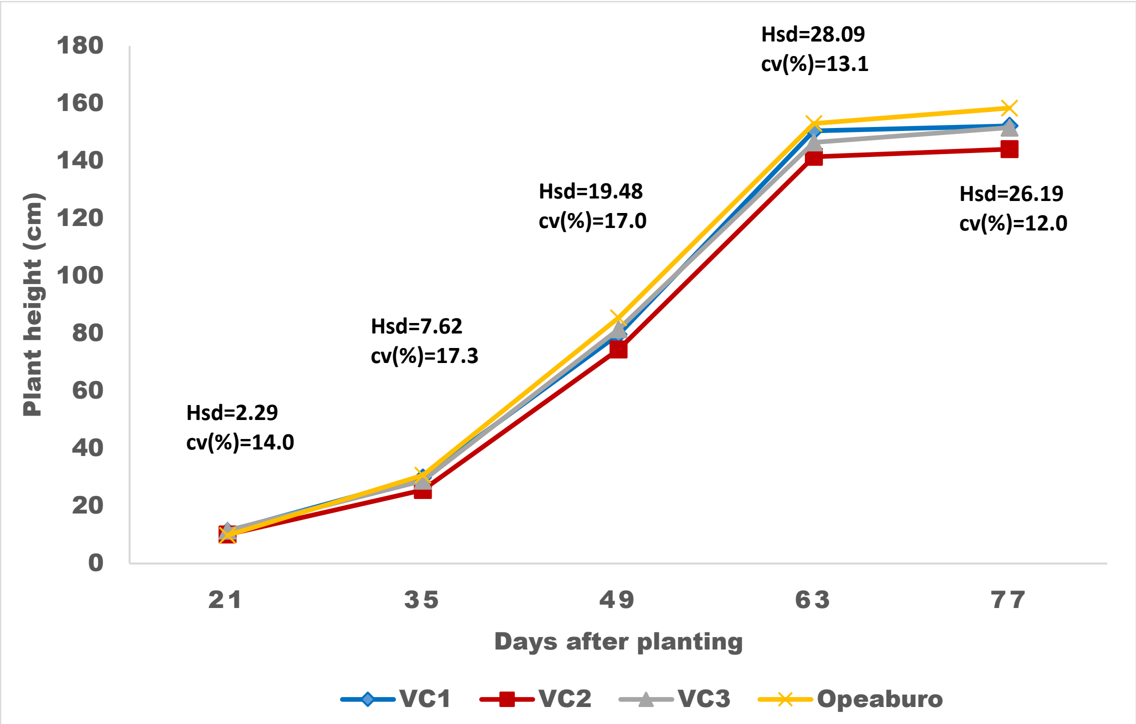

Figure 4.18: Plant height of maize as influenced by variety for 2022 major cropping season.

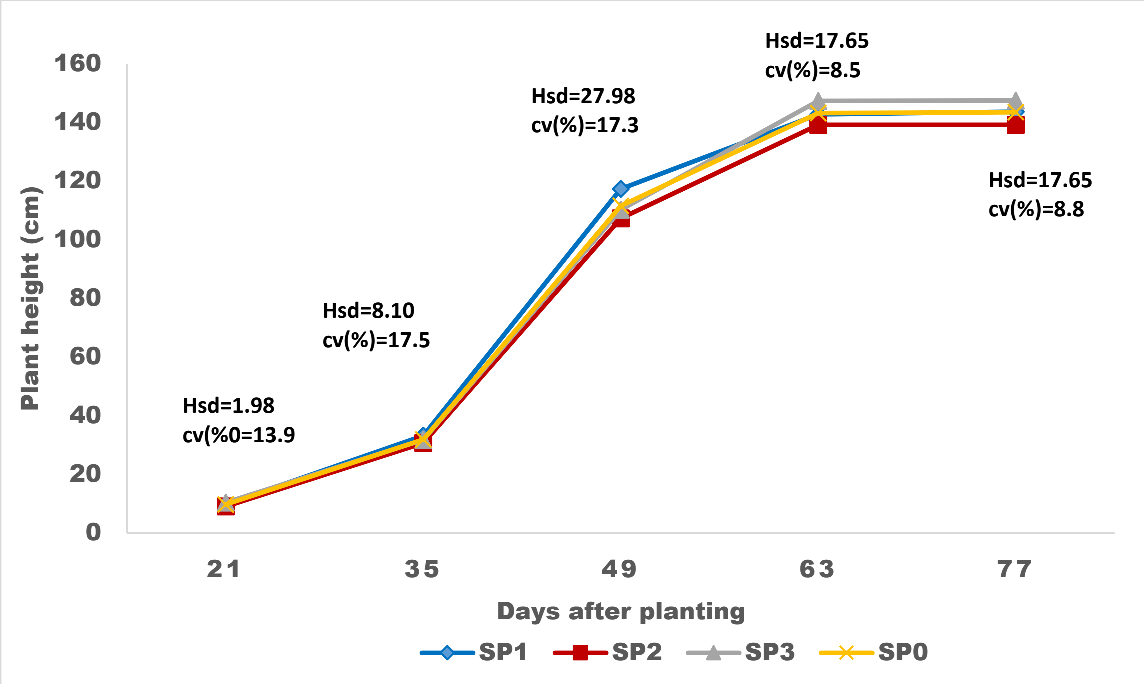

Figure 4.19:Plant height of maize as influenced by spatial arrangement for 2021 minor cropping season.

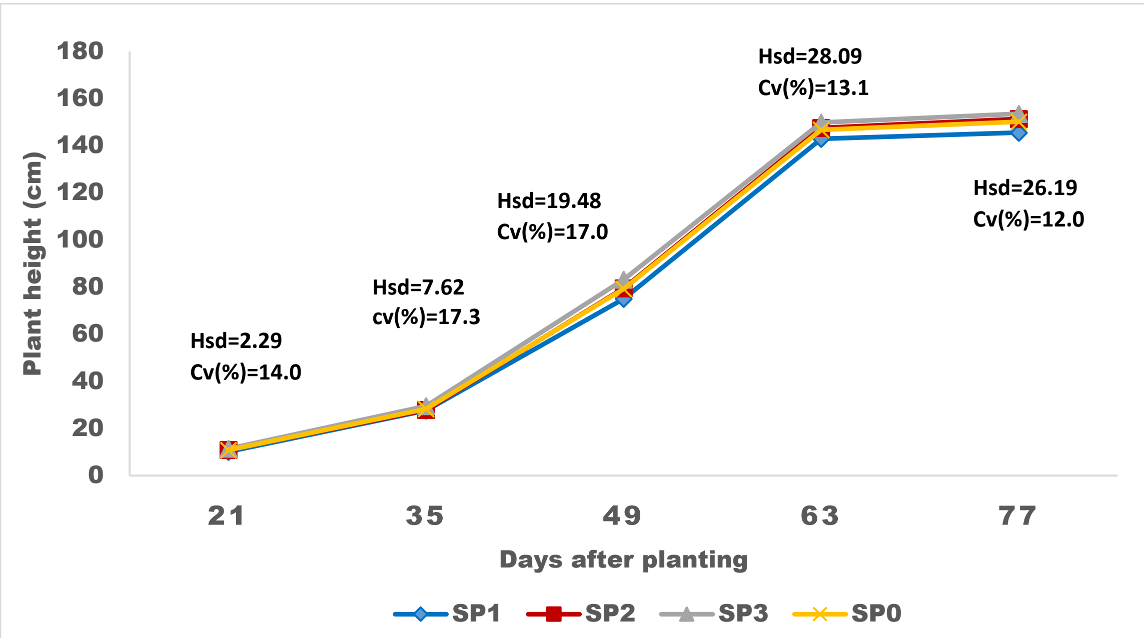

Figure 4.20: Plant height of maize as influenced by spatial arrangement for 2022 major cropping season.

4.4.2 Chlorophyll content of leaf (CCL)

Figures 4.21 and 4.22 are results of the Chlorophyll content of leaf (CCL) of maize for the 2021 minor and 2022 major cropping seasons. CCL decreased from 30 DAP to 72 DAP for both seasons. Generally, varietal combination 3 (VC3) had the highest CCL maize whereas sole Opeaburo had the lowest CCL for both seasons.

Results of Figures 4.23 and 4.24 show spatial arrangements of the Chlorophyll content of leaf (CCL) of maize for 2021 minor and 2022 major cropping seasons. Generally, there was a decreasing trend among the spatial arrangements from 30 DAP – 72 DAP for the 2021 minor season. However, for the 2022 major season, there was an increase in spatial arrangements from 30 DAP – 58 DAP, until 72 DAP where it declined. Spatial arrangement 3 (SP3) generally recorded the highest CCL whereas spatial arrangement 1 (SP1) had the lowest CCL.

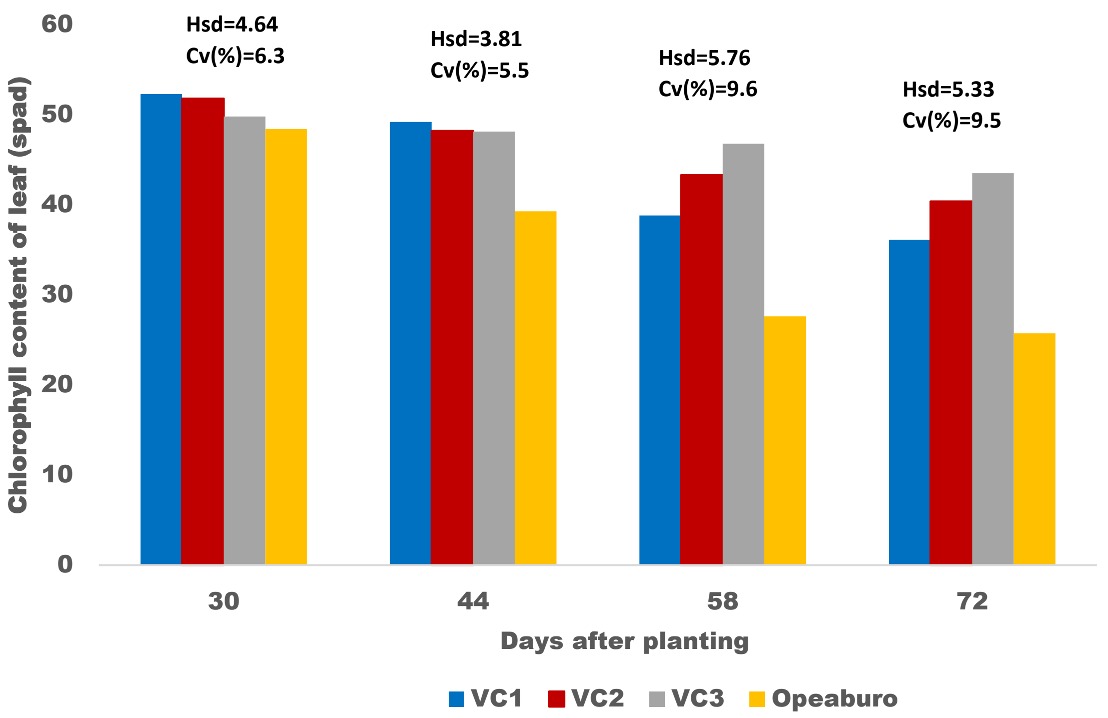

Figure 4.21: Chlorophyll content of leaf for maize as influenced by variety for 2021 minor cropping season.

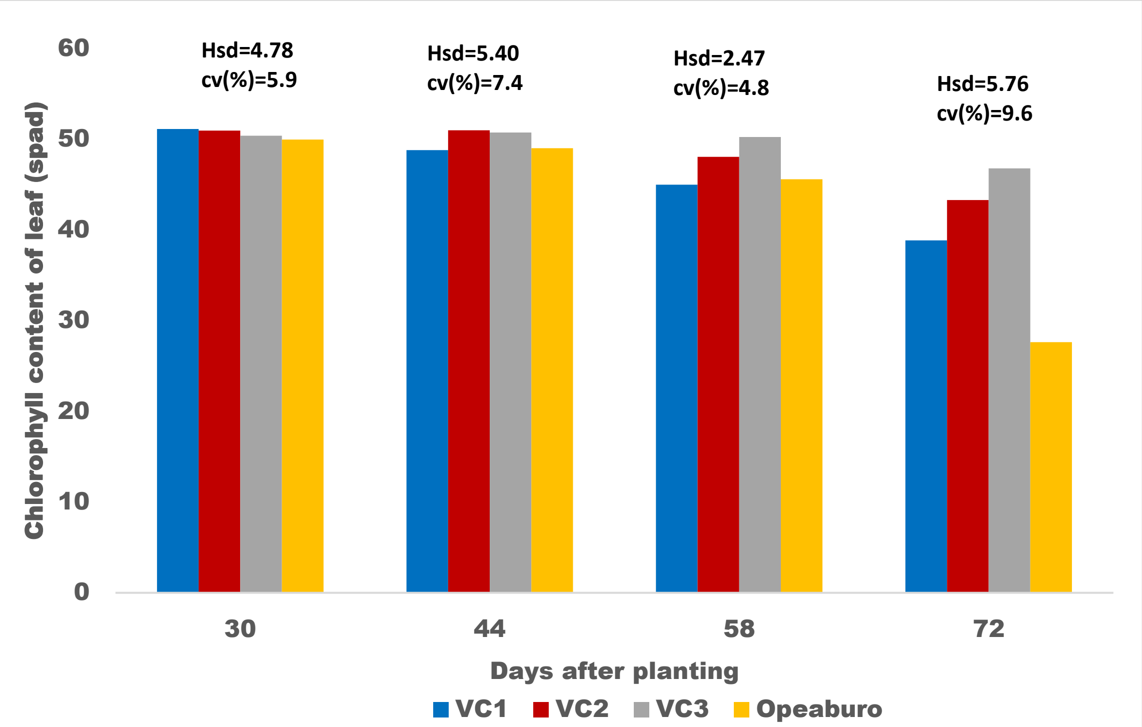

Figure 4.22: Chlorophyll content of leaf for maize as influenced by variety for 2022 major cropping season.

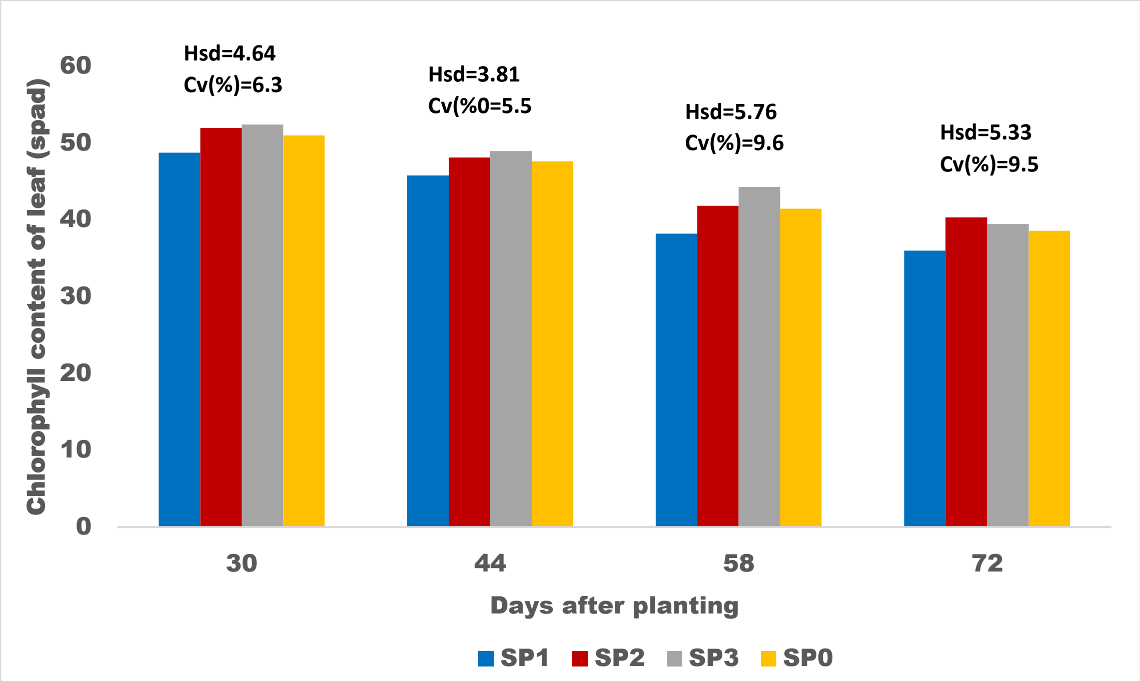

Figure 4.23: Chlorophyll content of leaf for maize as influenced by spatial arrangement for 2021 minor cropping season.

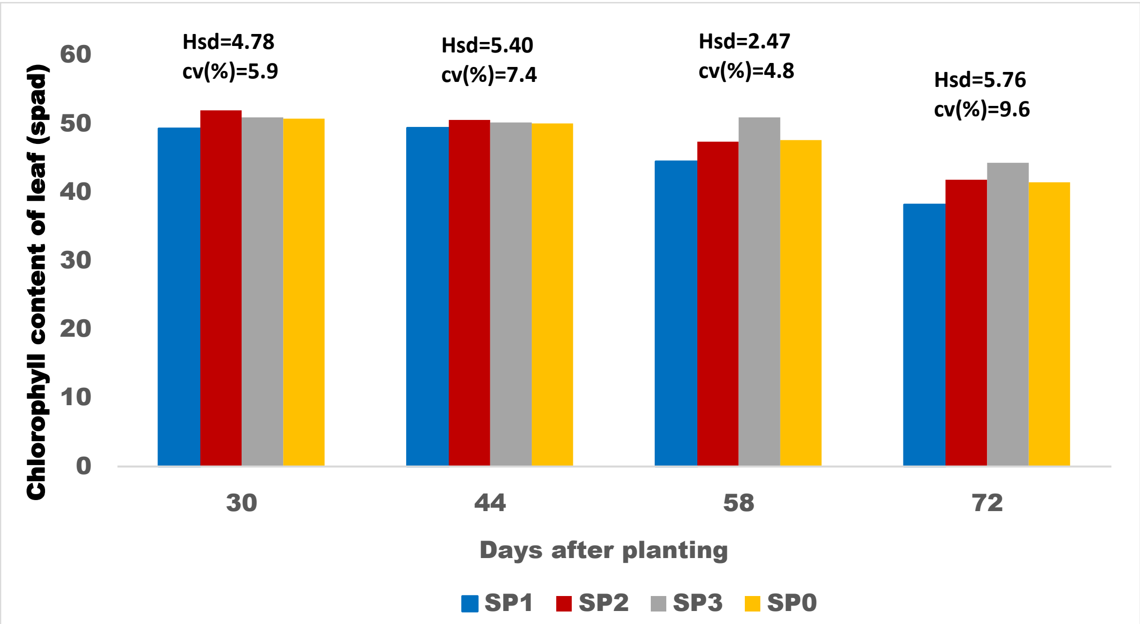

Figure 4.24: Chlorophyll content of leaf for maize as influenced by spatial arrangement for 2022 major cropping season.

4.4.3 Dry shoot weight (DSW)

Figures 4.25 and 4.26 are the results of the dry shoot weight of maize for the 2021 minor and 2022 major seasons. Generally, there was an increase trend from 21 – 63 DAP throughout the growing season for both seasons**.** Varietal combination 3 (VC3) generally had the greatest dry shoot weight for both the 2021 minor and 2022 major cropping seasons whereas varietal combination 1 (VC1) had the least for both seasons.

Results of spatial arrangements for dry shoot weight of maize are shown in Figures 4.27 and 4.28. Generally, there was an increase trend from 21 – 63 DAP throughout the growing season for both seasons**.** Varietal combination 3 (VC3) generally had the highest dry shoot weight for both the 2021 minor and 2022 major cropping seasons

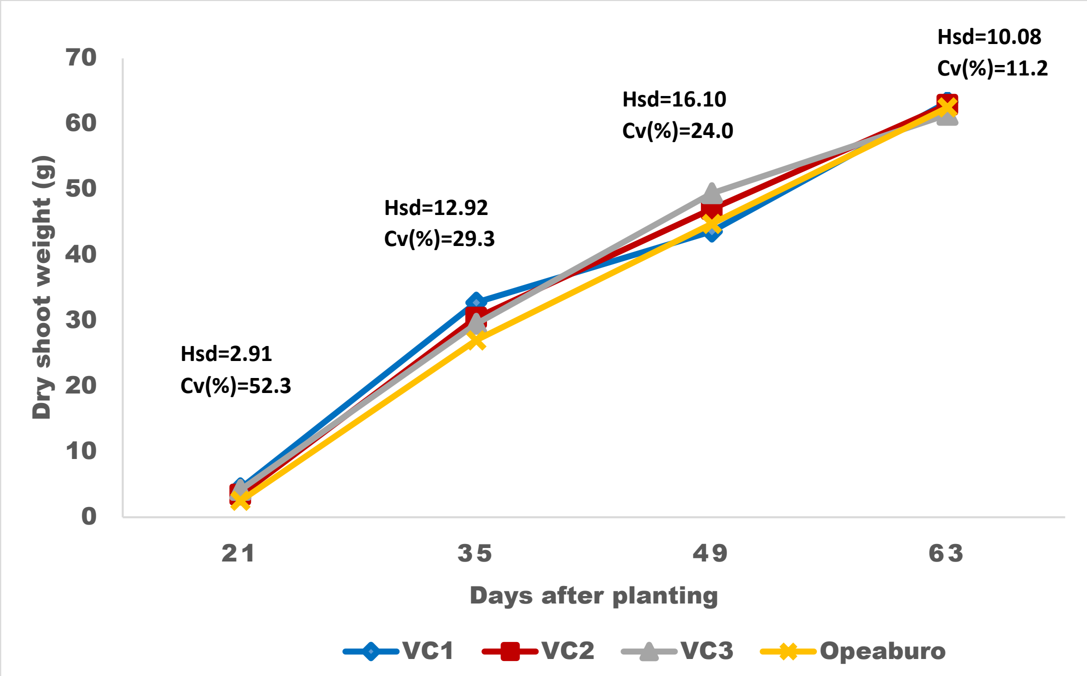

Figure 4.25: Dry shoot weight of maize as influenced by variety for 2021 minor cropping season.

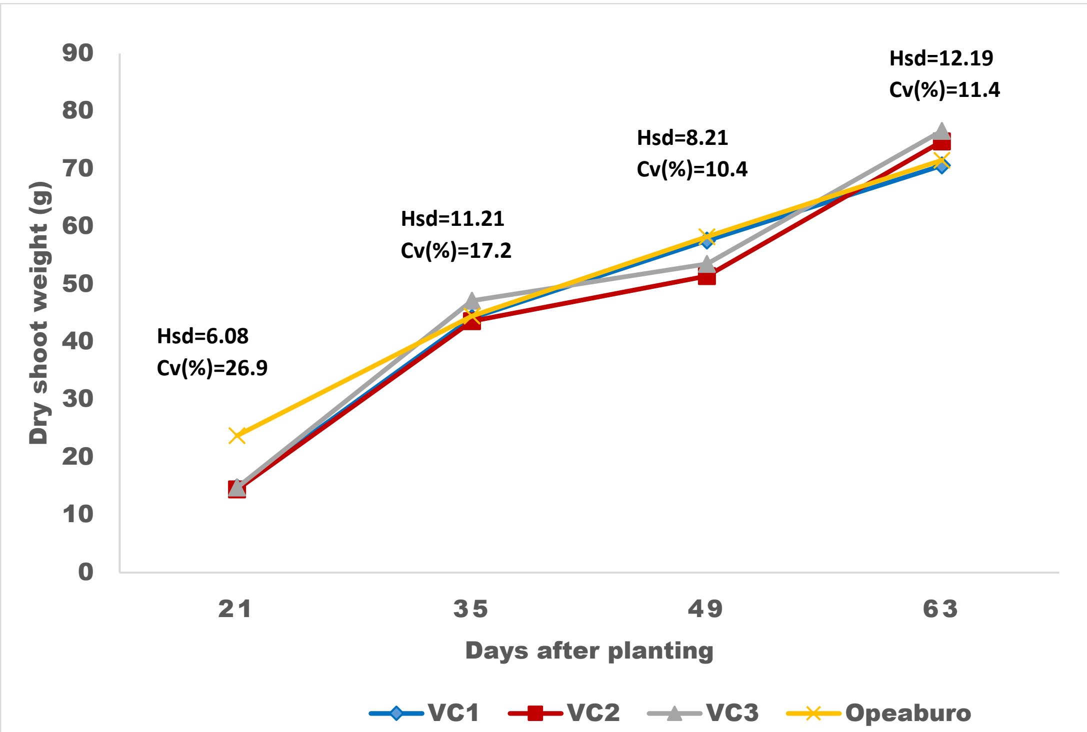

Figure 4.26: Dry shoot weight of maize as influenced by variety for 2022 major cropping season.

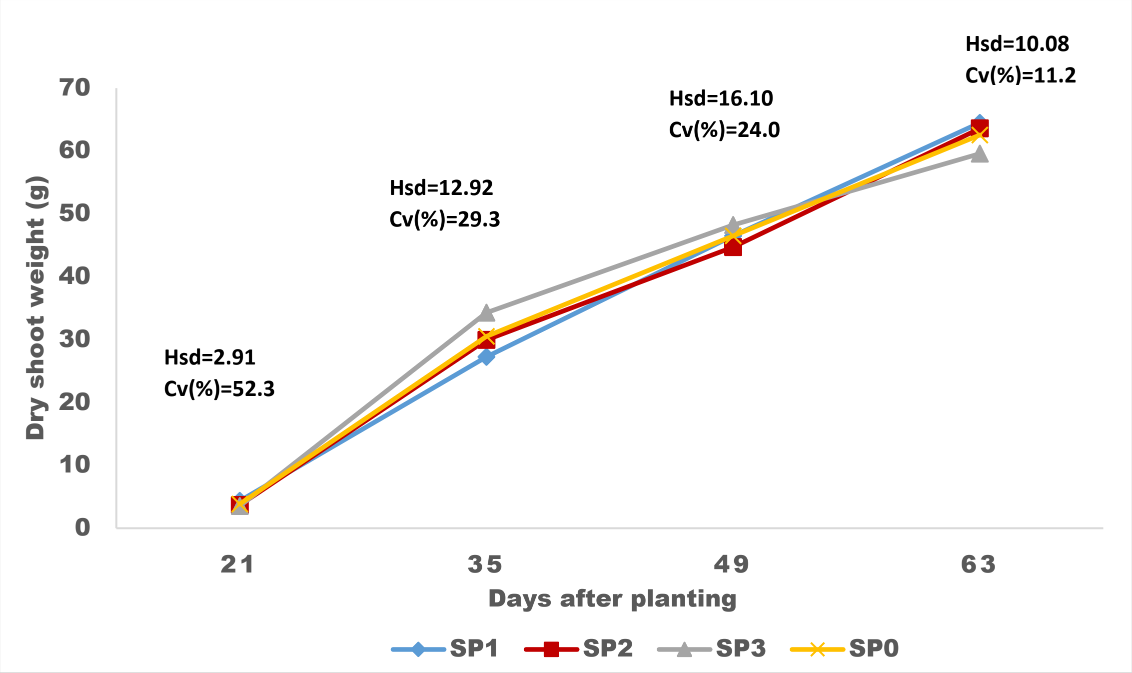

Figure 4. 27: Dry shoot weight of maize as influenced by spatial arrangement for 2021 minor cropping season.

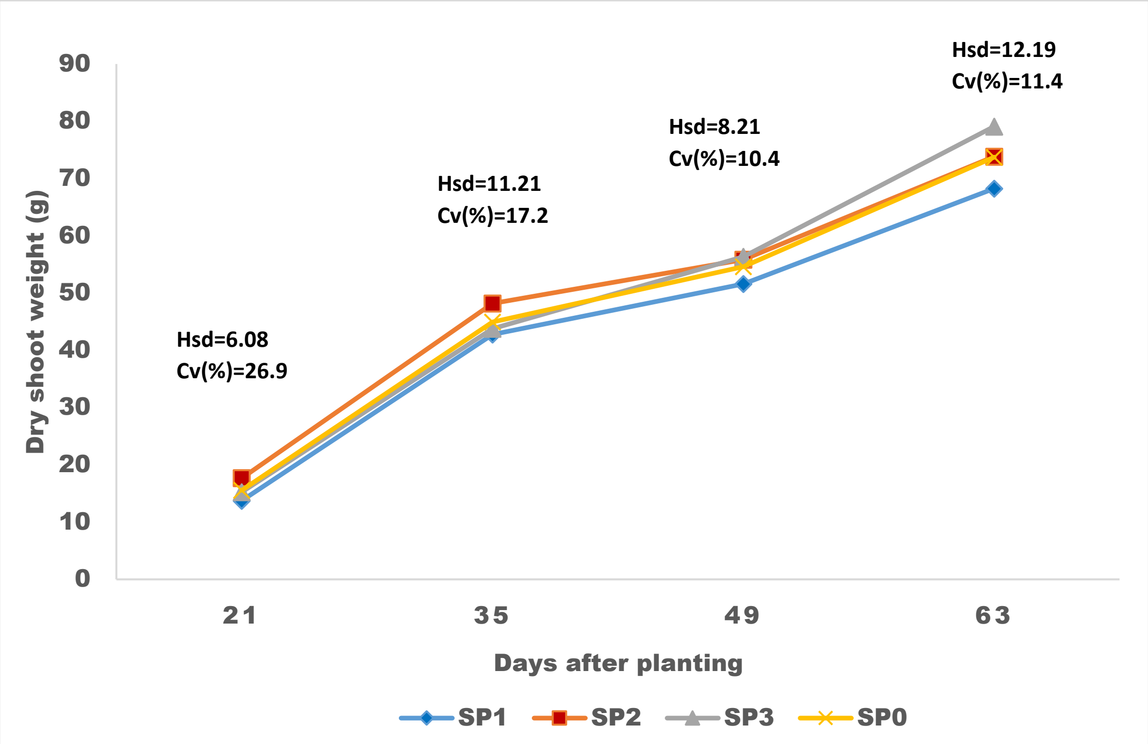

Figure 4. 28: Dry shoot weight of maize as influenced by spatial arrangement for 2022 major cropping season.

4.5 Yield and yield components of groundnut

4.5.1 Number of plants harvested

Table 4.7 shows results on number of plants harvested for groundnut for 2021 minor and 2022 major cropping seasons. There was a significant (P≤0.05) difference between the treatment means of the combined effect of maize and groundnut in number of plants harvested. Sole Yenyawoso had a significantly (P≤0.05) higher number of plants harvested (60.75) for 2021 minor cropping season, whereas for 2022 major cropping season, Opeaburo + Yenyawoso x SP2 and Opeaburo + Yenyawoso x SP2 and SP3 interactions had the greatest number of plants harvested (78.00). Sole Oboshie had the least number of plants harvested (44.00) for the 2021 minor cropping season, while for 2022 major cropping season, Opeaburo + Oboshie x SP2 interaction obtained a significant (P≤0.05) lower number of plants harvested (48.50) compared to the other spatial arrangements and their sole crops (Table 4.7). Significant (p≤0.05) differences existed between the treatment means of the seasons. Season x variety differed significantly between treatment means for 2021 minor and 2022 major cropping seasons. The 2022 major cropping season recorded a significantly (P≤0.05) higher number of plants harvested than 2021 minor season. However, between treatment means of season x spatial arrangement interaction, no significant difference was observed.

4.5.2 Biomass yield at harvest

Table 4.7 shows results on biomass yield at harvest. A significant (P≤0.05) difference existed between the treatment means of the combined effect of maize and groundnut. Sole Dehye exhibited significantly (P≤0.05) greater total biomass yield at harvest (4.28 kg) and (6.20 kg) respectively for the 2021 minor season and 2022 major cropping season. Opeaburo + Oboshie x SP1 interaction had the lowest biomass yield at harvest (1.34 kg) for 2021 minor cropping season, whereas for 2022 major cropping season, Opeaburo + Yenyawoso x SP2 interaction exhibited significantly (P≤0.05) lower total biomass yield at harvest (3.80 kg) compared to the other spatial arrangements and their sole crops. A significant (P≤0.05) difference existed between the treatment means of 2021 minor and 2022 major cropping seasons. The 2022 major cropping season recorded the highest biomass yield at harvest compared to 2021 minor cropping season. Season x variety and season x spatial arrangement did not differ significantly between treatment means for both seasons (Table 4.7).

Table 4.7: Number of plants harvested and Biomass yield at harvest of groundnut as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Treatment		**Number of plants harvested**		**Biomass yield at harvest (kg)**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	58.50	76.50	1.96	3.85
	SP2	59.25	78.00	2.53	3.80
	SP3	60.25	78.00	3.15	4.34
Opeaburo + Dehye	SP1	46.00	72.00	2.02	5.55
	SP2	49.50	72.50	3.01	5.50
	SP3	52.50	69.25	3.48	5.03
Opeaburo + Oboshie	SP1	43.00	51.25	1.34	4.18
	SP2	44.00	48.50	1.87	5.44
	SP3	43.50	49.00	1.89	4.58
Sole Yenyawoso	-	60.75	69.00	3.10	4.42
Sole Dehye	-	49.25	70.75	4.28	6.20
Sole Oboshie	-	44.00	50.00	2.62	4.75
CV (%)		**12.1**	**16.7**	**27.5**	**21.8**

Variety =	*HSD=6.91***	*p=<.001*	*HSD=0.88***	*p=0.021*
Season =	*HSD=5.17***	*p=<.001*	*HSD=0.43***	*p=<.001*
Spatial arrangement =	*NS*		*NS*	
Season x variety =	*HSD=9.36***	*p=0.008*	*NS*	
Season x spatial arrangement =	*NS*		*NS*	
Variety x spatial arrangement =	*NS*		*NS*	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference, CV (%) = Coefficient of variation.

4.5.3 Number of pods per plant

The results in number of pods per plant are shown in Table 4.8. The number of pods per plant ranged from 8 – 12 pods/plant for the 2021 minor season and 14 – 19 pods/plant for the 2022 major season. There was no significant effects of varietal combination, spatial arrangement nor varietal combination x spatial arrangement on the number of pods/plant. However, the 2022 major season had significantly ($P \leq 0.05$) greater number of pods/plant of about 58 – 75% more than the 2021 minor season. Sole Dehye recorded a significantly ($P \leq 0.05$) higher number of pods per plant (14.25) than the other spatial arrangements for the 2021 minor cropping season, while the lowest number of pods per plant (8.75) was observed in Opeaburo + Oboshie x SP1 interaction (Table 4.8) whereas for 2022 major season Opeaburo + Oboshie x SP2 had higher number of pods per plant (18.50) with the least by Opeaburo + Oboshie x SP3 interaction (Table 4.8).

4.5.4 Number of seeds per pod

Results in Table 4.8 shows the number of seeds per pod of groundnut for 2021 minor and 2022 major cropping seasons. There was a significant ($P \leq 0.05$) interactive difference between the treatment means in both cropping seasons. The number of seeds per pod ranged from 2 – 3 seeds for the for the groundnut varieties. Opeaburo + Yenyawoso x SP1 interaction had a higher mean number of seeds per pod (2.75) compared to the other spatial arrangements and their sole crops in both seasons. Season, season x variety, and season x spatial arrangement did not differ significantly in number of seeds per pod (Table 4.8).

Table 4.7: Number of pods per plant and number of seeds per pod of groundnut as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Treatment		**Number of pods per plant**		**Number of seeds per pod**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	9.00	16.50	2.00	2.00
	SP2	9.50	16.25	2.75	2.50
	SP3	12.00	17.50	2.00	2.00
Opeaburo + Dehye	SP1	9.75	17.25	2.00	2.00
	SP2	11.00	15.75	2.00	2.00
	SP3	10.00	15.75	2.00	2.00
Opeaburo + Oboshie	SP1	8.75	15.00	2.00	2.00
	SP2	9.00	18.50	2.00	2.00
	SP3	9.00	14.00	2.25	2.00
Sole Yenyawoso	-	12.00	17.25	2.00	2.00
Sole Dehye	-	14.25	16.50	2.00	2.00
Sole Oboshie	-	13.00	17.75	2.00	2.00
CV (%)		**17.6**	**23.8**	**9.6**	**8.2**

Variety =	*NS*		*HSD=0.11***	*P= 0.002*
Season =	*HSD=1.19***	*p=<.001*	*NS*	
Spatial arrangement =	*NS*		*HSD=0.11***	*p=0.008*
Season x variety =	*NS*		*NS*	
Season x spatial arrangement =	*NS*		*NS*	
Variety x spatial arrangement =	*NS*		*HSD=0.18***	*P = <.001*

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference, CV (%) = Coefficient of variation.

4.5.5 100 – Seed weight

Results of 100-seed weight for groundnut in 2021 minor and 2022 major cropping seasons are shown in Table 4.9. Interactively, a significant (P ≤ 0.05) difference occurred between the treatments means of 100-seed weight in both cropping seasons. The 100-seed weight ranged from 34.5 – 39 g for Yenyawoso, 33.8 – 44.5 g for Dehye and 54.3 – 72 g for Oboshie. Opeaburo + Oboshie x SP3 interaction had the highest mean 100-seed weight (66.50 g) compared to other spatial arrangements and sole crops, while Opeaburo +

Oboshie x SP2 interaction had the highest mean 100-seed weight (72.00 g) from other spatial arrangements and their sole crops in 2022 major cropping season (Table 4.28). For 2021 minor cropping season, Opeaburo + Dehye x SP1 interaction had significantly lowest mean 100-seed weight (33.75g) from other spatial arrangements, while for 2022 major cropping season, Opeaburo + Yenyawoso x SP1 interaction had the lowest mean 100-seed weight (37.25 g) from other spatial arrangements and sole crops. There were no significant effects of spatial arrangement or varietal combination x spatial arrangement interactions.

Table 4.8:100-seed weight of groundnut as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Treatment		**100 - Seed weight (g)**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	36.00	37.25
	SP2	34.50	38.75
	SP3	36.00	39.00
Opeaburo + Dehye	SP1	33.75	44.50
	SP2	37.00	43.25
	SP3	38.75	43.25
Opeaburo + Oboshie	SP1	54.25	70.50
	SP2	55.50	72.00
	SP3	66.50	67.00
Sole Yenyawoso	-	35.00	38.50
Sole Dehye	-	38.50	40.00
Sole Oboshie	-	66.25	68.00
CV (%)		19.1	9.9
Variety =		*HSD=4.45***	*p=<.001*
Season =		*HSD=2.80***	*p=<.001*
Spatial arrangement =		*NS*	
Season x variety =		*NS*	
Season x spatial arrangement =		*NS*	
Varietyx spatial arrangement =		*NS*	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference, CV (%) = Coefficient of variation.

4.5.6 Pod yield

The results for pod yield of groundnuts grown in intercrop or sole crop are shown in Table 4.10. Pod yield ranged from 1.30 – 3.58 t ha^{-1} for intercropped groundnuts compared with 1.88 – 2.73 t ha^{-1} for the sole crops. Yenyawoso and Dehye intercropped with Opeaburo had similar pod yields over the two seasons. Oboshie intercropped with Opeaburo had about 12 – 54 % more pod yield than Yenyawoso and Dehye for the two seasons. Opeaburo + Oboshie x SP2 interaction in 2022 major cropping season had significantly higher pod yield (3.58 t ha^{-1}) compared to the other spatial arrangements and their sole plots, while sole Dehye and Oboshie recorded significantly ($p \leq 0.05$) higher pod yield (1.93 t ha^{-1}) in 2021 minor cropping season. Opeaburo + Dehye x SP3 interaction had the lowest pod yield (1.65 t ha^{-1}) among treatments in 2022 major cropping season, while Opeaburo + Yenyawoso x SP1 interaction had the lowest pod yield (1.30 t ha^{-1}) for 2021 minor cropping period. The 2022 major cropping season recorded significantly higher pod yield (t ha^{-1}) from 2021 minor cropping season. Season x variety showed a significant difference with 2022 major season producing the higher pod yield (t ha^{-1}) than in 2021 minor season. There were no significant effects of spatial arrangement or varietal combination x spatial arrangement interactions (Table 4.10).

4.5.7 Grain yield

Table 4.10 shows results on grain yield (t ha^{-1}) of groundnut for 2021 minor and 2022 major seasons. There was a significant difference ($P \leq 0.05$) in the combined effect of grain yield for both cropping seasons. Sole Dehye had a significantly ($P \leq 0.05$) higher grain yield (1.28 t ha^{-1}) in 2021 minor cropping season, while Opeaburo + Oboshie x SP3 interaction had a statistically higher grain yield (2.03 t ha^{-1}) in 2022 major cropping season compared to other spatial arrangements and their sole plots. Opeaburo + Oboshie x SP1 interaction had the lowest grain yield (0.93 t ha^{-1}) for 2021 minor period and Opeaburo + Dehye x SP3 interaction had a significant (P≤0.05) lower grain yield (1.43 t ha^{-1}) in 2022 major cropping season than the 2021 cropping season (Table 4.10). There was a significant (p≤0.05) difference between seasons, variety x season, and variety x spatial arrangement. The 2022 major cropping season recorded a significant (P≤0.05) higher grain yield (t ha^{-1}) from the 2021 minor cropping season.

Table 4.9: Pod yield and grain yield of groundnut as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Treatment		**Pod yield (t ha^{-1})**		**Grain yield (t ha^{-1})**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	1.30	2.30	0.98	1.53
	SP2	1.33	2.25	1.03	1.60
	SP3	1.68	2.25	1.10	1.53
Opeaburo + Dehye	SP1	1.38	2.33	0.95	1.70
	SP2	1.50	1.90	0.98	1.58
	SP3	1.70	1.65	1.10	1.43
Opeaburo + Oboshie	SP1	1.45	2.73	0.93	1.63
	SP2	1.55	3.58	0.95	2.03
	SP3	1.60	3.28	1.00	1.85
Sole Yenyawoso	-	1.88	2.43	1.20	1.53
Sole Dehye	-	1.93	2.25	1.28	1.63
Sole Oboshie	-	1.93	2.73	1.18	1.63
CV (%)		**13.8**	**20.2**	**8.1**	**11.2**

Variety =	*HSD=0.39***	*p=0.025*	*HSD=0.09***	*p=0.035*
Season =	*HSD=0.22***	*p=<.001*	*HSD=0.07***	*p=<.001*
Spatial arrangement =	*NS*		*NS*	
Season x variety =	*HSD=0.48***	*p=<.001*	*HSD=0.18***	*p=<.001*
Season x spatial arrangement =	*NS*		*HSD=0.14***	*p=0.002*
Variety x spatial arrangement =	*NS*		*NS*	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference, CV (%) = Coefficient of variation.

4.5.8 Harvest index

Table 4.11 shows results on harvest index for both 2021 minor and 202 major cropping seasons of groundnut. There were no significant effects of spatial arrangement or varietal combination x spatial arrangement interactions (Table 4.11). Opeaburo + Oboshie x SP1 interaction had a significantly ($P \leq 0.05$) highest harvest index (0.32) in 2021 minor cropping season. In 2022 major cropping season, Opeaburo + Yenyawoso x SP2 interaction statistically had the highest harvest index (0.20) compared to the other spatial arrangements and their sole plots. In both 2021 minor and 2022 major cropping periods, Dehye grown as a sole crop had significantly ($P \leq 0.05$) lowest harvest index of 0.13 and 0.12, respectively. The 2021 minor cropping season recorded significantly ($P \leq 0.05$) higher harvest index compared to the 2022 major cropping season. Season x variety and season x spatial arrangement interaction showed no significant difference in harvest index for both cropping seasons (Table 4.11).

4.5.9 Shelling percentage

The results of shelling percentage of groundnut for 2021 minor and 2022 major cropping seasons are shown in Table 4.11. There was a significant ($P \leq 0.05$) difference in the shelling percentage between treatments for both cropping seasons. Opeaburo + Yenyawoso x SP2 interaction had a significantly ($P \leq 0.05$) higher shelling percentage (76.61%) in 2021 minor cropping season, while Opeaburo + Dehye x SP3 interaction had a statistically higher shelling percentage (86.11%) in 2022 major cropping season than the other spatial arrangements and their sole plots. However, Sole Oboshie had significantly ($P \leq 0.05$) lowest shelling percentages (61.26% and 60.00%) for both 2021 minor and 2022 major cropping seasons, respectively. The season x variety interaction was significant in shelling percentage. There were no significant effects of spatial arrangement or varietal combination x spatial arrangement interactions.

Table 4.10: Harvest index and shelling percentage of groundnut as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Treatment		**Harvest index**		**Shelling percentage (%)**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	0.22	0.18	74.93	65.20
	SP2	0.18	0.20	76.61	71.94
	SP3	0.17	0.17	66.35	71.54
Opeaburo + Dehye	SP1	0.22	0.14	68.39	71.15
	SP2	0.16	0.12	65.95	83.86
	SP3	0.14	0.13	66.38	86.11
Opeaburo + Oboshie	SP1	0.32	0.17	65.44	63.82
	SP2	0.23	0.17	64.82	58.41
	SP3	0.23	0.19	62.35	58.38
Sole Yenyawoso	-	0.18	0.16	64.45	64.86
Sole Dehye	-	0.13	0.12	67.96	71.90
Sole Oboshie	-	0.23	0.15	61.26	60.00
CV (%)		**23.3**	**24.7**	**9.8**	**15.0**
Variety =		*HSD=0.03***	*p=<.001*	*HSD=5.43***	*p=<.001*
Season =		*HSD=0.02***	*p=<.001*	*NS*	
Spatial arrangement =		*NS*		*NS*	
Season x variety =		*NS*		*HSD=10.01***	*p=0.014*
Season x spatial arrangement =		*NS*		*NS*	
Variety x spatial arrangement =		*NS*		*NS*	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference, CV (%) = Coefficient of variation.

4.6 Yield and yield components of maize

4.6.1 Number of plants harvested

Table 4.12 shows results number of plants harvested of maize for 2021 minor and 2022 major cropping season. In 2021 minor season, there were significant differences ($P \leq 0.05$) between the treatment means. In contrast, the 2022 major season did not show any significant ($P > 0.05$) difference among the treatment means. Opeaburo + Yenyawoso x SP3 interaction had a significantly ($P \leq 0.05$) higher number of plants harvested for 2021 minor season, while for 2022 major cropping season, Opeaburo + Yenyawoso x SP2 plots had the highest number of plants harvested. Opeaburo + Yenyawoso x SP2 interaction had the lowest number of plants harvested for 2021 minor cropping season, which was statistically significant (Table 4.12). There was a significant ($P \leq 0.05$) difference between the treatment means of 2021 minor and 2022 major seasons. The 2022 major cropping season recorded the highest number of plants harvested compared to 2021 minor cropping season. Season x variety and season x spatial arrangement did not show any significant ($P > 0.05$) among the treatment means (Table 4.12).

4.6.2 Stover weight per plot

Table 4.12 shows results of Stover weight per plot of maize for 2021 minor and 2022 major cropping seasons. There was no interactive difference between the treatment means. However, for 2022 major cropping season, a significant ($P \leq 0.05$) difference existed between the treatment means. Opeaburo + Yenyawoso x SP3 and Opeaburo + Oboshie x SP2 interaction had higher stover weight per plot at harvest (10.47 kg) compared to the other treated plots (Table 4.12). Conversely, Opeaburo + Yenyawoso x SP2 interaction had significantly ($P \leq 0.05$) lower Stover weight per plot at harvest (7.60 kg) for 2022 major cropping season. There was a significant ($p \leq 0.05$) difference between the treatment means of 2021 minor and 2022 major cropping season. For season x variety and season x spatial arrangement, no significant (P>0.05) difference was shown among the treatment means. The 2022 major cropping season recorded the highest Stover weight per plot at harvest from 2021 minor cropping season.

Table 4.11: Number of plants harvested and Stover weight per plot at harvest of maize as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Treatment		**Number of plants harvested**		**Stover weight per plot at harvest (kg)**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	31.25	37.75	4.54	8.69
	SP2	28.00	38.25	4.94	7.60
	SP3	35.50	35.75	5.44	10.47
Opeaburo + Dehye	SP1	33.50	36.50	5.53	5.60
	SP2	30.50	35.75	6.87	8.83
	SP3	32.50	36.50	5.63	9.81
Opeaburo + Oboshie	SP1	31.75	37.25	5.82	7.92
	SP2	32.00	37.00	5.78	10.47
	SP3	29.75	35.75	5.97	9.03
Sole Opeaburo	-	28.25	38.00	5.59	10.28
CV (%)		**13.8**	**5.9**	**26.5**	**29.6**

Variety =	*NS*		*NS*	
Season =	*HSD=1.54***	*p=<.001*	*HSD=4.55***	*p=<.001*
Spatial arrangement =	*NS*		*NS*	
Season x variety =	*NS*		*NS*	
Season x spatial arrangement =	*NS*		*NS*	
Variety x spatial arrangement =	*NS*		*NS*	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference, CV (%) = Coefficient of variation.

4.6.3 Cob diameter

Table 4.13 illustrates results of cob diameter of maize for 2021 minor and 2022 major cropping seasons. There was a significant (P≤0.05) difference between the treatment means for both seasons. The cob diameter ranged from 4.22 – 4.93 cm for both seasons. For 2021 minor season, plots with Opeaburo + Oboshie x SP3 interaction had a significantly (P≤0.05) higher mean cob diameter (4.67 cm), while plots with Opeaburo + Yenyawoso x SP2, Opeaburo + Oboshie x SP1 interactions, and sole Opeaburo had the lowest mean cob diameter (4.27 cm). In 2022 major cropping season, Opeaburo + Dehye x SP3 treated plots had a statistically higher mean cob diameter (4.93 cm), while plots with Opeaburo + Dehye x SP1 interaction had the lowest mean cob diameter (4.22 cm). There was a significant (P≤0.05) difference between the treatment means 2021 minor and 2022 major season. The cob diameter was not significantly affected by varietal combination, spatial arrangement, nor varietal combination x spatial arrangement interaction (Table 4.13).

4.6.4 Cob length

The cob length of maize results are shown in Table 4.13. Generally, the cob length ranged from 14.99 – 16.50 cm for both season. For 2021 minor cropping period, plots with Opeaburo + Oboshie x SP3 interaction had a significantly (P≤0.05) higher mean cob length (16.41 cm), while sole Opeaburo had the highest mean cob length (17.08 cm) for 2022 major cropping season. For 2021 minor season, plots with Opeaburo + Yenyawoso x SP1 interaction and sole Opeaburo had the lowest mean cob length (4.99 cm) significantly (P≤0.05), while for 2022 major cropping season, Opeaburo + Dehye x SP1 interaction treated plots had the lowest mean cob length (13.17 cm) significantly (P≤0.05). There was no significant (P>0.05) difference between the treatment means of season and season x variety interaction for both seasons (Table 4.13). However, season x spatial arrangement recorded a statistical difference.

Table 4.12: Cob diameter and cob length of maize as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Treatment		Cob diameter (cm)		Cob length (cm)	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	4.34	4.59	14.99	14.51
	SP2	4.39	4.62	15.67	15.69
	SP3	4.27	4.81	15.67	16.50
Opeaburo + Dehye	SP1	4.42	4.22	15.54	13.17
	SP2	4.39	4.47	15.47	15.45
	SP3	4.34	4.93	15.36	15.96
Opeaburo + Oboshie	SP1	4.27	4.56	15.29	14.71
	SP2	4.44	4.83	15.97	16.38
	SP3	4.67	4.67	16.41	15.94
Sole Opeaburo	-	4.27	4.90	14.99	17.08
CV (%)		**4.7**	**6.2**	**5.4**	**12.7**

Variety =	*NS*		*NS*	
Season =	*HSD=0.12***	*p=<.001*	*NS*	
Spatial arrangement =	*HSD=0.15***	*p=0.031*	*HSD=1.50***	*p=0.011*
Season x variety =	*NS*		*NS*	
Season x spatial arrangement =	*NS*		*HSD=1.39***	*p=0.042*
Variety x spatial arrangement =	*NS*		*NS*	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference, CV (%) = Coefficient of variation.

4.6.5 100 - seed weight

Results in Table 4.14 highlights results of 100-seed weight of maize for 2021 minor and 2022 major season. No significant (P>0.05) difference among varietal combination nor varietal combination x spatial arrangement interaction effects on 100-seed weight. With seasons, the 2022 major season produced slightly higher 100-seed weight (22.5 – 30.75g) than the 2021 minor season (19.75 – 26.50g). Opeaburo + Oboshie x SP3 interaction had a higher mean 100-seed weight (26.50g) compared to other spatial arrangements and their sole crops for 2021 minor season (Table 4.14). Similarly, for 2022 major cropping season, Opeaburo + Oboshie x SP2 interaction had the highest mean 100-seed weight (30.75g) compared to other spatial arrangements and their sole crops. The lowest mean 100-seed weight for 2021 minor season was recorded by Opeaburo + Yenyawoso x SP3 interaction (19.75g), while Opeaburo + Dehye x SP1 interaction had the lowest mean 100-seed weight (22.50g) for 2022 major cropping season (Table 4.14).

4.6.6 Grain yield

The maize grain yield results are indicated in Table 4.14. The intercropped maize yield ranged from 2.70 – 3.93 t ha^{-1} and when intercropped with the three groundnut varieties for 2021 minor and 2022 major seasons, respectively. The yield of intercropped Opeaburo was not significantly affected by varietal combinations, spatial arrangement nor varietal combination x spatial arrangement interaction. However, on the average between seasons, the 2022 major season had approximately 30 – 58% higher for maize grain yield than the 2021 minor season (Table 4.14). Opeaburo + Oboshie x SP3 interaction had significantly ($P \leq 0.05$) higher grain yield (3.93 t ha^{-1}) of maize compared to Opeaburo + Yenyawoso x SP3 interaction with the lowest grain yield (2.70 t ha^{-1}) for 2021 minor cropping season. In 2022 major cropping season, Opeaburo + Oboshie x SP2 interaction had significantly ($p \leq 0.05$) higher grain yield (6.03 t ha^{-1}) of maize compared to the lowest grin yield grain yield (2.88 t ha^{-1}) by Opeaburo + Dehye x SP1 interaction (Table 4.14).

Table 4.13:100-seed weight and grain yield of maize as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Treatment		**100 - Seed weight (g)**		**Grain yield (t ha^{-1})**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	20.75	27.50	3.68	4.38
	SP2	24.50	26.75	2.80	3.53
	SP3	19.75	27.75	2.70	5.83
Opeaburo + Dehye	SP1	21.00	22.50	2.90	2.88
	SP2	22.00	28.25	2.88	4.48
	SP3	23.25	28.50	3.20	5.20
Opeaburo + Oboshie	SP1	20.00	26.75	3.05	3.90
	SP2	25.25	30.75	3.05	6.03
	SP3	26.50	25.75	3.93	4.95
Sole Opeaburo	-	21.00	28.50	2.93	5.40
CV (%)		**11.5**	**16.1**	**24.0**	**27.8**

Variety =	*NS*		*NS*	
Season =	*HSD=317.00***	*p=<.001*	*HSD=0.49***	*p=<.001*
Spatial arrangement =	*HSD=2.12*	*p=0.033*	*HSD=0.64***	*p=0.019*
Season x variety =	*NS*		*NS*	
Season x spatial arrangement =	*NS*		*NS*	
Variety x spatial arrangement =	*NS*		*NS*	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference, CV (%) = Coefficient of variation.

4.6.7 Harvest index

Tale 4.15 shows study results on harvest index (HI) of maize for 2021 minor and 2022 major season. There was no significant (P>0.05) effects among varietal combination nor varietal combination x spatial arrangement interaction on harvest index for both cropping seasons. Similarly, there was no significant difference between the two seasons for harvest index (HI). Harvest index (HI) ranged from 0.32 – 0.41 for the 2021 minor season and 0.31 – 0.37 for the 2022 major season. Opeaburo + Yenyawoso x SP1 interaction had a significantly (P>0.05) higher harvest index of 0.41. In 2022 major cropping period, Opeaburo + Yenyawoso x SP3 and Opeaburo + Oboshie x SP2 interactions had statistically higher harvest index of 0.37 compared to the other spatial arrangements and their sole plots (Table 4.15). The lowest harvest index (HI) during 2021 minor cropping period was recorded in the plot with Opeaburo + Yenyawoso x SP3 interaction with a value of 0.32. During 2022 major cropping period, Opeaburo + Yenyawoso x SP2 interaction had the lowest harvest index (HI) with values of 0.31 and 0.12 respectively.

4.6.8 Shelling percentage

Results of shelling percentage (%) of maize for 2021 minor and 2022 major seasons are shown in Table 4.15. Shelling percentage (%) ranged from 60 – 77% and 63 – 75% for the 2021 minor and 2022 major seasons, respectively. Shelling percentage (%) was not significant among the varietal combinations, spatial arrangement nor varietal combination x spatial arrangement interactions. Similarly, there was no significant difference between the two seasons for shelling percentage (%). In 2021 minor cropping season, Opeaburo + Oboshie x SP2 interaction had a significantly ($p \leq 0.05$) higher shelling percentage (76.88%), while Opeaburo + Yenyawoso x SP1 interaction had the highest shelling percentage (74.80%) in 2022 major cropping season compared to the other spatial arrangements and their sole plots (Table 4.15). The lowest shelling percentages were recorded by Opeaburo + Dehye x SP1, which were 60.44% and 63.31% for both 2021 minor and 2022 major cropping periods, respectively.

Table 4.14:Harvest index and shelling percentage of maize as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Treatment		**Harvest index**		**Shelling percentage (%)**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	0.39	0.32	73.99	74.80
	SP2	0.41	0.31	66.98	70.06
	SP3	0.32	0.37	66.87	70.19
Opeaburo + Dehye	SP1	0.39	0.34	72.01	69.39
	SP2	0.34	0.32	60.44	63.31
	SP3	0.36	0.34	73.99	69.13
Opeaburo + Oboshie	SP1	0.34	0.35	74.73	67.13
	SP2	0.34	0.37	76.88	72.90
	SP3	0.37	0.36	76.82	74.04
Sole Opeaburo	-	0.35	0.34	65.64	69.21
CV (%)		**23.2**	**14.8**	**11.2**	**13.2**
Variety =		*NS*		*NS*	
Season =		*NS*		*NS*	
Spatial arrangement =		*NS*		*NS*	
Season x variety =		*NS*		*NS*	
Season x spatial arrangement =		*NS*		*NS*	
Variety x spatial arrangement =		*NS*		*NS*	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference, CV (%) = Coefficient of variation.

4.6.9 Land equivalent ratio (LER)

Table 4.16 shows results of Land equivalent ratio (LER) for maize and groundnut intercrop. Land equivalent ratio shows the effectiveness of intercropping over the pure stand. When the land equivalent ratio (LER) equals 1, it indicates that the yield of intercrop and sole crops is the same. LER values greater than 1 suggest the usefulness of intercrop cultivation, while LER values less than 1 indicate the unprofitability of intercrop cultivation. The land equivalent ratio was calculated for maize and groundnut intercropping. In the 2021 minor cropping season, Opeaburo + Oboshie x SP3 interaction recorded the highest land equivalent ratio of 1.29 (129 %) followed by Opeaburo + Dehye x SP3 Opeaburo + Yenyawoso x SP3 interaction with a land equivalent ratio of 1.09 (109 %) and 1.04 (104 %). Opeaburo + Yenyawoso x SP1 interaction gave a lesser land equivalent ratio of 0.82 (82 %). In the 2022 major cropping season, Opeaburo + Oboshie x SP2 interaction recorded the highest land equivalent ratio of 1.41 (141 %) followed by Opeaburo + Oboshie x SP3 and Opeaburo + Yenyawoso x SP3 interactions with land equivalent ratio of 1.14 (114 %) and 1.12 (112 %) respectively (Table 4.16). Opeaburo + Yenyawoso x SP1 and Opeaburo + Dehye x SP1 interactions gave a lesser land equivalent ratio of 0.82 (82 %) and 0.59 (59 %), respectively. LER was not significant among the varietal combinations, spatial arrangement nor varietal combination x spatial arrangement interactions. Similarly, there was no significant difference between the two seasons for LER (Table 4.16).

Table 4.15: Land equivalent ratio (LER) of maize and groundnut as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping season.

Treatment		LER	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	1.82	1.88
	SP2	1.84	1.75
	SP3	2.04	2.12
Opeaburo + Dehye	SP1	1.87	1.59
	SP2	1.88	1.81
	SP3	2.09	1.83
Opeaburo + Oboshie	SP1	2.01	1.76
	SP2	1.98	2.41
	SP3	2.29	2.14
Tukey's HSD ($p \leq 0.05$)		**0.25**	**0.36**
Variety =		NS	
Season =		NS	
Spatial arrangement =		NS	
Season x variety =		NS	
Season x spatial arrangement =		NS	
Variety x spatial arrangement =		NS	
Season x Variety x spatial arrangement =		NS	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference.

4.7 Correlation analysis of growth and yield and yield components of groundnut for 2021 minor and 2022 major seasons

Table 4.17 shows results on the correlation analysis of growth and yield and yield components of groundnut. According to the correlation analysis conducted in the 2021 minor cropping period, there was a strong, positive, and highly significant correlation observed. There was a highly significant correlation observed between pod yield and grain yield (r=0.79). The number of pods per plot exhibited a positive and highly significant correlation with grain yield (r=0.80). Furthermore, the number of branches per plant was positively and significantly correlated with 100-seed weight (r=0.38) (Table 4.17).

The correlation analysis conducted during the 2022 major cropping period of 2022 revealed a strong, positive, and highly significant correlation. Pod yield was highly and significantly correlated with grain yield (r=0.80). 100-seed weight exhibited a significant correlation with pod yield (r=0.58) and grain yield (r=0.57). Plant height was also significantly correlated with shelling percentage (r=0.40). The number of branches showed a significant correlation with the chlorophyll content of leaves (r=0.34), pod yield (r=0.39), and significantly correlated with 100-seed weight (r=0.56). Additionally, the chlorophyll content of leaves was highly correlated with 100-seed weight (r=0.56), Table 4.17.

Table 4.16:Correlation analysis of growth and yield and yield components of groundnut as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Parameters	1	2	3	4	5	6	7
2021							
1. Plant height		-0.20	0.01	0.13	-0.56	-0.03	0.09
2. Number of branches per plant			0.12	-0.18	0.38**	0.09	-0.08
3. Chlorophyll content of leaves				0.07	0.07	-0.18	-0.19
4. Shelling percentage					-0.38	-0.69	-0.16
5. 100 – seed weight						0.27	0.05
6. Pod yield							0.79***
7. Grain yield							
2022							
1. Plant height		-0.28	-0.20	0.40**	-0.46	-0.37	-0.22
2. Number of branches per plant			0.34*	-0.24	0.56***	0.39**	0.31*
3. Chlorophyll content of leaves				-0.11	0.56***	0.16	0.09
4. Shelling percentage					-0.35	-0.84	-0.41
5. 100 – seed weight						0.58***	0.57***
6. Pod yield							0.80***
7. Grain yield							

*Numbers against the parameters in columns correspond with variables in rows. * =Significant at P=0.05; ** =Significant at P=0.01; *** =Significant at P<0.001.*

4.8 Correlation analysis of growth and yield and yield components of maize for 2021 minor and 2022 major seasons

Table 4.18 shows results of the correlation analysis of growth and yield and yield components of maize. 100-seed weight was significantly correlated with grain yield (r=0.37) while shelling percentage was significantly correlated with grain yield (r=0.46). Cob diameter was highly correlated with cob length (r=0.72), 100-seed weight (r=0.48), and grain yield (r=0.52). Cob length was also significantly correlated with 100-seed weight (r=0.45) and grain yield (r=0.38). Plant height was positively and highly significantly correlated with grain yield (r=0.56). The chlorophyll content of leaves was also significantly correlated with 100-seed weight (r=0.36), Table 4.18.

The correlation analysis results for the 2022 major indicated a strong and positive correlation between the various parameters analysed. 100-seed weight was highly correlated with grain yield (r=0.72). Cob diameter was highly correlated with cob length (r=0.83), 100-seed weight (r=0.78), and grain yield (r=0.80). Cob length was highly correlated with 100-seed weight (r=0.71) and grain yield (r=0.73). Plant height also correlated highly significantly with 100-seed weight (r=0.76) and grain yield (r=0.82), Table 4.18.

Table 4.17: Correlation analysis of growth and yield and yield components of maize as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Parameters	1	2	3	4	5	6	7
2021							
1. Plant height		-0.02	0.26	0.57***	0.25	0.09	0.56***
2. Chlorophyll content of leaves			0.14	0.23	0.36*	0.24	0.23
3. Cob diameter				0.72***	0.48**	0.05	0.52***
4. Cob length					0.45**	0.10	0.38*
5. 100 – seed weight						0.22	0.37*
6. Shelling percentage							0.46**
7. Grain yield							
2022							
1. Plant height		0.07	0.54***	0.82***	0.76***	-0.22	0.82***
2. Chlorophyll content of leaves			0.24	0.20	0.13	-0.01	0.20
3. Cob diameter				0.83***	0.78***	-0.13	0.80***
4. Cob length					0.71***	-0.27	0.73***
5. 100 – seed weight						-0.10	0.72***
6. Shelling percentage							-0.01
7. Grain yield							

*Numbers against the parameters in columns correspond with variables in rows. * =Significant at P=0.05; ** =Significant at P=0.01; *** =Significant at P<0.001.*

CHAPTER FIVE

5.0 DISCUSSION

5.1 Influence of Variety and Spatial arrangement on phenology of Groundnut and Maize

The results show that Yenyawoso consistently emerged the earliest days to 50% seedling emergence, percentage plant establishment, and days to 50% flowering compared to Dehye and Oboshie. This might be due to genetic differences. This agrees with Li *et al.* (2022), who stated that genetic differences between groundnut varieties can affect their growth and development. According to Owusu–Akyaw *et al*. (2019), Yenyawoso may have genetic traits that make it better adapted to the growing conditions and tolerant to certain environmental factors giving it an advantage over the other groundnut varieties. Opeaburo + Yenyawoso x SP2 and SP3 interaction resulted in the earliest days to 50% seedling emergence for both cropping seasons.

The increased growth rates observed in SP2 and SP3 may be attributed to reduced interspecific competition and a moderate soil coverage offered by the maize plants, resulting in lower soil temperatures.

This observation aligns with the findings of previous studies, which suggest that intercropping aids in maintaining favourable soil micro-climates (Khan *et al.*, 2022). Similarly, other researchers have reported that variations in crop canopies lead to more efficient light utilization in spatial arrangements compared to single-crop cultivation (Maitra *et al*., 2019). For Opeaburo + Oboshie x SP1 and SP3 having late seedling emergence for the 2021 minor and 2022 major cropping periods respectively might probably be that the spatial arrangements did not provide optimal conditions for the growth and development of this groundnut variety. This might be because the seeds were planted too closely together, which leads to competition for resources like water, nutrients, and sunlight. Kumar *et al*. (2022) stated that unfavorable weather conditions, such as excessive rainfall or drought, can also delay seedling emergence.

The higher percentage plant establishment by Opeaburo + Yenyawoso x SP2 and SP3 in the 2021 season, and Opeaburo + Yenyawoso x SP2 in the 2022 season, could be due to a combination of factors related to temperature, seed quality, and rainfall. Temperature plays a crucial role in the germination and early growth of plants. The 2021 season may have had more favorable temperature conditions, such as optimal soil and air temperatures for seed germination and seedling growth. In 2022, the temperature conditions may have been suitable for the specific combination of Opeaburo + Yenyawoso x SP2, leading to better plant establishment for this particular hybrid. It's possible that the seeds used in the Opeaburo + Yenyawoso x SP2 and SP3 combinations in 2021 had superior quality, resulting in higher plant establishment rates compared to other combinations. This supports findings by Ansah *et al*. (2017) who stated that Yenyawoso performed best in terms of establishment.

The late days to 50% flowering by Opeaburo + Oboshie x SP2 and Opeaburo + Oboshie x SP3 interactions in 2021 minor and 2022 major cropping seasons might be due to the fact that days to flowering of groundnut and in particular, Oboshie depends on whether it is planted solely or intercropped. This study revealed that, groundnut plant flowers early when planted solely and a little late when intercropped with maize. The results showed that the shading effects caused by taller maize plants delayed flowering and maturity of Oboshie groundnut variety. This agrees with findings reported by Legese *et al*. (2019).

For maize, the non-significant difference between treatment means in both 2021 minor and 2022 major cropping seasons of days to 50% emergence might be due to the fact that the same variety of maize (Opeaburo) was used for the study.

The significant interactive effects observed in percentage plant establishment in the 2021 minor cropping season could be due to variations in rainfall patterns, which might have affected the growth and development of maize. For instance, the weather conditions during the two cropping seasons were different, and variations in temperature, rainfall, and humidity, can affect plant growth and development (Table 3.1 and 3.2). The results agree with Yao *et al*. (2022). In contrast, the absence of significant differences in the 2022 major cropping season could be attributed to favourable growing conditions and that minimized the impact of environmental and other factors on the growth of maize crop.

The significant impact on the days to 50% tasseling of maize during the 2021 minor cropping season, and not during the 2022 major cropping season could be due to variations in weather patterns that might have affected plant growth and development differently in the two seasons. The weather conditions during the two cropping seasons were different, with variations in temperature, rainfall, and humidity, which can affect plant growth and development (Table 4.1 and 4.2). Prolonged exposure of crop plants to high temperatures can disrupt cellular processes, reduce photosynthetic efficiency, and even lead to cellular damage. Insufficient rainfall can lead to drought stress, where maize plants do not receive an adequate amount of water for optimal growth. Opeaburo + Yenyawoso x SP2 interaction recorded the earliest days to 50% tasseling for 2021 cropping season, while Opeaburo + Oboshie x SP2 interaction had the earliest days to 50% tasseling for 2022 major cropping season. This could be attributed to genetic differences in the groundnut varieties and their effect on maize growth. Onat *et al*. (2017), stated that peanut cultivars vary in growth habit. The significant differences between the treatment means for both the 2021 minor and 2022 major cropping seasons of maize, suggest that the interactions between the groundnut varieties and spatial arrangements might have resulted in variations in nutrient availability, light penetration, or other factors that affect plant growth and development. The higher days to 50% tasseling recorded by SP2 and SP3 could be due to low interspecific competition provided by the maize plants which lowers the soil temperature. Also, these rows of groundnut probably gave higher N fixation which promoted early tasseling of the maize.

The earliest days to 50% silking by Opeaburo + Yenyawoso x SP2 interaction in 2021 period of production, and Opeaburo + Oboshie x SP2 in 2022 season might be due to temperature, and genetic influence. The findings of this study are consistent with previous research on the effects of genetics and environmental conditions on the days to 50% silking of maize. The two rows of groundnut probably gave higher N fixation which promoted early silking.

5.2 Influence of Variety and Spatial arrangement on vegetative growth of Groundnut and Maize

The differences in plant height between groundnut varieties during the 2021 minor cropping season could be attributed to genetic variation. The variations in plant height observed in this study confirm the findings of Konlan *et al.* (2013), Dapaah *et al*. (2014) and Essilfie *et al.* (2020) who reported variations among cultivars in plant height of groundnut. Opeaburo + Dehye x SP2 and SP3 interaction recording the highest plant heights could be attributed to its genetic makeup, as well as favourable climatic conditions (rainfall and temperature) during the cropping season. Gao *et al*. (2022), reported that intercropping groundnut with maize increased the plant height of groundnut compared to sole cropping, especially in the early growth stages. Similarly, Zhang *et al.* (2023), opined that intercropping groundnut and maize increased plant height of groundnut compared to sole cropping. Although maize provided shade to the groundnut, and as a result, the limited sunlight hindered the proper formation of groundnut leaves, the shading effect was positive on the intercropped groundnut, which grew taller compared to the groundnut plants grown alone as well as in SP1. The results demonstrated that the intercropped groundnut plants produced greater height compared to the sole groundnut plants, potentially due to competition for sunlight between the maize and groundnut intercropped. Since maize plants were taller and cast shadows on the groundnut, the intercropped groundnut adapted by growing in a way that allowed it to emerge from the shadows and receive more light, resulting in slightly increased height compared to its sole counterparts. The shading caused by the maize encouraged elongation of the groundnut internodes as a strategy to intercept more sunlight. These findings align with previous research conducted by Han *et al*. (2022), which also highlighted the positive impact of shading on legume crop growth and height, ultimately affecting their yield.

For maize, plant height is an important morphological trait and its variation can be influenced by different factors including variety and spatial arrangement. The higher plant height by Opeaburo + Yenyawoso x SP2 and SP3 interaction could be due to variations in the spatial arrangement of the crops. The study showed that certain spatial arrangements resulted in higher plant height at specific plant growth stages, while other arrangements resulted in lower plant height. This suggests that the spatial arrangement of crops can have a significant impact on plant growth and development (Chen *et al*., 2022). The SP2 and SP3 spatial arrangements recording the highest plant height might be due to the fact that the plants committed resources to grow taller to intercept sunlight for photosynthesis hence as a survival mechanism.

The non-significant difference in number of branches of groundnut varieties at 21 and 35 DAP in both 2021 minor and 2022 major cropping seasons could be due to the fact that the plant was in the early growth stage for the differences in the varieties be obvious and treatment effect on the number of branches not significant. However, as the plants continued to grow, significant differences were observed between treatment means of groundnut varieties from 49 to 77 DAP, which suggests that the impact of variety on the number of branches per plant was more apparent as the plants matured. The significant difference between treatments in number of branches per plant from 49 to 77 DAP could be due to differences in genetic traits. Onat *et al.* (2017) reported that groundnut varieties vary in growth habits and branching patterns. Yenyawoso consistently produced the greatest number of branches between the varieties at its early growth stage (21 DAP), indicating that it may have an early advantage in branching.

Oboshie however consistently had the greatest number of branches per plant in 2021 minor cropping season compared to the other groundnut varieties from 49 to 77 DAP in both cropping seasons, which suggests that it may have a superior ability to branch and produce more pods later compared to the other varieties. Wang *et al.* (2020), stated that the presence of intercropped maize created a situation of higher interspecific competition among the groundnut plants, leading to limited access to essential resources such as water, nutrients, light, and space. As a consequence, the intercropped groundnut plants produced fewer branches compared to the sole groundnut plants. This suggests that the row intercropping technique posed a competitive threat to the cooperation between the crops.

The sole groundnut plants, not being affected by mutual shading from the maize, enjoyed full exposure to sunlight, which likely enhanced their photosynthesis process and subsequent conversion of assimilates into branching. As a result, the sole groundnut plants developed more branches than their intercropped counterparts due to reduced intraspecific competition. These findings align with similar outcomes observed in a study conducted by Bugilla *et al*. (2023) as well as in this study during the minor cropping season.

For groundnut, Opeaburo x Yenyawoso x SP1 interaction had the highest Chlorophyll content of leaf at 30 and 44 DAP, while Opeaburo x Oboshie x SP2 interaction had the highest mean Chlorophyll content of leaf at 58 and 72 DAP. At 30 DAP, Opeaburo + Yenyawoso x SP3 recorded the lowest Chlorophyll content of the leaf, while at 44 DAP, Opeaburo x Dehye x SP1 attained the least Chlorophyll content of the leaf, and at 58 DAP, Opeaburo + Oboshie x SP3 and Opeaburo + Yenyawoso x SP3 had the lowest Chlorophyll content of leaf. The results suggest that the Chlorophyll content of groundnut leaf is influenced by variety, spatial arrangement, and the combined effect of groundnut and maize intercropped.

For maize, Opeaburo + Oboshie x SP3 had the highest Chlorophyll content of leaf from 58 DAP to 72 DAP in both cropping seasons could be that Oboshie groundnut variety and spatial arrangement had a significant impact on the Chlorophyll content of maize leaf. Different crop combinations can affect nutrient availability in the soil. The presence of the Oboshie groundnut variety in specific spatial arrangements might have created a microclimate that is conducive to higher chlorophyll content in maize leaf, possibly due to factors like shading or moisture retention. Sole Opeaburo had the lowest Chlorophyll content of leaf. Nutrient deficiencies particularly those related to essential nutrients for chlorophyll synthesis such as nitrogen can lead to lower chlorophyll content (Zahir *et al*., 2023).

The significant differences observed in the treatment means of dry shoot weight of maize in both cropping seasons suggest that the combination of groundnut and maize can have an impact on the dry shoot weight of maize. Findings by Ananthi *et al.* (2017) have it that, different combinations of varieties and spatial arrangements can have different effects on the dry shoot weight of maize at different stages.

5.3 Influence of Variety and Spatial arrangement on yield and yield components of Groundnut and Maize

The significant difference between groundnut varieties and the combined effect of maize and groundnut on number of plants harvested might be attributed to a combination of genetic, climatic, and intercrop interaction factors. Sole Yenyawoso had a greater number of plants harvested for the 2021 minor cropping season, whereas, for the 2022 major cropping season, Opeaburo + Yenyawoso x SP2 and Opeaburo + Yenyawoso x SP3 interaction had the greatest number of plants harvested. This could probably be due to the influence of climatic conditions such as rainfall and temperature on varieties (Mausbach *et al*., 2022). In line with findings by Essilfie *et al*. (2020), indicated that the significantly greater number of plants harvested in groundnut could be due to differences in genetic traits and its response to initial high rainfall experienced during the growing season.

For maize, 2022 major cropping season produced a significantly higher number of plants harvested than 2021 minor cropping season. However, no significant difference existed between treatment means. This might be due to differences in weather conditions that might have affected the number of plants harvested for maize crops in each season. The highest number of plants harvested in Opeaburo + Yenyawoso x SP3 in 2021 minor cropping season could probably be linked to better growth of maize in terms of percentage plant establishment. This agrees with findings by Mausbach *et al.* (2022).

The non-significant in number of pods per plant in the 2021 minor cropping season could be that the treatment effects were similar (Onat *et al*., 2017). The variation in the number of pods per plot between different varieties of groundnut could be due to differences in genetic traits such as yield potential and adaptation to climatic conditions during the experimental period. This is in conformity with earlier findings by Khan *et al*. (2022), that, the differences in number of pods among the varieties could be attributed to genotypic differences and their response to adverse climatic effects.

The variation in 100-seed weight of groundnut in both the 2021 minor and 2022 major cropping seasons might be due to genotypic and climatic differences. Khan *et al.* (2022) reported that genotype is one of the major factors that influence seed weight in groundnuts, and the varieties can differ significantly in their seed size and weight. The significantly higher mean 100-seed weight produced by Opeaburo + Oboshie x SP2 and SP3 interactions compared to other treatments in both seasons suggests that these varieties might be genetically predisposed to producing larger seeds. Asante *et al*. (2020) in their study reported that the seeds of Oboshie are genetically big and had the highest 100-seed weight.

For maize, there was a significant difference between treatment means in 100-seed weight in both cropping seasons. Opeaburo + Oboshie x SP3 and SP2 interactions respectively had a higher 100-seed weight compared to other spatial arrangements and their sole crops for the 2021 minor and 2022 major cropping season. This could be because maize and different groundnut varieties (Opeaburo and Oboshie) might have varying genetic traits that influence seed development and weight. These genetic differences can result in variations in seed size and weight. The combination of Opeaburo maize and Oboshie groundnut in SP3 and SP2 interactions might have created a more favourable nutrient availability that enhanced seed development. Adequate nutrient availability, including nitrogen from groundnut, can contribute to larger seed size. Meanwhile, the lowest mean 100-seed weight recorded by Opeaburo + Yenyawoso x SP3 in the 2021 minor cropping season and Opeaburo + Dehye x SP1 in 2022 major cropping season could be due to the selected plant combinations which might have led to higher competition for essential plant growth resources such as nutrients, water, and light. Increased competition can result in reduced resource availability for individual seeds, leading to smaller seed sizes (Postma *et al*., 2021).

Harvest index refers to the portion of the crop that is used for economic purposes with reference to the whole crop (Herridge *et al*., 2022). For groundnut, the highest harvest index by Opeaburo + Oboshie x SP1 interaction in 2021 minor cropping season and Opeaburo + Yenyawoso x SP2 in the 2022 major cropping season could be due to genetic differences and how they respond to environmental conditions. In a study by Burroughs *et al.* (2023), it was observed that harvest index (HI) varied among soybean genotypes due to genetic and environmental factors. The study found that genotypes with higher harvest index had better yield potential and were more efficient in using photosynthetic assimilates. The SP1 and SP2 produced the highest harvest index and are linked to the highest grain yield produced in both cropping seasons.

For maize, the harvest index is an important agronomic trait that measures the efficiency of a plant to convert photosynthetically fixed carbon into edible plant parts. The highest harvest index by Opeaburo + Yenyawoso x SP1 in 2021 minor cropping season and Opeaburo + Yenyawoso x SP3 and Opeaburo + Oboshie x SP2 in 2022 major cropping season could be that the treatments had a similar effect on harvest index.

Shelling percentage is the percentage of the weight of the seeds in the pods after they have been shelled, relative to the total weight of the pods. The results presented indicate that for groundnut the shelling percentage values for all treatments were high in both seasons. Opeaburo + Yenyawoso x SP2 in 2021 minor cropping season had the highest shelling percentage. This indicates that the spatial arrangement combination may be optimal for achieving a high shelling percentage in the groundnut varieties used. Sole Oboshie had significantly lower shelling percentages from Opeaburo + Yenyawoso x SP1 and SP2 in the minor cropping seasons which suggests that the groundnut variety may not be the best choice for achieving a high shelling percentage.

For maize, in both 2021 minor and 2022 major cropping seasons, high shelling percentage values were observed across all treatments. This indicates that the maize kernels were effectively separated from the cobs, resulting in good results overall. In the 2021 minor cropping season, the Opeaburo + Oboshie x SP2 interaction resulted in a significantly higher shelling percentage (76.88%). Similarly, in the 2022 major cropping season, the Opeaburo + Yenyawoso x SP1 interaction had the highest shelling percentage (74.80%) compared to other spatial arrangements and their sole plots although non-significant. These interactions indicate that certain combinations of maize varieties and spatial arrangements led to more favourable shelling percentages. The treatment combination of Opeaburo + Dehye x SP2 had the lowest shelling percentage in both cropping seasons. This could be due to poor compatibility between the maize varieties and the intercrop groundnut and their response to rainfall and temperature for the development and maturation of maize cobs.

For groundnut, the highest pod and grain yield produced by sole Dehye and Oboshie in 2021 minor cropping season and Opeaburo + Oboshie x SP2 interaction in the 2022 major cropping season could be due to genotypic difference and favourable rainfall which could have resulted in higher pod yield for these varieties. According to Elahi *et al*. (2022), seasonal changes to rainfall could lead to changes in soil water content, which is likely to affect plant growth and yield. Sutharsan and Srikrishnah (2015) found that different spatial arrangements had a significant impact on groundnut grain yield. This finding is consistent with the study by Harbau and Sanusi (2023), who reported that the interaction between variety and spatial arrangement significantly influenced groundnut yield. The higher rainfall experienced in 2022 than in 2021 cropping seasons might have enhanced plants to produce more pods. The lower pod yield observed in Opeaburo + Yenyawoso x SP1 in 2021 minor cropping season and Opeaburo + Dehye x SP3 in the 2022 major cropping season suggest that these combinations may be less well adapted to the climatic conditions (rainfall, temperature, and relative humidity) during the experimental period.

For maize, Opeaburo + Oboshie x SP3 and SP2 interactions recorded the highest grain yield, in the minor and major cropping seasons respectively. This shows that the genetic traits of the maize variety was favourable for higher maize productivity. The significant boost in yield in the intercropped plants may be attributed to the beneficial effects of groundnut in the spatial arrangement. Gabasawa (2021), opined that groundnut has been known to engage in symbiotic biological nitrogen fixation, which allows it to take up a portion of its nitrogen requirements from the atmosphere, thereby reducing the strain on soil nitrogen reserves. In this study, the intercropping of groundnut with maize proved advantageous for the maize plants, as they benefited from the nitrogen-fixing ability of groundnut roots and the transfer of nitrogen-fixation products to the maize. The intercropped of maize and groundnut at SP2 and SP3 provided an enabling environment for improved utilization of growth resources and partitioning of assimilates for higher yield than other intercrops. Conversely, Opeaburo + Yenyawoso x SP3 and Opeaburo + Dehye x SP1 interactions consistently had the lowest grain yield, suggesting potential incompatibilities in its genetic traits related to yield potential. This is in line with Asibuo *et al*. (2018). The least grain yield in the crop mixtures might be attributed to the effect of intercropping and plant population pressure on maize plants, probably the intercrops competed well with the maize for growth resources such as soil water, light, and soil nutrients. Generally, the major cropping season trial outperformed the minor cropping season trial in terms of grain yield, which probably might be due to well distributed rainfall pattern, appropriate temperature, suitable soil-water relationships, and efficient dry matter partitioning in maize during the major cropping season of 2022.

The significant difference between treatments in cob diameter and cob length observed in the combined effect of maize and groundnut treatment for both cropping seasons could be due to the interaction between the two crops. According to Karimuna *et al*. (2022), intercropping maize with legumes such as groundnut can improve maize cob diameter and cob length due to improved soil fertility and nutrient availability.

5.4 Influence of Variety and Spatial arrangement on Land equivalent ratio (LER) of Maize and Groundnut intercrop.

The land equivalent ratio is the total yield ratio from an intercrop to the ratio of total yield collected from the same plant species in the sole crop. Ennin *et al.* (2001) also defined

Land equivalent ratio (LER) as the total land area required under sole cropping to give yields obtained in the intercropping. According to Mohammed (2019a), LER indicates the magnitude of sole cropping required to produce the same yield on a unit of intercropped land. In the 2021 minor cropping season, Opeaburo + Oboshie x SP3 interaction recorded the highest land equivalent ratio of 1.29 (129 %) followed by Opeaburo + Dehye X SP3 and Opeaburo + Yenyawoso X SP3 interaction with a land equivalent ratio of 1.09 (109 %) and 1.04 (104 %), respectively. Opeaburo + Dehye x SP1 interaction gave a lesser land equivalent ratio of 0.82 (82 %). In the 2022 major cropping season, Opeaburo + Oboshie x SP2 interaction recorded the highest land equivalent ratio of 1.41 (141 %) followed by Opeaburo + Oboshie X SP3 and Opeaburo + Yenyawoso x SP3 interactions with land equivalent ratio of 1.14 (114 %) and 1.12 (112 %), respectively. Opeaburo + Yenyawoso x SP1 and Opeaburo + Dehye x SP1 interactions gave a lesser land equivalent ratio of 0.82 (82 %) and 0.59 (59 %), respectively for both seasons. In conclusion, the intercrops had a yield advantage over the sole crops.

According to Wu *et al*. (2023), certain varieties may have characteristics that make them more suitable for intercropping with specific crops, leading to variations in LER. Weather conditions can vary from one year to the next. Factors such as temperature and rainfall might have a significant impact on crop growth and yield. The weather in 2021 might have been more conducive to the success of the Opeaburo + Oboshie x SP3 combination, while the conditions in 2022 might have favored Opeaburo + Oboshie x SP2. The lower LER by Opeaburo + Dehye x SP1 interaction might have exhibited competitive growth behaviors, meaning they competed for resources like water, sunlight, and nutrients. This competition can lead to reduced overall yields and lower LER. Limited availability of essential resources, such as nutrients or water, might have constrained the growth of the crops in this combination (Aasfar *et al*., 2023). Inadequate resource allocation can result in lower yields and a lower LER. The advantage of intercrops with LER (1.29 and 1.41) over the sole crops (0.82 and 0.59) might be that different crops have varying root depths and nutrient requirements. When intercropped, they can utilize resources (water, nutrients, sunlight) more efficiently. For example, one crop might have shallow roots, while another has deep roots, reducing competition for resources. Also, legumes in an intercrop may fix nitrogen, benefiting neighboring non-legume crops. According to Mei *et al.* (2021), when the land equality ratio (LER) equals 1, it indicates that the yield of intercrop and sole crops is the same. LER values greater than 1 suggest the usefulness of intercrop cultivation, while LER values less than 1 indicate the unprofitability of intercrop cultivation. In this current study, the land equality ratio (LER) was greater than 1 therefore agrees with this statement. Zea *et al.* (2016) revealed that land equivalent ratios (LER) of more than 1 imply that the intercrops had a yield advantage over the sole crops. An LER of 1.29 and 1.41 respectively indicates that if planted in pure stands, the yield produced in the total intercrop would have required 29 % and 41 % more land, while an LER of 0. 57 indicates that the yield produced in the total intercrop was only 57 % of that of the same amount of land as pure stands planted. This support findings by Mohammed (2019a).

5.4 Correlation coefficients on growth, yield and yield components Groundnut and Maize.

For groundnuts, the results of the correlation analysis suggest that certain plant characteristics and yield parameters are strongly and positively correlated with each other. In the 2021 minor cropping season, the number of pods per plot was found to be highly correlated with both pod yield and grain yield, indicating that increasing the number of pods per plot could lead to higher pod and grain yield. Similarly, in the 2022 major cropping season, the number of pods per plot of groundnut was highly significantly correlated with 100-seed weight, pod yield, and grain yield, emphasizing the importance of this characteristic in determining yield. Additionally, plant height was found to be significantly correlated with shelling percentage, indicating that taller plants may have higher shelling percentages. According to Esan *et al*. (2023), the positive correlation between plant height and shelling percentage of groundnut has also been reported in other legume crops. Furthermore, the leaf chlorophyll content was highly significantly correlated with 100-seed weight, suggesting that green and more vigorous plants may produce larger seeds. The significant correlation between the number of branches per plant and 100-seed weight in both cropping periods suggests that increasing the number of branches could lead to heavier seeds, which is an important determinant of yield. These findings are consistent with previous studies that have also reported a positive correlation between the number of pods per plant, pod yield, and grain yield in groundnut crops (Khan *et al.*, 2022).

For maize, the results of the correlation analysis suggest that different varieties measured were positively and significantly correlated in both the 2021 minor and 2022 major cropping seasons. Shamuyarira *et al*. (2022) found similar results, where plant height was positively correlated with yield and other agronomic traits in wheat. Additionally, Asfaw (2022) reported a positive correlation between plant height and yield in maize. These findings suggest that plant height can be used as an indicator of yield potential in crops. Moreover, the correlation between the number of leaves per plant and yield observed in this study is consistent with the findings of previous studies. Similarly, Chen *et al*. (2021) found a positive correlation between the number of leaves per plant and yield in soybeans.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study assessed the growth, yield and yield components, and LER of intercropping maize with groundnut in the Forest-Savanna transition zone of Ghana.

Based on the results of the studies across both seasons, the following conclusions were drawn:

Objective 1:

- For maize and groundnut phenology and growth, Oboshie intercropped with Opeaburo at SP2 and SP3 and Yenyawoso intercropped with Opeaburo at SP2 and SP3 enhanced phenology and growth of the groundnut and maize varieties.

Objective 2:

- For both maize and groundnut yield and yield components, Oboshie intercropped with Opeaburo at SP2 and SP3 and Yenyawoso intercropped with Opeaburo at SP2 and SP3 enhanced 100-seed weight, pod yield, seed yield, harvest index (HI), shelling percentage (%) of the groundnuts and the stover weight, cob diameter and length, 100-seed weight, grain yield, harvest index (HI), and shelling percentage (%) of the maize crop.

Objective 3:

- For both maize and groundnut land equivalent ratio (LER), Oboshie intercropped with Opeaburo at SP2 and SP3 enhanced LER of maize and groundnut.

- Opeaburo intercropped with Oboshie or Yenyawoso at SP2 and SP3 are recommended for consideration for possible adoption by farmers who prefer intercropping the two crops rather than growing them as sole crops.

6.2 Recommendations for future/further research

Based on the experimental results, it is recommended that:

- Further studies could consider the relative times of planting the component crops since it can influence competition and the use of resources.
- The systems could be tested in the Guinea Savannah and Costal Savannah zones where intercropping is common among resource-poor farmers.

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