AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

PRODUCTIVITY (GROWTH AND YIELD) PERFORMANCE OF MAIZE + COWPEA INTERCROPPING AS AFFECTED BY VARIETAL COMBINATION AND RELATIVE TIMES OF PLANTING

ALEX OFORI

MASTER OF PHILOSOPHY CROP SCIENCE (AGRONOMY)

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

MAMPONG-ASHANTI

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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 CROP SCIENCE (AGRONOMY)

NOVEMBER, 2024

DECLARATION

STUDENT'S DECLARATION

I 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 been presented for another degree elsewhere.

Signature…………………………………….

Date………………………….……………

SUPERVISORS' DECLARATION

We hereby declare that this thesis 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 (AAMUSTED).

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(Principal Supervisor)

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Date…………………………….

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DEDICATION

This thesis is dedicated to the lovely wife, Happy Gbedze, my father, Samuel Kwasi Manu Antwi, and my brother, Fredrick Mantey Dzifa for seeing me through successfully in completing this programme.

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LIST OF ABBREVIATIONS

CSIR-CRI	Council for Scientific and Industrial Research of Crop Research Institute
RTP	Relative Times of Planting
M2WBC	Maize planted 2 weeks before Cowpea
C2WBM	Cowpea planted 2 weeks before Maize
SIM	Maize and Cowpea planted simultaneously
VC	Varietal Combination
LER	Land Equivalent ratio
LSD	Honestly Significant Difference
CV	Coefficient of variation
DAP	Days after planting

ABSTRACT

Two field trials were carried out from August to December 2021 in the minor rainy season and from March to July 2022 in the major rainy season to determine the varietal combination and relative times of planting effects on growth and yield performance of maize cowpea intercrop system. The experimental design used was 3 x 3 factorial laid out in a Randomized Complete Block Design (RCBD) with four replications. The treatments were: (A) three varietal combinations [(i) Abontem maize + Zamzam cowpea, (ii) Opeaburo maize + Zamzam cowpea and (iii) Omankwa maize + Zamzam cowpea] and three relative times of planting [(i) maize planted 2 weeks before cowpea (M2WBC), (ii) maize planted simultaneously with cowpea (SIM) and (iii) cowpea planted 2 weeks before maize (C2WBM)]. The results showed that, for cowpea phenology, cowpea planted after Opeaburo maize had the highest percentage plant establishment, early flowering and podding. In maize, Opeaburo maize planted before cowpea promoted plant establishment, while sole Opeaburo advanced early tasseling and silking. Regarding vegetative growth, cowpea and Omankwa and Abontem planted simultaneous showed improved plant height while sole cowpea yielded higher dry matter. For maize, sole Omankwa and Opeaburo resulted in taller plants, and intercropping with Omankwa promoted leaf development. The highest cowpea grain yield (346.50 kg ha^{-1}) for the 2021 minor season was recorded by sole cowpea whereas for the 2022 major cropping season, sole cowpea recorded the highest pod yield (450.75 kg ha^{-1}) followed by Opeaburo and cowpea planted simultaneously (405.25 kg ha^{-1}). Again, the sole cowpea produced more pods per plant and higher seed weight. In maize, Abontem planted simultaneous with cowpea had higher 100-seed weight and harvest index, while sole Omankwa and Opeaburo performed better in cob size. Omankwa planted after cowpea had the highest grain yield. The land equivalent ratio (LER) for both maize and cowpea was maximized when maize was

planted two weeks before cowpea in the Abontem + Zamzam combination, and in simultaneous planting of Opeaburo + Zamzam. Abontem planted before cowpea and simultaneous are recommended for farmers who prefer intercropping cowpea and maize.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Maize *(Zea mays* L.) is a major crop grown by many farmers, which serves as a staple food in many rural communities across the West Africa. It is one of the most important cereals grown in Africa (Ampah *et al.,* 2020). It is an important dual-purpose crop used in human diet and animal feed (Iderawumi *et al.,* 2018). Almost every part of the maize plant has economic value: the grain, leaves, stalk, tassel, and cob can all be used to produce a large variety of food and non-food products. Maize is the third most important cereal for human consumption after rice and wheat. Small scale farmers in Southern Ghana practice intercropping systems by using traditional combination of five to six crops.

Cowpea (*Vigna unguiculata* (L.) Walp) is an important legume in the dry savannas of Africa, particularly in West Africa of the 12.5 million cowpea-cultivated hectares around the world (Ampah *et al.,* 2020). Nigeria is one of the largest cowpea producers in the world with an average production of 2.92 million tonnes, followed by Niger with 1.10 million tonnes (FAO, 2012). Cowpea is a food and forage crop that grows in semi-arid tropical regions. Cowpea does not require a high rate of nitrogen fertilization; its roots have nodules in which soil bacteria called Rhizobia inhabit and help to fix nitrogen from the air into the soil in the form of nitrates (Abubakar *et al.,* 2018). Cowpea is an important crop due to its role in human and animal nutrition.

According to Ampah *et al.* (2020), intercropping is the agricultural practice of cultivating two or more crops in the same period of time and it offers farmers the opportunities to engage nature's principle of diversity on their farms. Intercropping is an important agronomic strategy that involves the cultivation of two or more crops on the same plot of land (Iqbal *et al.,* 2019). Intercropping systems provide 15-20% of the global food supply (Feng *et al.,* 2021). Intercropping of cowpea with cereals is a common farmer's practice in various parts of the world. Intercropping is the predominant cropping system for food crop production in Ghana. It has been estimated that about 52-60 percent of small scale farmers in Southern Ghana are involved in intercropping of maize and cowpea using the local open pollinated maize varieties (MoFA, 2010). In Northern Ghana, intercropping is predominantly practiced to ensure food security because of scarcity of land and erratic rainfall.

In Ghana, cowpea plays an important role in the cropping systems because of its ability to fix atmospheric nitrogen. Farmers plant various intercrop component crops randomly without defined rows, lacking knowledge in times of planting and temporal arrangements of component crops. Intercropping has ecological, biological and socio-economic advantages over sole cultivation. Several studies have shown the importance of the intercropping system of cereals and legumes, which is considered as an old practice in tropical agriculture (Iqbal *et al.,* 2019). It provides food and income at different periods of the year for the family (Emede and Adegoke, 2011). Yield advantages resulting from intercropping may be due to component crops having different durations or growth patterns, hence, make major demands on resources at different times, thereby resulting in better temporal use of growth resources (Mbah and Muoneke, 2007). Ampah *et al.* (2020) suggested that cowpea could be included in farming systems of the humid areas because of its potential to provide green manure in addition to producing primary products of grain and fodder. When nitrogen fertilizer is not applied, intercropped legumes will fix most of their nitrogen from the atmosphere and not compete with maize for nitrogen resources (Adu-Gyamfi *et al.,* 2007). Yields of intercropping are often higher than in sole cropping systems (Bitew *et al.*, 2021). The reasons are mainly that resources such as water, light and nutrients can be utilized more effectively than in the respective sole cropping systems (Legese *et al.,* 2021). Grain legumes, particularly cowpeas, are thought to have the fewest adoption problems and are widely cultivated by farmers, mainly for home consumption of seeds and sometimes leaves in northern Ghana.

1.2 Problem Statement and Justification

Despite the importance of intercropping, very few reports are found in the literature concerning the influences of this system on the physiology and productivity of hybrid maize. Toungos *et al.* (2018) reported that intercropping offers several advantages to small scale farmers; by intercropping with appropriate crop at an appropriate sowing date, these may benefit from improved soil fertility, increased productivity and reduced risk of total crop failure. Ampah *et al.* (2020) observed that different planting time of component crops improved the resource utilization and reduced competition, this is in contrast with that of Muzari *et al. (*2012) who reported that time of introducing cowpea in maize had no effect on growth attribute of maize, but delay in cowpea introduction beyond 14 days after sowing maize caused significant decrease in growth parameter of cowpea. In most cases, local maize is grown mixed with local cowpea resulting in low yield, which can be attributed to improper crop mixing and planting date. The beneficial effects of maize plus cowpea have not been fully exploited; variety and sowing date that will improve the growth and performance of the two components of the intercrop.

Maize (*Zea mays* L.) is widely cultivated with cowpea (*Vigna unguiculata L.* Walp.) in the West African savannah (Ewansiha *et al*., 2014). The most common benefit of intercropping is that it produces a higher yield on a given plot of land making it more efficient to use the available growth resources and nutrient requirement based on the utilization of growth resources by the component crops (Lithourgidis *et al.*, 2011). The intercrop of maize and cowpea is an alternative system for small-scale farmers to improve income and food production per unit of area (Iqbal *et al.*, 2018) and reduces the risk of total cultural insufficiency due to the limits of the environment (Maitra *et al.*, 2020). Despite the large number of maize and cowpeas, their production is very low to meet the demand of Ghanaians.

Intercropping system continue to dominate the supplying pattern of small holder farmers. Intercropping of cereal and legume crops helps maintain and improve soil fertility and plays an important role in subsistence food production in developing countries (Muzari *et al.*, 2012) because farmers cannot afford inorganic fertilizers. Limited work has been done on new varieties of maize and cowpea that have been released in Ghana since 200 regards to their intercropping. Therefore, there is the need to conduct research on varietal combination and relative times of planting effect on growth and yield performance of maize-cowpea intercrop system.

1.3 Objectives of the Study

The main objective of the study was to assess the effects of varietal combination and relative times of planting on growth, yield and productivity of maize + cowpea intercropping systems.

The specific objectives of the study were to:

i. Evaluate the effect of intercropping maize varieties with cowpea on growth and yield of component maize and cowpea crops.
ii. Assess the land use efficiency (LER) of maize + cowpea intercropping system.

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin and Distribution of Maize and Cowpea

The primary centre of origin of maize is considered by most authorities to be Central America and Mexico, where many diverse types of maize are found. The discovery of fossil maize pollen with other archaeological evidence in Mexico indicates Mexico to be the native of maize. Maize is cultivated throughout the world. From 58 °N latitude to 40°S latitude, the crop spreads and is cultivated over 139 million ha of area and around 600 million tonnes of maize is produced. It occupies the third position next to rice and wheat in area and production. USA, China, Brazil, Mexico, India, Romania, Philippines, Indonesia are some of important countries that cultivate maize crop. It is a staple human food, feed for livestock, for fermentation and many industrial uses. Maize is a major staple food crop grown in diverse agro-ecological zones and farming systems, and consumed by people with varying food preferences and socio-economic backgrounds in sub-Saharan Africa (SSA).

The central role of maize as a staple food in SSA is comparable to that of rice or wheat in Asia, with consumption rates being the highest in eastern and southern Africa (ESA). Of the 22 countries in the world where maize forms the highest percentage of calorie intake in the national diet, 16 are in Africa. Maize accounts for almost half of the calories and protein consumed in ESA, and one-fifth of the calories and protein consumed in West Africa. An estimated 208 million people in SSA depend on maize as a source of food security and economic wellbeing. Maize occupies more than 33 million ha of SSA's estimated 200 million ha of cultivated land. Cowpea (*Vigna unguiculata* L. Walp.) (2n=2x=22) is a member of the Phaseoleae tribe of the Leguminosae family. Members of the Phaseoleae include many of the economically important warm season grain and oil seed legumes, such as soybean (*Glycinemax*), common bean (*Phaseolus vulgaris*), and mungbean (*Vigna radiata*). The name cowpea probably originated from the fact that the plant was an important source of hay for cows in the southeastern United States and in other parts of the world. Cowpea plays a critical role in the lives of millions of people in Africa and other parts of the developing world, where it is a major source of dietary protein that nutritionally complements staple low-protein cereal and tuber crops, and is a valuable and dependable commodity that produces income for farmers and traders (da Silva, 2018; Dhital, 2021). Cowpea is a valuable component of farming systems in many areas because of its ability to restore soil fertility for succeeding cereal crops grown in rotation with it (Yadav *et al.*, 2019, Etana *et al,* 2013).

2.2 Maize and Cowpea as a Staple Food in Ghana

Most maize produced in Ghana are of the white variety, but only yellow maize is produced and all of them are used primarily for human consumption. Ampah *et al.* (2020) reported that about 87% of maize produced is used for local consumption. Per capital consumption continues to grow, increasing, for example, from 38.4 kilograms per head per year in 1980 to 43.8 kilograms per head per year in 2010 to 2011 which is about 14% increase (MoFA, 2010). Most of the maize produced is consumed directly by farming families (57percent) and the rest of the production is subject to formal or informal trade (30 percent).A small amount of maize is produced and used for animal feed in the poultry industry (about 13 percent). Virtually all yellow maize is imported and used for animal feed production.

2.3 Soil Requirement for Cowpea and Maize

They grow best in slightly acid to slightly alkaline soils (pH5.5-8.3). Like most legumes; cowpea does not withstand water logged or flooded conditions. El Naim *et al* (2010) reported that cowpea can also be used as green manure. Cowpea as reported by Islam *et al.* (2021), is an excellent cover crop to suppress weeds, provide erosion control and attract beneficial insects. Cowpea can spread on the soil preventing erosion. Saha *et al.* (2018) added that the intermediate and semi-determinate manure of growth of cowpea provides good ground cover. Paramisparam *et al.* (2021) have stated that most upland soils in the humid and sub humid tropics are susceptible to nutrient depletion with intensity because of their low buffering capacity. Agegnehu *et al.* (2021) have also stated that low soil fertility due to continuous cropping is common to many African soils which are infertile due to low organic inputs resulting from minimum retention of crop residues in the field. Increasing population and other pressures on the arable land have brought about shortening of fallow periods and intensification of cultivation resulting in increased erosion, soil degradation and decline in productivity (Otsuka *et al.,* 2014). In the tropics is the most important of the essential major nutrients and is often the most limiting nutrient to crop growth under continuous cultivation. Nitrogen fertilization is therefore, necessary for increased crop yields (Fischer and Connor, 2018).

Various authors also reported that nitrogen is made available for biological purposes through mineralization and fixation be it chemical or biological. The increasing prices nitrogen fertilizers is one factor adversely affecting its use by farmers. However, where costs are even reasonable, fertilizers are often unavailable or where available, it is usually too late to be of greatest benefit to the crops. Another problem associated with industrially manufactured nitrogen is its environmental pollution potential. Streams, rivers, and groundwater are prone to contamination by washed off fertilizers. Torrential rainfall in the tropics clearly aggravates leaching and pollution problems. Biological Nitrogen Fixation (BNF) by legumes provides an alternative and cheaper source of N for crop production.

Grain legumes are mostly grown in mixtures with water either non-leguminous crops like maize, sorghum or millet (Layek *et al.,* 2018). In intercropping systems, especially under small scale farm conditions, the ability of the legume to grow without N fertilizer under reduce cost of fertilizer input

2.4 General Overview on Intercropping

Intercropping is the growing of two or more crops simultaneously on the same field such that the period of overlap is long enough to include the vegetative stage (Biruk *et al.*, 2021). Intercropping is the practice of cultivating two or more crops simultaneously on the same piece of land during the same time span (Maitra *et al*., 2020). Intercropping refers to the growing of crops simultaneously on the same piece of land with base crop necessarily in distinct row management crop intensification is in both time and space dimension. On the other hand, intercropping may be explained as the cultivation of two or more crop simultaneously on the field with or without a row management. Maitra *et al.,* (2019) stated that intercropping involves growing of two or more crops on the same land in the same season.

Agriculture in semi-arid and arid regions of Sub-Saharan Africa (SSA) faces the challenges of water scarcity (Hadebe *et al.,* 2017), land degradation and climate change. Strategies proposed to improve the productivity of these cropping systems include the use of improved/appropriate variety and greater efficiency in the use of resources for land, water and solar radiation. In this regard, the combination of drought-resistant cereals such as maize with legumes, other crops, emerged as a strategy to maximize land and water use efficiency. The practice of cultivating two or more crops in the same space and at the same time is common among smallholder farmers (Seran & Brintha, 2010). This common combination in intercropping systems mostly involves cereal legumes including maize-soya, maize-cowpea, maize-peanut, millet and rice-legumes (Matusso *et al.,* 2014). Scientists have reported a number of research studies on intercropping legumes from cereals, with intercropping successes as compared to monocropping. In this way, farmers can produce to take advantage of location-specific agro climatic circumstances to improve production (Williams *et al.,* 2019). Interconnecting systems are known to make more efficient use of growth factors while capturing and allowing better use of radiant energy (Wagacha *et al.,* 2012), available water and nutrients (Sullivan, 2019). Prevent pest and diseases, suppress weeds and maintain and improve soil fertility (Dwivedi & Tomar, 2015). Culture system refers to the spatial and temporal arrangement of different cultures exploit natural resources and increase productivity per unit area and time (Li, 2020). The spatial arrangement of crops contributes to the efficient use of land, soil moisture, nutrients and solar radiation. This is achieved by choosing suitable crops of various morpho-physiological natures and planning their planting geometry to reduce mutual competition for resources and enhance complementarities to increase overall productivity. In general, this is achieved by intercropping.

2.5 Cereal-legumes intercropping systems

In combination, there is a main crop grown with one or more added crops where the main harvest is of paramount importance for reasons of economic or food production (Lithourgidis *et al.,* 2011; Maitra & Ray, 2019). In the SSA region, intercropping of cereals and pulses for wheat is practiced mainly by small farmers (Odendo *et al.,* 2011; Matusso *et al.,* 2014). The main reason why these farmers fertilize grains and pulses for grains is that they are especially important for humans as they are high in protein and are sometimes sold for cash income (Odendo *et al.,* 2011). In addition, intercropping gives them crop stability for several seasons (Haussmann *et al.,* 2012), when one crop is off, the other can still give a reasonable rendering (Lithourgidis *et al.,* 2011). In addition, pulses contribute to maintaining and improving soil fertility thanks to their capacity to biologically fix atmospheric nitrogen (Gogoi *et al.,* 2018, Dwivedi *et al.,* 2015).

2.6 Benefits of intercropping

The intercrop of corn and legumes is widespread among small farmers because of the capacity of the legume to cope with soil erosion and declining soil fertility levels. The main reasons why small farmers fertilize are flexibility, maximization of profit, minimization of risk in relation to total harvest failure, soil conservation and improvement of soil fertility, weed control and balanced nutrition (Sewhag and Devu, 2021). Other advantages of intercropping include potential for increased profitability and low fixed costs for soil after a second harvest in the same field (Sharmili *et al.*, 2021).

In addition, intercropping can provide higher yield than single crops, greater yield stability, more efficient use of nutrient requirements, improved weed control, insurance against total crop loss, improved quality by variety and even maize as a single crop larger area to produce the same yield as maize in a companion system (Nweke, 2018). For example, pigeon pea or cowpea regularly intercropped can help maintain maize yield to some extent when maize is grown without mineral fertilizer on sandy soil in Sub-humid zones of Zimbabwe. Intercropping maize with cowpea has been reported to increase light penetration into catch crops, thereby reducing water evaporation and improving soil moisture conservation compared to maize alone (Mobasser *et al.,* 2014).

On the other hand, it is often believed that traditional support systems are more effective in controlling weeds, pests and diseases than monocultures. Weed growth depends critically on the competitive ability of the entire crop community, which is largely intercropped. It depends on the competitive capacities of the component crops and their respective plant populations. For example, intercropping of cereals and cowpea has been observed to significantly reduce striga infestation (Mamudu *et al.,* 2019). This was attributed to the cowpea ground cover which created unfavorable conditions for striga germination (Dwivedi *et al.*, 2015). Mashingaidze (2004) found that intercropping maize reduced weed biomass by 50 - 66% when established at a density of 222,000 plants ha1 for beans equivalent to 33 percent of the maize density (37,000 plants ha1). Other studies in which intercropping systems have been used as an integrated weed management tool reported the same results (Matusso *et al.,* 2014). For pests and diseases, the effect most often cited is that one crop can provide a barrier to the spread of a pest or disease from the other crop (Ratnadass *et al.,* 2012). Massawe *et al.* (2016) noted that the germination worm infestation in sole corn was greater than in soybean corn. The mean percentage of European corn borer infestation was significantly higher in corn monoculture seeds (70%) than in cowpea intercrops (Matusso *et al*., 2014).

In addition, the interconnecting systems control soil erosion by preventing raindrops from touching bare ground where they tend to seal surface pores, prevent water from entering the soil and increase surface runoff (Asodewine, 2020, Asekabta, 2018). Paudel (2016) found that in the cowpea intercropping system, cowpea acts as a better cover crop and reduces soil erosion than the maize-beans. Kebede and Bekeko (2020) found that taller crops act as a wind barrier for short crops, in taller cereal crops with short legume crops. Likewise, intercropping cowpea reduced runoff by 20 - 30% compared to pure sorghum and 45 - 55% compared to monoculture cowpea. In addition, soil loss was reduced with intercropping by more than 50% compared to monocultures of sorghum and cowpea monocultures (Zohry *et al.*, 2020). Mousavi (2011) reported that with intercropping of maize and beans in varying proportions, production increased due to reduced competition between species compared to competition within species. The production of more associated crops can be attributed to the higher growth rate, reduction of weeds, pests and diseases, etc. effective use of resources due to differences in resource consumption (Eskandari et al., 2012; Ouma and Jeruto, 2010).

Moreover, if there are "complementary effects" between the components of the association, the production increases by effect reduce competition between them (Mahapatra, 2011). Increased plant diversity in intercropped fields may reduce the impact of pest and disease outbreaks by providing more habitats for predatory insects and increasing the distance between plants in the same crop. The ecological benefits of intercropping include less land needed for agricultural production, reduced use of inorganic fertilizers, pesticide and herbicide use, and a reduction in soil erosion (Massawe *et al*., 2016).

Intercropping also has several benefits to the farmer including a reduction in farm inputs, addition of cash crops, and diversification of diet, increased labour utilization efficiency, and reduced risk of crop failure due to uncertainties of the weather. The amount of time to plant the multiple varieties of seeds would be reduced, thus increasing labour utilization efficiency. Intercropping presents a large level of risk reduction for the smallholder in Northern Ghana. If one crop is completely lost due to pests or drought, the farmer can still harvest the other crop from the field. Due to the unpredictable rainy season and the different water needs of each crop, many varieties of the same crop in an intercropped field gives the farmer a better chance that some crops will survive. One important advantage of intercropping is its ability to reduce pest and disease damage. In general, Mousavi *et al.* (2011) reported that strategies involved in reducing pest infestation and damage in intercropping can be divided into three groups. First is delimiter crop hypothesis in which the second specie breaks down the ability of a pest to attack its host and is used more in proprietary pests. Secondly, trap crop hypothesis, in which the second specie attract their pests or pathogen that normally it damages major species and is used more generally by pests and pathogens.

In a review by Arshad *et al*. (2018) on intercropping, in 53% of the experiments intercropping reduced the pest, and in 18% increased the pest than the pure cropping. Increasing pests can be due to several reasons, such as the second crop is a host for pests in intercropping, or increasing the shade in canopy, provides favourable conditions for pests and pathogens activity. In addition, plant residues can be as a source for pathogens inoculated as also reported by (Peters *et al.,* 2003). More species diversity in agricultural ecosystems can limit the plant pathogenic spread. Intercropping systems increases biodiversity like the natural ecosystems. This increase in diversity reduces pest damage and diseases (Mousavi *et al.*, 2011).

2.7 Limitations of Intercropping

There have been several reports on yield reduction in mixed cropping due to competition for light, water and nutrients, or allelopathic effects that can occur between mixed crops can reduce yields (Lithourgidis *et al.,* 2011). Therefore, the selection of appropriate crops, planting rates and changes in the spatial arrangement of crops are necessary. Adu Gyamfi *et al.* (2007) reported that when nitrogen fertilizer is added to the field, intercropped cowpea uses the inorganic nitrogen instead of fixing nitrogen from the air and therefore competing with maize for nitrogen. However, when nitrogen fertilizer is not applied, the associated legumes will repair most of .their nitrogen from the atmosphere and do not compete with corn for nitrogen resources .A major disadvantage of animal husbandry is believed to be difficult with practical management, especially where there is a high degree of mechanization or where the constituent crops have different requirements for fertilizers, herbicides and pesticides. Additional cost for separation of mixed grains and lack of marketing of mixed grains, problems at harvest due to lodging, and grain loss at harvest also can be serious drawbacks of intercropping.

Mechanization is also a major problem in intercropping. The machines used for sowing, weeding, fertilizing and harvesting are designed for large and uniform fields and not for small-scale production (Lithourgidis *et al.,* 2011). A reduction in the yield of constituent crops may occur due to intense competition (Ahmad, 2019).The situation where two or more plants share the same growth factors each well below their cumulative needs and in the same environment (Mohammed, 2019). Basic morphophysiological changes and agronomic characteristics such as fertilizer application, sowing time, and the proportion of crop mix are fundamental determinants of competition between component crops. When the constituent crops are arranged in certain rows, the degree of competition is determined. The cereal component of a cereal legume intercrop has an advanced growth rate, height advantage and a more widespread root system which gives it the upper hand over competition from associated legumes. Ofori and Stern (1987) reported that the yield of the legume component normally decreases by about 52% of the yield of a single crop, while grain yield was only reduced by 11%. Significantly, it was noted that the cereal constituent depresses the legume in an intercrop. This was attributed to abridged photosynthetic active radiation of the legume by the screening from cereal crop.

2.9 Residual effects of cereal-legume cropping system

Legume can accumulate nitrogen in the soil and it may not become available until after the growing season, improving soil fertility for the benefit of a later harvest. The kernel yield of maize was significantly 46% higher when grown after soybeans compared to maize and 20% higher in natural fallow. Chibudu (1998) found that maize yields increased by about 25%.and 88ter the maismucuna and maiscowpea combination systems, respectively. Maize kernel yield was 85% higher after two years of soybean and 66% higher after two years of cowpea compared. Furthermore, Akinnifesi *et al.* (2007) found that over 4 consecutive cropping seasons, grain yields of maize increased by 340 percent in gliricidia-maize intercropping, when compared to unfertilized sole maize. Bationo *et al.* (1995) reported that intercropping of cowpea with millet may enhance millet grain yields by 30 percent above the control. According to Peoples and Herridge (1990) to maximize the contribution of legume N to a following crop, it is necessary to maximize total amount of N in legume crop, the proportion of N derived from N_2 fixation, the proportion legume N mineralized and the efficiency of utilization of this mineral Unfortunately, it is not always possible to optimize these factors.

2.10 Intercropping Effects on Soil Fertility Maintenance

Maintaining soil fertility is often one of the challenges in agriculture production. Intercropping is one of the options available to maintain soil fertility and crop yield. Cowpea and maize intercropping affects soil fertility maintenance by N fixation and differential uptake by plants. This residual effect of the intercrop on the next crop is largest when the remains are left on the field and ploughed under after harvest. However, soil depletion can still occur when the nutrients taken up by the plants are not replaced with manure or fertilizers because large amount of nitrogen is removed in the grain harvested. Intercropping systems do not only provide nitrogen and other nutrients to the associated crops but also increase the amount of humus in the soil (Muzari *et al.,* 2012). This results in an improved soil structure reducing the need for soil tillage, whilst water loss, soil erosion and leaching of nutrients are reduced.

2.11 Allelopathic effects

According to Xie Yang (2021), allelopathy can be defined as the direct or indirect release of chemical substances into the environment by one plant to harmfully affect another plant. Allelopathy as the beneficial or harmful effect that is caused by one plant on another thus releasing chemical from plant parts by leaching, root exudates, volatilisation, residue decomposition and other processes in both natural and agricultural systems. Allelopathy can affect many parts of the plant ecology such as plant occurrence, growth, plant succession, the structure of the plant communities, dominance, diversity and productivity. The magnitude ofthe effect of allelopathy depends on the extent of any other stresses, such as environmental conditions or biological factors (insect or disease pressure) that occur during the growing season.

Allelopathy also plays an important role in suppressing the growth of weed species (Bhadoria *et al.,* 2011). Planting mixtures of cover crops with cereals can take an advantage of allelopathic potential where cover crops suppress the weeds. The suppression of weeds through allelopathy has been shown to be species sensitive, therefore, a broader spectrum of weed control may be possible by growing a mixture of different crop species, each contributing allelopathic activity towards specific weed species (Schulz *et al*, 2013). Commonly known effects of allelopathy include reduction in seed germination and seedling growth and there is no common mode of action or physiological target site for all allelochemicals (Ferguson & Rathinasabathi, 2013). However, there are some known sites of action for some allelochemicals including cell division, pollen germination, mutant uptake, photosynthesis, and specific enzyme functions.

Allelopathic inhibition is complex and can involve the interaction of different classes of chemicals like phenolic compounds, flavinoids, terponoids, alkaloids, carbohydrates, and amino acids with mixtures of different compounds sometimes having a greater allelopathic effect than individual compounds alone. Most of the chemicals are found to be inhibitory and are caused by phytotoxic substances that are actively released from the living plants into the environment through root exudation, leaching, volatilization, and passive liberation through decomposition of plant residues. These phytotoxic substances, termed allelochemicals, are usually considered to be secondary metabolites and do not appear to play a role in primary metabolism essential for plant survival (Ramawat *et al.*, 2019). Iqbal *et al*. (2019) identified a number of classes of allelochemicals causing inhibition of germination and growth.

Factors such as physiological and environmental stress, pests and diseases, solar radiation, herbicides, and less than optimal nutrients, moisture, and temperature levels can also affect allelopathic weed suppression. Different plant parts can also have allelopathic activity that varies over a growing season and include flowers, leaves, leaf litter and leaf mulch, stems, bark, root, soil and soil leachates and their derived compounds. Allelochemicals can also persist in the soil, affecting both neighbouring plants as well as those planted in succession (Abou El-Ghit 2016). El-Khawas & Shehata (2005) found that seedling emergence was reduced with treatment of *Acacia nilotica* and *Eucalyptus rostrata* on morphological, biological and molecular criteria of maize and kidney pea. Recent yield decline in cropping systems has been attributed to allelopathic effects (El-Khawas & Shehata, 2005). These allelopathy associated problems have been observed both in monocultures and multiple cropping systems. Continuous monoculture causes the accumulation of phytotoxins and harmful microbes in the soil that give rise to phytotoxicity and reduced soil fertility. A number of weed species possesses allelopathic properties, which have growth inhibiting effects on crops. Allelocompounds inhibiting plant growth affect many physiological processes, among others, the effect of ion uptake and hydraulic conductivity (water uptake) are particularly important. Since the root is the first organ to come into contact with the allelochemicals in the rhizosphere the degree of inhibition depends on their concentration (Zhang *et al.,* 2018, El-khawas and Shehata 2005). Some plants are able to escape allelopathic chemical(s) due to their "hypersensitivity" i.e. some plant root tips become strongly affected by allelochemical(s), which can inhibit growth (Chon *et al.*, 2002).

2.12 Varietal Combination, Growth and Yield of Component Crops

According to Kebede and Bekeko (2020), cowpea is relatively new crop in Ghana. However, it can play an important role in the cropping systems because of its ability to fix atmospheric nitrogen. Farmers also plant various intercrop component crops. Yield advantages realized in intercropping have been attributed to the principle of temporal and spatial complementarily of the component crops. Lithougudis *et al*. (2011) have stated that, in recent years, the role of biological nitrogen fixation of legumes in improving the nitrogen economy, productivity of legume intercrops and the intercrop soil environment has been emphasized. Plant height also has some significant influence on yield as experienced at a study at Kwadaso in 1987 (Dapaah *et al.,* 2003). Seran and Brintha (2010) reported that although yield of the individual crops may be lower in the intercropping systems compared to the monocrops, efficiency of land use (LER) may increase by intercropping. They stated differences in the depth of rooting, lateral roots spread and root densities are some of the factors that affect competition between the component crops in an intercropping system for nutrients. Nweke (2018). added that the cereals component, maize in this research, is usually taller, has a faster growing or more extensive roots system, particularly a larger mass of fine roots and its competitiveness for soil nitrogen from the atmosphere (Awad, 2020). This is expressed as facilitative effects of intercrop components, meaning that maize and cowpea have complementary effects in consuming nitrogen (Iderawumi *et al*., 2012). In intercrops, maize receives its required nitrogen from soil and cowpea from biological fixation of atmospheric Nitrogen. This provides the maize more available nitrogen in intercropping compared with its sole crop. Thus, forage quality of maize is improved by intercropping due to more nitrogen available for maize in intercropping.

Photosyntetically active radiation seems to play a relatively important role in determining total intercrop productivity. This was confirmed when Eskandari and Ghanbari (2009), who reported that more PAR interception by different intercropping systems have been observed. Layek *et al.* (2018) reported that intercropping may be more efficient at exploiting a larger total soil volume if components crop has different rooting habits, especially girth of rooting. Lower soil moisture content in intercrops treatment compared to sole crop could not be due to higher evaporation from the soil surface, because soil temperature under intercrops were lower than sole crops (Mao *et al.,* 2012). One explanation for more water extraction with intercrop resulting in drier soil profile compared to that sole crop (Eskandari & Kazemi 2011). Maize-cowpea intercrops produced greater dry matter yield than either species grown alone. Also, intercropping maize with cowpea showed advantages in land use efficiency expressed as LER when compared with the optimum density of either sole crop. Probably, the greater LER of the intercrops was mainly due to a greater resource use and resource complementarily than when the species were grown separately.

2.13 Effects of relative times of planting on growth and yield of maize cowpea intercropping system

Planting date is a variable in tropical companion systems that is under the direct control of the farmer. The effects of variations in the relative planting time of component crops in maize-cowpea intercropping systems were integrated in 2021 and 2022 cropping seasons Cowpea was either planted the same day with the three varieties of maize or two weeks before or after maize. Intercropping lessened the growth and yield of cowpea and maize relative to their sole crops (Khonde *et al.,* 2018). However, cowpea yield was depressed more by maize, especially when cowpea was planted two weeks after maize comparative assessment of maize and cowpea mixtures (El-Lateef *et al.*, 2015). Haruna *et al.* (2018) suggested that it is better to grow cowpea two weeks before maize than to practice monoculture or maize two weeks before cowpea. Maize reduced cowpea yields more than the effect of cowpea on maize yields (Ofori and Stem, 1987)

Relative time of planting and spatial arrangement are agronomic practices which have been reported to influence yield advantage of cereal with legume intercrops by affecting interspecific competition and the degree of complementarity of the component crops. Sullivan (2001) reported that having one crop mature before its companion crops lessens the interspecific competitions between the two component crops. Similarly, Okpara (2000) noted that relative sowing time of component crops in a vegetable cowpea/maize intercrop significantly increased the growth and yield of the component crops. The determination of the most suitable time of introducing any of the component crops into a mixture is one of the agronomic challenges the small-holder farmers face, as this determines the final yield of the crops. It also reduces the severity of interspecific competition between and among the component crops for the limited growth factors

2.14 Effect of Intercropping on Growth and Yield of Maize

Corn has been recognized as a common component in most intercopious tropical systems. High leaf area index and slight interception for mixed maize on pure crops. Although Prasad and Brooks (2005) found that an increase in corn implant density significantly affects the lai in corn and soy pots. Reddy and Reddi (2007) also observed separately that maize grain yield increased after intercropping with groundnuts and chickpeas. The goal of maximum maize-legume intercropping is to obtain a full maize yield plus the yield of the selected legume (Chui and Richards, 1984).However, a decline in maize yield has been reported due to variation in spacing between cowpea crops. Experiment also carried out in Indian Agric. The research institute revealed a large accumulation of dry matter from corn and peanuts associated in the 1:1 row ratio arrangement. Similarly, Maluleke *et al.* (2005) found that maize dry matter decreased as the Lablab population increased. Mangasini *et al.* (2012) found that the vegetative growth of the harvesting of the components in a mixture is influenced by the inter layer. Chui and Richards (1984) report that intercropping impaired panicle formation and specification of maize for up to 2 days, especially when soybean concentration is full in the population. Maize and cowpea intercropping have been observed to significantly reduce ear length, ear length and dryness ear weight, dry grain yield and total dry plant biomass. Ali and Mohammad (2012) observed that the highest and total dry yield of dry leaves/stemsplant protein was linked to forage maize intercropping with Karaj and Multicut, respectively. The yield increase seen in a corn/soybean strip selection arrangement was primarily due at the grant in border rows of corn with soy (Li *et al.,* 2001) the density of the plant influences both intra and inter specific competition and has particularly a significant effect on the yield of corn grain (Floresschez *et al.*, 2013). Intercropping maize legumes could significantly increase forage quality and quantity. However, it was noted that the farmer's field had the highest amount of vegetative biomass when legume crops are crossed with maize (Amos *et al.*, 2012).

2.15 Effect of Intercropping on Growth and Yield of Legumes (Cowpea)

Several research works have been reported on the response of legumes to intercropping mainly with annual cereal crops. Intercropping arrangement did not affect the mass of 100 peanut kernels, however, the number of pods for the hills, the weight and percentage of pods were significantly subjective due to the different treatments. The research also revealed that the space for larger grains can be changed to some extent without reducing its yield offering a more promising environment for the associated legume. Hongchun *et al.* (2013) reported that intercropping with maize did not disturb the fresh weight of groundnuts associated with monoculture. The use of twin rows rather than irregular single rows of each species improved the yield of intercropped soybeans without significantly varying the performance of maize compared to monoculture. Intercropping significantly reduced the number of soybean leaves per plant by 58%, the leaf area index (LAI) of 75% and phytomass at the beginning of the seed - filling of 78% (Maluleke *et al.,* 2005), however, Chui and Richards (1984) maintained that grouping maize plants at three to a hill enlarged intercrop soybean leaves per plant, LAI and phytomass relative to the conservative maize planting of one plant per hill. Soybeans yield was concentrated by up to 90% in intercropping with maize in the equal row. Legumes are viewed as serious component in conservation Agriculture (Meyer, 2010).

2.16 Physiological Response of Companion Crops in Cereal-Legumes Intercropping Systems

Various physiological growth parameters including leaf area index, leaf area duration, crop growth rate and net uptake have been identified as reliable indicators to predict final yields. The index of the foliar region of the component collections has been reduced in the cracking relative to the pure cut, but a general general zoneper unit land area resulted in a significant increase in mixed fodder yield (Geren *et al.* 2008). On the contrary, Redo *et al.* (2013) concluded that intercropping a corn with sorghum in replacement series of 2:2 rows resulted in the greatest leaf area, resulting in the highest dry matter accumulation. It was also reported that when soybean plantings were delayed for 15 days, forage sorghum performed relatively better physiological growth likely due to less competition for growth resources in the early stages of growth.

Delayed inoculation of one of the constituent cultures showed a positive influence on the physiological growth of both cultures. Akram and Goheer (2006) reported that concurrent cereal-legumes intercropping resulted in severe competition for growth resources and that grain growth has been negatively affected. Compared to cereals, legumes (cowpeas and rice beans) suffered relatively greater losses in forage yield (Iqbal *et al.*, 2018). Crossing sorghum rows with black gram in a 1:1 ratio resulted in improved growth parameters including leaf area crop growth rates and rates, while yield was significantly increased compared to sorghum monoculture (Rathore *et al.* 2012). However, in legume compression systems, relatively higher grains produced a shaded effect that reduces the physiological growth of legumes.

2.17 Intercropping productivity

One of the most important reasons for intercropping is to ensure that an increased and diverse productivity per unit area is obtained compared to sole cropping (Sullivan, 2003). For instance, using LER in a maize-cowpea intercropping system, Kipkemoi (2002) reported that it was greater than one under intercrop. Muoneke *et al.* (2007) found that the productivity of the intercropping system indicated yield advantage of 2-63 percent as depicted by the LER of 1.02-1.63 showing efficient utilization of land resource by growing the crops together. Raji (2007) had also reported higher production efficiency in maize/cowpea intercropping systems. Addo-Quaye *et al.* (2011) found that LER was greater than unity, implying that it will be more productive to intercrop maize and cowpea than grow them in monoculture. Prasad and Brook (2005) reported that Land equivalent ratios of all maize-cowpea intercrops were greater than unity (1.30 to 1.45), indicating higher efficiency of intercropping compared to sole crops. Intercropping productivity, otherwise known as yield advantage, is essential in any study of intercropping. Production systems involving associated food crops are widespread in tropical latitudes.

Intercropping is most productive when the component crop varies greatly in growth duration so that their peak resource growth condition occurs at different time periods. The interaction of several factors will optimize the most effective use of restrictive resources in the. These factors range from the genetic makeup of the constituent crops to the environmental and agronomic manipulation of the microenvironment. High productivity of intercopia is achieved if premature constituent maturation is cultivated with little interference in late harvest. It is known that maize (*Zea mays* L.) is a strategic crop and it is used for human consumption, animal and poultry feeding, as well as, industrial purposes. It is the world's most widely grown cereal and produced cereal crop. The total cultivated area of maize has reached about 1.7 million fads. Consequently, it is expected that maize cultivar and its plant distribution could play a vital role with any cropping system to increase land usage. However, the cropping system adopted by the farmer in Ghana must be physically viable, sustainable, less exhaustive acceptable to farming community and most important thing is that it should be economical.

The biggest complementary effects and biggest yield advantages occur when the component crops have different growing periods, so make their major demands on resources at different times. Consequently, intercropping systems that include legumes can provide symbiotically fixed N and potentially increase yield through improved resource use efficiency. Undie *et al.* (2012) reported that the total farming system productivity is assessed by land equivalent ratio (LER) and the portion of land saved. Land equivalent ratio was first defined as the relative land area required as sole crops to produce the yields achieved in intercropping (Martin-Guay *et al.,* 2018). Land equivalent yield values could also be thought of as relative yields. It combines the yields of two or more unlike crops into one index for comparison with sole culture of or among intercrop systems.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Experimental site description

The experiments were conducted during the minor season of 2021 (August to December, 2021) and the major season of 2022 (March to July, 2022) at the experimental fields of AAMUSTED, Mampong-Ashanti. Mampong-Ashanti (7^0, 8^1, N and 1^0, 24^1, W) is located in the forest-savannah agroecological zone of Ghana. Mampong-Ashanti is about 457.5 m above sea level. The soils at Mampong-Ashanti belong to the Bediese series of the Savannah Ochrosol. The soil is sandy loam, well drained with thin layer of organic matter with characteristics deep yellowish red colour, friable and free from stones. The pH ranges from 6.5 – 7.0. Mampong-Ashanti has a bimodal rainfall pattern with annual rainfall between 1094.4 mm and 1200 mm and monthly mean rainfall of about 91.2 mm. The major season start from March and ends in July, with a peak rainfall in June, while the minor season occurs between August and November with a peak rainfall in October. The mean daily temperature ranges from 25 ^{0}C to 37 ^{0}C.

3.2 Experimental Design and Treatments

The experimental design used was 3 x 3 factorial laid out in a Randomized Complete Block Design (RCBD) with four replications. The treatments were: (A) three varietal combinations [(i) Abontem maize + Zamzam cowpea, (ii) Opeaburo maize + Zamzam cowpea and (iii) Omankwa maize + Zamzam cowpea] and three relative times of planting [(i) maize planted 2 weeks before cowpea (M2WBC), (ii) maize planted simultaneously with cowpea (SIM) and (iii) cowpea planted 2 weeks before maize (C2WBM)]. Four sole crops of three maize varieties and the cowpea variety were added. Each plot of the maize + cowpea intercrop consisted of 3 sets of 1 row maize alternating with two (2) rows cowpea. Each row length was 5 m long. The middle one set of the intercrop served as the harvestable rows or plots. The between row spacing for the intercrops were 50 cm and the within row spacing were 40 cm for the maize and 20 cm for the cowpea. The plant spacing for the sole maize was 80 cm x 40 cm while that for the sole cowpea was 50 cm x 20 cm. Each intercrop consisted of six rows and the two middle rows served as harvestable rows or plot.

3.3 Cultural/Management Practices

3.3.1 Land Preparation and Planting

The land was prepared by the conventional method of both ploughing and harrowing. Sowing of maize and cowpea in the intercrops where the maize was planted first or the cowpea planted first and the simultaneous planting of both crops was done on 14th September 2021 and 8th April 2022. Then the maize and cowpea which were planted 2 weeks after the cowpea or maize were planted on the 29th September 2021 and 22nd April 2022. Seeds of both maize and cowpea varieties were obtained from the Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI) at Fumesua. The maize varieties were Omankwa, Opeaburo, and Abontem and the cowpea variety was Zamzam. Omankwa is one of the CSIRCRI/SARI hybrid varieties released in Ghana with white seed colour. It is an early maturing variety and has a potential yield of 5-6 tons per hectare. Opeaburo is a hybrid which is drought resistant, very big cob and high yielding. It was released in 2008. Abontem is a hybrid with a high yielding and drought tolerant variety. It has a potential yield of 5-6 tons per hectare. Zamzam is an erect type of cowpea with a white seed colour, released by of Crops Research Institute the Council for Scientific and Industrial Research (CSIR-CRI) in 2009 and it has a yield potential of 500 kg/ha.

3.3.2 Weed Control

Weeding was done manually with a hoe and 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. The weeding was to ensure that the weeds do not compete with the crops for nutrients and soil water to ensure optimum yield.

3.3.3 Pest and Disease Control

Emaster (a.i. *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 15L knapsack sprayer. Cowpea plants were sprayed with 0.3L per hectare Karate (R) (a.i. cypermethrin 10) at weekly intervals for three weeks after flowering began, to control pod foliage and insect infestation.

3.4 Data collected

3.4.1 Maize Data

3.4.1.1 Percentage Plant Establishment

Both sole and intercrop maize percentage plant establishment was determined twenty-one (21) days after the sowing of seeds by counting the number of plants that had been established within the two central rows as a percentage of the number of plants expected to be established in the two central rows.

3.4.1.2 Days to 50% Tasseling

Days to 50% tasseling for both sole and intercrop maize was estimated as the number of days after sowing when 50% of the plants in the central harvested rows had tasseled.

3.4.1.3 Days to 50% Silking

The days to 50% silking for both sole and intercrop was determined as the number of days after sowing when 50% of the plants in the two central harvested rows had produced silk.

3.4.1.4 Plant height

The height of five randomly selected and tagged plants from the two central harvested rows were measured at three (3) weeks after planting and every two weeks using a meter rule.

3.4.1.5 Number of Leaves per plant

Leaves count was carried out on the five tagged plants in the central harvested rows at two weeks intervals from the third to the tenth week after planting. The leaves of five plants were counted and the mean determined.

3.4.1.6 Number of plants harvested

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

3.4.1.7 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 a Vernier caliper after de-husking and the mean was estimated.

3.4.1.8 Cob length

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

3.4.1.9 100-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.

3.4.1.10 Grain Yield

The grain yield was measured from grains of plants harvested from the harvestable area per plot of both sole and intercrop maize. The results were then used to compute the yield per hectare.

3.4.1.11 Harvest Index

Harvest index was estimated from five selected plants at harvest from the central harvestable area. The whole plants with the cobs were weighed from the above ground biomass and the seeds from these plants shelled to obtain seed yield.

Harvest index was estimated as:

$$\text{Harvest index (HI)} = \frac{Grain\ weight}{Above\ ground\ biomass(stover + grain)}$$

3.4.2 Cowpea Data

3.4.2.1 Percentage Plant Establishment

Both sole and intercrop cowpea percentage plant establishment was determined twenty-one (21) days after the sowing of seeds by counting the number of plants that had been established within the two central rows as a percentage of the number of plants expected to be established in the two central rows.

3.4.2.2 Days to 50% Flowering

Days to 50% flowering of cowpea was determined as the number of days after sowing when 50% of the plants in the central harvestable rows had flowered.

3.4.2.3 Plant Height

The plant height was determined from the base of the plant to the apex leaf using a meter rule for both sole and intercrop of cowpea from the five randomly selected and tagged plants in the two central rows, three weeks after planting and every two weeks interval.

3.4.2.5 Number of plants harvested

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

3.4.2.6 Number of pods per plant

The total number of pods per plant for both sole and intercrop cowpea were counted from the five plants randomly selected and tagged from the two central harvestable rows and the mean was recorded.

3.4.2.7 Number of seeds per pod

The number of seeds per pod of cowpea from ten (10) randomly selected pods from the central rows of both sole and intercrop cowpea were counted and their mean determined.

3.4.2.8 100-Seed weight

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

3.4.2.9 Shelling percentage

All pods from the two central rows per plot for sole and intercrop cowpea were weighed using the Westinghouse electronic weighing scale. The pods were shelled and the grain weight determined. Shelling percentage was then computed as:

Shelling % = $\frac{Grain\ weight}{Weight\ of\ pods}\ x\ 100\%$

3.4.2.10 Grain yield

The grain yield was determined from grains from plants in the harvestable area per plot of both sole and intercrop cowpea. The results were used to compute grain yield per hectare.

3.5 Land Equivalent Ratio (Intercrop Productivity)

Land equivalent ratio (LER) 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 order 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.

3.6 Data Analysis

The data was analysed using the analysis of variance (ANOVA) with SAS statistical software package (SAS 9.6). Least Significant Difference (LSD) was used to separate the treatment means at 5% probability level.

CHAPTER FOUR: RESULTS

4.1 Maize Phenology

4.1.1 Percentage plant establishment

The percentage plant establishment of the intercrops maize ranged from 62.5 – 96.25 % for the 2021 and 68.75 – 95.63 % for the 2022 growing seasons (Table 4.1). The percentage plant establishment for the sole crops ranged from 70– 88.13 % and 70.63 – 90 % for the 2021 and 2022 growing seasons, respectively (Table 4.1). With the exception of season, percentage plant establishment did not differ among varietal, relative times of planting, variety x relative times of planting, variety x season, relative times of planting, nor variety x relative times of planting x season interactions for both seasons. However, the percentage plant establishment was slightly higher in the 2022 major season than the 2021 minor season (Table 4.1).

Table 4.1: Percentage plant establishment of maize as influenced by variety and relative times of planting (RTP) for 2021 minor and 2022 major cropping seasons

Treatment		Percentage plant establishment (%)		
Varietal combination (VC)	**Relative times of planting (RTP)**	**2021**	**2022**	**Mean**
Abontem + Zamzam	M2WBC	62.50	95.63	**79.07**
	SIM	91.88	88.13	**90.01**
	C2WBM	75.63	93.13	**84.38**
Opeaburo + Zamzam	M2WBC	88.13	73.13	**80.63**
	SIM	85.00	93.13	**89.07**
	C2WBM	96.25	68.75	**82.50**
Omankwa + Zamzam	M2WBC	79.38	90.00	**84.69**
	SIM	92.50	82.5	**87.50**
	C2WBM	76.88	89.38	**83.13**
Sole Abontem	-	70.00	89.38	**79.69**
Sole Opeaburo	-	88.13	70.63	**79.38**
Sole Omankwa	-	83.75	90.00	**86.88**

Season	*LSD(0.05)=1.76*	(p=<.0001)
Varietal combination (VC)	*LSD(0.05)=NS*	
RTP	*LSD(0.05)= NS*	
Variety x RTP	*LSD(0.05)= NS*	
Variety x Season	*LSD(0.05)= NS*	
RTP x Season	*LSD(0.05)= NS*	
Variety x RTP x Season	*LSD(0.05)= NS*	

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

4.1.2 Days to 50% tasseling

The results for the days to 50% tasseling for maize varieties Abontem, Opeaburo, and Omankwa in intercrops and sole crops are shown in Table 4.2. The days to 50 % tasseling of the intercropped maize ranged from 48 - 52 days in 2021 and 48 – 51 days in 2022. The days to 50% tasseling for the sole maize ranged from 47 – 51 days and 47 – 52 days for the 2021 and 2022 growing seasons, respectively (Table 4.2). Significant ($p \leq 0.05$) differences were observed among varietal combinations and relative times of planting (RTP). There were no significant differences between the seasons nor any of the interactions of the factors (variety x relative times of planting, variety x season, relative times of planting x season nor variety x relative times of planting x season interactions). Generally, Omankwa intercropped with Zamzam tasseled late (52 days) compared with Abontem and Opeaburo (48 days). Similarly, maize planted 2 weeks after cowpea also tasseled later than when maize was planted 2 weeks before cowpea or simultaneously.

4.1.3 Days to 50% silking

The results for the days to 50% silking for maize varieties (Abontem, Opeaburo, and Omankwa) intercrops and sole crops are shown in Table 4.2. Similar to days to tasselling, the days to 50% silking for maize component crops differed among varietal combinations and relative times of planting. There were no differences in seasons nor any of the factor interactions. Omankwa intercropped with Zamzam silked late (56.7 days) than Abontem (53 days) and Opeaburo (53 days). Maize planted 2 weeks before cowpea generally silked later compared to maize planted simultaneously or 2 weeks after cowpea.

Table 4.2: Days to 50% tasseling and days to 50% silking of maize as influenced by variety and relative times of planting (RTP) for 2021 minor and 2022 major cropping seasons.

Treatment		**Days to 50% tasseling**			**Days to 50% silking**		
Varietal combination (VC)	**Relative times of planting (RTP)**	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**
Abontem + Zamzam	M2WBC	48	51	**49.50**	53	57	**55.00**
	SIM	48	49	**48.50**	53	55	**54.00**
	C2WBM	49	49	**49.00**	53	55	**54.00**
Opeaburo + Zamzam	M2WBC	49	49	**49.00**	53	54	**53.50**
	SIM	48	49	**48.50**	52	53	**52.50**
	C2WBM	48	49	**48.50**	53	55	**54.00**
Omankwa + Zamzam	M2WBC	52	49	**50.50**	57	55	**56.00**
	SIM	52	48	**50.00**	56	55	**55.50**
	C2WBM	52	48	**50.00**	57	53	**55.00**
Sole Abontem	-	48	52	**50.00**	53	56	**54.50**
Sole Opeaburo	-	47	48	**47.50**	54	55	**54.50**
Sole Omankwa	-	51	47	**49.00**	57	53	**55.00**

Season	*LSD(0.05)=NS*		*LSD(0.05)=NS*	
Varietal combination (VC)	*LSD(0.05)=0.74*	(p=<.0001)	*LSD(0.05)=1.09*	(p=<.0001)
RTP	*LSD(0.05)=0.74*	(p=0.0032)	*LSD(0.05)=1.09*	(p=0.0127)
Variety x RTP	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
Variety x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
RTP x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
Variety x RTP x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

4.2 Maize growth

4.2.1 Plant height of maize

Figures 4.1a and 4.1b show result of plant height of maize varieties and their intercrops from 21 DAP to 77 DAP for the growing seasons. The plant height increased throughout the entire period from 21 DAP to 77 DAP for both seasons. Generally, Opeaburo + Zamzam + cowpea planted 2 weeks before maize showed the highest increase in height for the 2021 growing season with Omankwa + Zamzam where maize was planted 2 weeks before cowpea (Figure 4.1a). For the 2022 growing season, sole Opeaburo had the highest increased in height followed by Omankwa + Zamzam where maize was planted 2 weeks before the cowpea (Figure 4.1b).

4.2.2 Number of leaves per plant of maize

Figures 4.2a and 4.2b show result of the number of leaves per plant of maize varieties and their intercrops from 21 DAP to 63 DAP for the growing seasons. The number of leaves per plant increased throughout the entire period from 21 DAP to 63 DAP for both seasons. There were no significant difference recorded among the treatments means for both growing seasons. Despite the non-significant difference, the number of leaves per plant was generally higher in Sole Opeaburo compared to the other maize varieties and their intercrops.

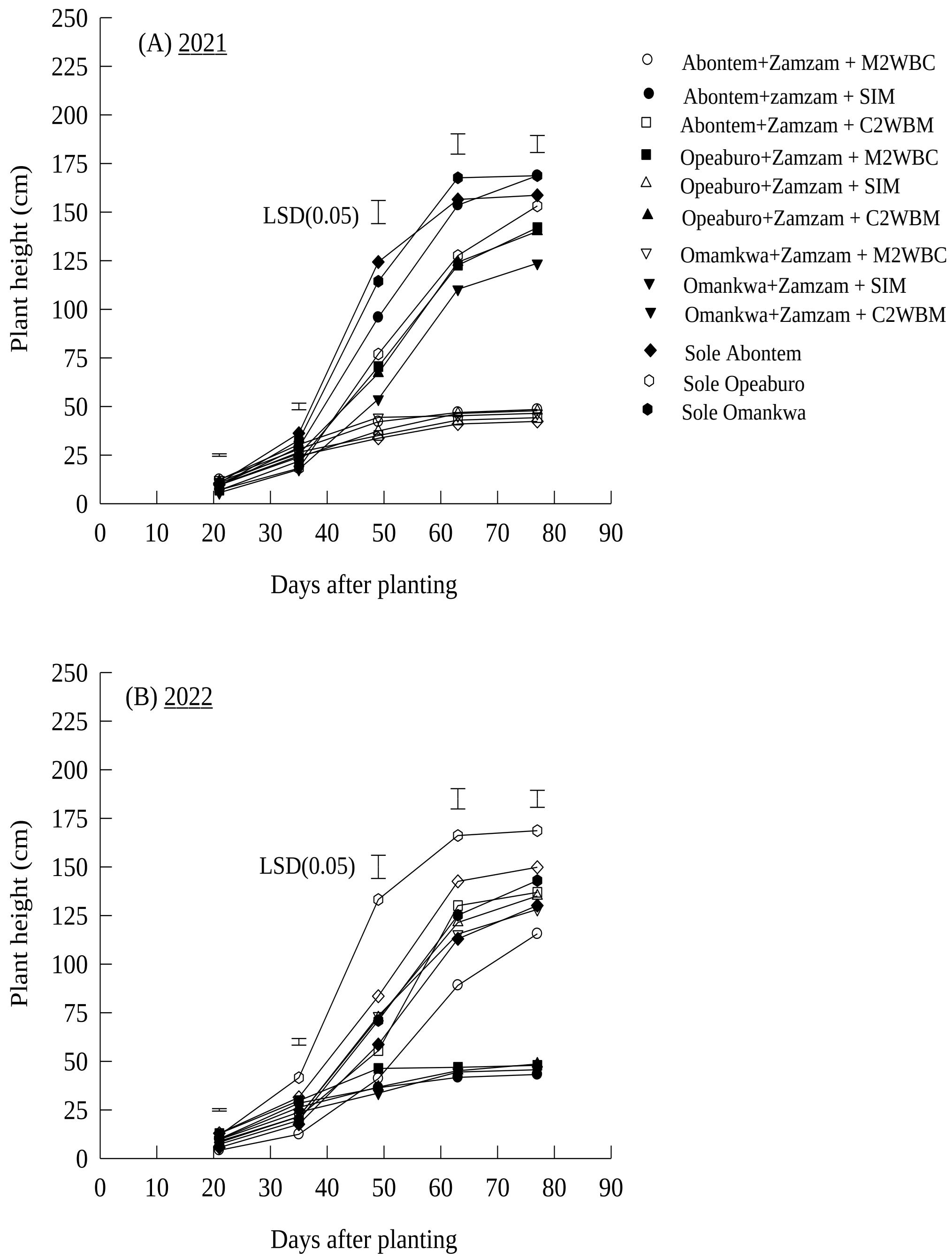

Fig. 4.1. Plant height of maize as influenced by varietal combination and relative times of planting in maize + cowpea intercrop at Mampong during 2021 and 2022 growing seasons.

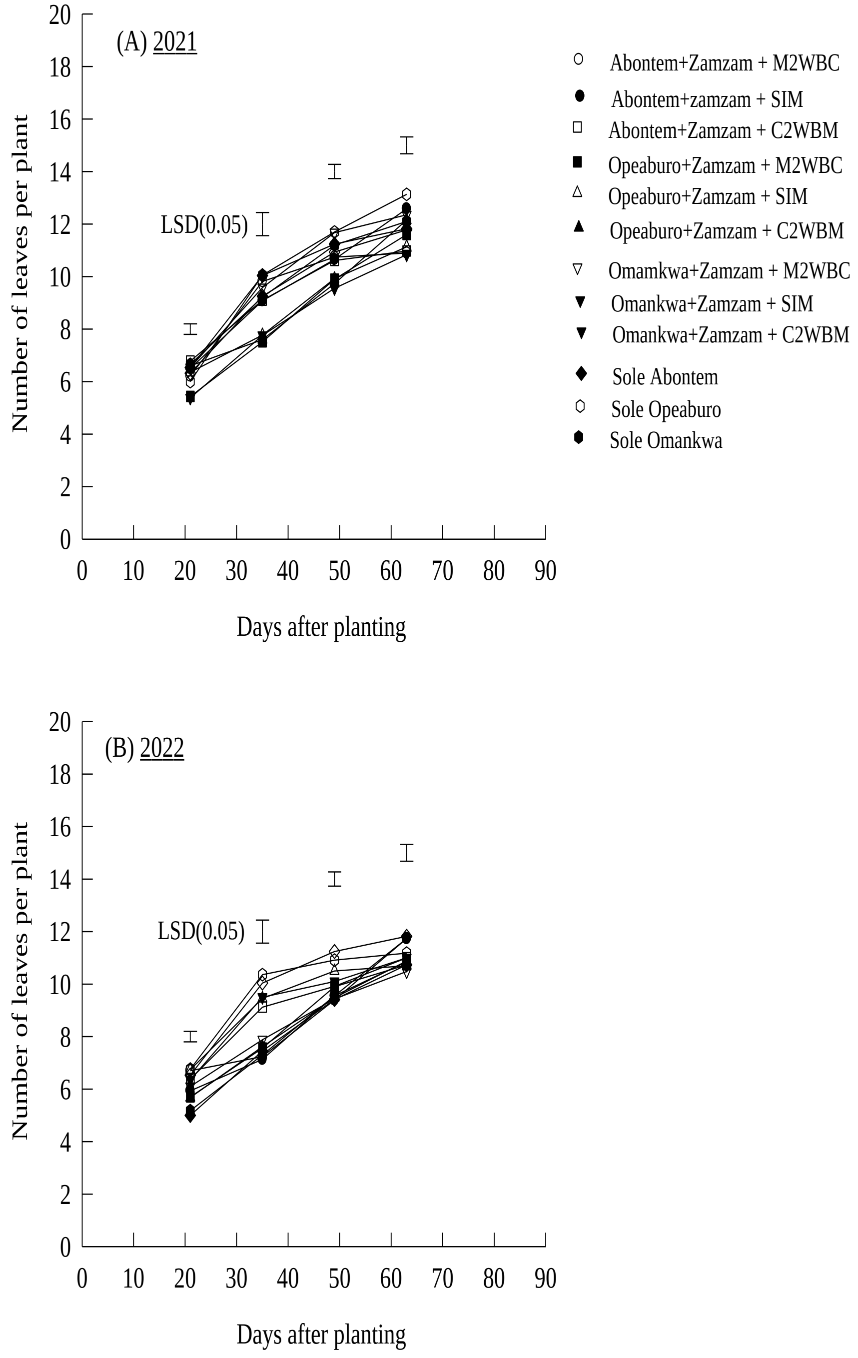

Fig. 4.2. Number of leaves per plant of maize as influenced by varietal combination and relative times of planting in maize + cowpea intercrop at Mampong during 2021 and 2022 growing seasons.

4.3 Yield and yield components of maize

4.3.1 Number of plants harvested

Table 4.3 shows results on number of plants harvested for maize for 2021 minor and 2022 major cropping seasons. The number of plants harvested for Abontem intercropped with cowpea ranged from 19.50 – 39.50, Opeaburo intercropped with cowpea ranged from 22.25 – 37.00, Omankwa intercropped with cowpea ranged from 20.50 – 36.25, sole Abontem ranged from 27.25 – 35.00, sole Opeaburo ranged from 21.75 – 34.00, whereas sole Omankwa ranged from 29.75 – 36.00 for both seasons. The highest number of plants harvested (39.00) for maize for the 2021 minor cropping season was recorded by Opeaburon maize planted 2 weeks after cowpea whereas for the 2022 major cropping season, Abontem maize planted 2 weeks before cowpea had the highest number of plants harvested (39.50) (Table 4.3).

The least number of plants harvested (19.50) for maize for the 2021 minor season was recorded by Abontem maize planted 2 weeks after cowpea while for the 2022 major cropping season, the least number of plants harvested (20.50) was recorded by Omankwa intercropped with cowpea at relative times of planting 2 (RTP2). Significant ($P \leq 0.05$) differences existed between the treatment means of the variety and season. Meanwhile, relative times of planting (RTP), season x variety interaction, season x relative times of planting interaction, variety x relative times of planting (RTP) interaction nor season x variety x relative times of planting (RTP) did not differ significantly between treatment means for 2021 minor and 2022 major cropping seasons. Likewise for contrast, no significant difference was observed between the treatment means for both cropping seasons. Generally, the 2022 major cropping season recorded the highest number of plants harvested than 2021 minor season.

Table 4.3: Number of plants harvested of maize as influenced by variety and relative times of planting (RTP) for 2021 minor and 2022 major cropping seasons.

Treatment		Number of plants harvested per plot		
Varietal combination (VC)	**Relative times of planting (RTP)**	**2021**	**2022**	**Mean**
Abontem + Zamzam	M2WBC	19.75	39.50	**29.63**
	SIM	37.00	29.75	**33.38**
	C2WBM	19.50	37.25	**28.38**
Opeaburo + Zamzam	M2WBC	34.50	24.00	**29.25**
	SIM	22.25	37.00	**29.63**
	C2WBM	39.00	24.75	**31.88**
Omankwa + Zamzam	M2WBC	26.50	35.25	**30.88**
	SIM	36.25	20.50	**28.38**
	C2WBM	26.25	34.75	**30.50**
Sole Abontem	-	27.25	35.00	**31.13**
Sole Opeaburo	-	34.00	21.75	**27.88**
Sole Omankwa	-	29.75	36.00	**32.88**
Season		*LSD(0.05)=1.96*	(p=<.0001)	
Varietal combination (VC)		*LSD(0.05)=1.70*	(p=0.0043)	
RTP		*LSD(0.05)= NS*		
Variety x RTP		*LSD(0.05)= NS*		
Variety x Season		*LSD(0.05)= NS*		
RTP x Season		*LSD(0.05)= NS*		
Variety x RTP x Season		*LSD(0.05)= NS*		

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

4.3.2 Cob diameter

Results in Table 4.4 shows cob diameter for maize for 2021 minor and 2022 major cropping seasons. The cob diameter for Abontem intercropped with cowpea ranged from 35.10 – 47.90 cm, Opeaburo intercropped with cowpea ranged from 31.13 – 43.10 cm, Omankwa intercropped with cowpea ranged from 33.00 – 44.55 cm, sole Abontem ranged from 42.95 – 45.23 cm, sole Opeaburo ranged from 45.80 – 54.65 cm, whereas sole Omankwa ranged from 44.38 – 56.33 cm for both seasons. The widest cob diameter (56.33 cm) for maize for the 2021 minor cropping season was recorded sole Omankwa whereas for the 2022 major cropping season, sole Opeaburo had the widest cob diameter (54.65). The smallest cob diameter (31.13 cm) for maize for the 2021 minor season was recorded by Opeaburo maize and cowpea planted simultaneous while for the 2022 major cropping season, the smallest cob diameter (35.10 cm) was recorded by Abontem maize planted 2 weeks before. Significant ($P \leq 0.05$) differences existed between the treatment means of the relative times of planting (RTP), season, and relative times of planting (RTP) x season interaction. Meanwhile, season x variety interaction, season x relative times of planting interaction, variety x relative times of planting (RTP) interaction nor season x variety x relative times of planting (RTP) did not differ significantly between treatment means for 2021 minor and 2022 major cropping seasons. For contrast, no significant difference was observed between the treatment means for both cropping seasons.

4.3.3 Cob length

Table 4.4 shows results of cob length for maize for 2021 minor and 2022 major cropping seasons. The cob length for Abontem intercropped with cowpea ranged from 11.77 – 29.25 cm, Opeaburo intercropped with cowpea ranged from 9.26 – 14.95 cm, Omankwa intercropped with cowpea ranged from 11.26 – 15.33 cm, sole Abontem ranged from 14.61 – 15.10 cm, sole Opeaburo ranged from 14.19 – 17.10 cm, whereas sole Omankwa ranged from 13.82 – 15.18 cm for both seasons. The longest cob (17.10 cm) for maize for the 2021 minor cropping season was recorded sole Opeaburo whereas for the 2022 major cropping season, sole Omankwa had the longest cob length (15.18 cm). The shortest cob length (9.26 cm) for maize for the 2021 minor season was recorded by Opeaburo maize and cowpea planted simultaneous while for the 2022 major cropping season, the least cob diameter (11.77 cm) was recorded by Abontem maize and cowpea planted simultaneous. No significant ($P > 0.05$) differences existed between the treatment means of variety, relative times of planting (RTP), season, relative times of planting (RTP) x season interaction, season x variety interaction, season x relative times of planting interaction, variety x relative times of planting (RTP) interaction nor season x variety x relative times of planting (RTP) did not differ significantly between treatment means for 2021 minor and 2022 major cropping seasons. For contrast also, no significant difference was observed between the treatment means for both cropping seasons.

Table 4.4: Cob diameter and cob length of maize as influenced by variety and relative times of planting (RTP) for 2021 minor and 2022 major cropping seasons.

Treatment		**Cob diameter (cm)**			**Cob length (cm)**		
Varietal combination (VC)	**Relative times of planting (RTP)**	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**
Abontem + Zamzam	M2WBC	41.53	43.25	**42.39**	13.28	29.25	**21.27**
	SIM	47.90	35.10	**41.50**	16.93	11.77	**14.35**
	C2WBM	42.50	42.38	**42.44**	14.45	14.80	**14.63**
Opeaburo + Zamzam	M2WBC	42.48	42.33	**42.41**	14.58	14.75	**14.67**
	SIM	31.13	43.00	**37.07**	9.26	31.75	**20.51**
	C2WBM	43.10	39.43	**41.27**	14.95	14.93	**14.94**
Omankwa + Zamzam	M2WBC	43.68	42.30	**42.99**	14.58	15.05	**14.82**
	SIM	44.55	33.00	**38.78**	15.30	11.26	**13.28**
	C2WBM	42.48	41.65	**42.07**	12.40	15.33	**13.87**
Sole Abontem	-	45.23	42.95	**44.09**	14.61	15.10	**14.86**
Sole Opeaburo	-	45.80	54.65	**50.23**	17.10	14.19	**15.65**
Sole Omankwa	-	56.33	44.38	**50.36**	13.82	15.18	**14.50**

Season	*LSD(0.05)=1.26*	(p=<.0001)	*LSD(0.05)=4.93*	(p=0.0243)
Varietal combination (VC)	*LSD(0.05)=NS*		*LSD(0.05)=NS*	
RTP	*LSD(0.05)= 1.54*	(p=<.0001)	*LSD(0.05)= NS*	
Variety x RTP	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
Variety x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
RTP x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
Variety x RTP x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

4.3.4 100-seed weight

Table 4.5 shows results of 100-seed weight for maize in 2021 minor and 2022 major cropping seasons. The 100-seed weight for Abontem intercropped with cowpea ranged from 26.40 – 38.50 g, Opeaburo intercropped with cowpea ranged from 27.74 – 33.75 g, Omankwa intercropped with cowpea ranged from 26.85 – 33.50 g, sole Abontem ranged from 28.99 – 32.50 g, sole Opeaburo ranged from 29.71 – 38.00 g, and sole Omankwa ranged from 28.05 – 33.50 g for both seasons (Table 4.5). Abontem maize and cowpea planted simultaneous had the highest 100-seed weight (38.50 g) for the 2021 minor season followed by sole Opeaburo (38.00 g) whereas for the 2022 major cropping season, sole Omankwa had the greatest 100-seed weight (33.50) followed by Opeaburo maize planted simultaneous with 100-seed weight of 32.50 g for cowpea (Table 4.5).

The least 100-seed weight (26.40 g) for the 2021 minor season was recorded by Abontem maize planted 2 weeks before cowpea while for the 2022 major cropping season, the least 100-seed weight (26.50 g) was recorded by Abontem intercropped with cowpea at relative times of planting 2 (RTP2). Significant ($P \leq 0.05$) differences existed between the treatment means variety x relative times of planting (RTP) interaction. For season, variety, relative times of planting (RTP), seasons x variety interaction season x variety interaction, season x relative times of planting interaction, nor season x variety x relative times of planting (RTP) did not differ significantly between treatment means for 2021 minor and 2022 major cropping seasons. For contrast, no significant difference was observed between the treatment means for both cropping seasons (Table 4.5).

4.3.5 Grain yield

The results for grain yield of maize as influenced by variety and relative times of planting (RTP) for 2021 minor and 2022 major cropping seasons are shown in Table 4.5 below. Grain yield ranged from 0.50 – 2.52 t ha^{-1} for Abontem intercropped with cowpea, 0.24 – 2.04 t ha^{-1} for Opeaburo intercropped with cowpea, 0.26 – 4.16 t ha^{-1} for Omankwa intercropped with cowpea, for sole Abontem ranged from 2.69 – 2.87 t ha^{-1}, sole Opeaburo ranged from 2.06 – 3.46 t ha^{-1}, and sole Omankwa ranged 2.94 – 3.22 t ha^{-1}. The greatest grain yield (4.16 t ha^{-1}) for the 2021 minor season was recorded Omankwa maize planted 2 weeks after cowpea whereas for the 2022 major cropping season, sole Omankwa recorded the highest grain yield (2.94 t ha^{-1}). The least grain yield (0.24 t ha^{-1}) for the 2021 minor season was recorded by Opeaburo maize and cowpea planted 2 weeks before cowpea while for the 2022 major cropping season, the least grain yield (0.26 t ha^{-1}) was recorded by Omankwa intercropped with cowpea at relative times of planting 2 (RTP2). No significant ($P>0.05$) differences existed between the treatment means of the seasons, variety, relative times of planting (RTP), season x variety interaction, season x relative times of planting interaction, variety x relative times of planting (RTP) interaction nor season x variety x relative times of planting (RTP) did not differ significantly between treatment means for 2021 minor and 2022 major cropping seasons.

Table 4.5: 100-seed weight and grain yield of maize as influenced by variety and relative times of planting (RTP) for 2021 minor and 2022 major cropping seasons.

Treatment		100-seed weight (g)			Grain yield (t ha^{-1})		
Varietal combination (VC)	**Relative times of planting (RTP)**	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**
Abontem + Zamzam	M2WBC	26.40	28.00	**27.20**	1.76	2.89	**2.33**
	SIM	38.50	26.50	**32.50**	3.52	1.5	**2.51**
	C2WBM	32.09	30.75	**31.42**	2.14	3.09	**2.62**
Opeaburo + Zamzam	M2WBC	33.75	27.46	**30.61**	2.79	2.64	**2.72**
	SIM	29.75	32.50	**31.13**	1.24	2.88	**2.06**
	C2WBM	33.25	27.74	**30.50**	3.04	1.9	**2.47**
Omankwa + Zamzam	M2WBC	26.85	29.00	**27.93**	3.28	2.74	**3.01**
	SIM	33.50	27.50	**30.50**	3.09	1.26	**2.18**
	C2WBM	30.25	31.00	**30.63**	5.16	2.75	**3.96**
Sole Abontem	-	28.99	32.50	**30.75**	3.69	3.87	**3.78**
Sole Opeaburo	-	38.00	29.71	**33.86**	4.46	3.06	**3.76**
Sole Omankwa	-	28.05	33.50	**30.78**	4.22	3.94	**4.08**

Season	*LSD(0.05)=2.38*	(p=0.0015)	*LSD(0.05)=0.68*	(p=0.0591)
Varietal combination (VC)	*LSD(0.05)=NS*		*LSD(0.05)=NS*	
RTP	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
Variety x RTP	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
Variety x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
RTP x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
Variety x RTP x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

4.3.6 Harvest index

Results in Table 4.6 shows harvest index of maize as influenced by variety and relative times of planting (RTP) for 2021 minor and 2022 major cropping seasons. Harvest index ranged from 0.25 – 1.36 for Abontem intercropped with cowpea, 0.28 – 0.44 for Opeaburo intercropped with cowpea, 0.26 – 0.43 for Omankwa intercropped with cowpea, for sole Abontem ranged from 0.32 – 0.38, sole Opeaburo ranged from 0.27 – 0.42, and sole Omankwa ranged 0.28 – 0.39. The highest harvest index (0.49) for the 2021 minor season was recorded by Abontem intercropped with cowpea at relative times of planting 2 (RTP2) whereas for the 2022 major cropping season, Abontem maize and cowpea planted simultaneous recorded the highest harvest index (1.36). The least grain yield (0.25) for the 2021 minor season was recorded by Abontem maize planted 2 weeks after cowpea while for the 2022 major cropping season, the least grain yield (0.26) was recorded by Omankwa intercropped with cowpea at relative times of planting 1 (RTP1). Significant ($P \leq 0.05$) differences existed between the treatment means of relative times of planting (RTP), season x variety interaction, season x relative times of planting interaction, variety x relative times of planting (RTP) interaction nor season x variety x relative times of planting (RTP) interactions, except for season and variety which did not differ significantly between treatment means for 2021 minor and 2022 major cropping seasons.

Table 4.6: Harvest index of maize as influenced by variety and relative times of planting (RTP) for 2021 minor and 2022 major cropping seasons.

Treatment		**Harvest index**		
Varietal combination (VC)	**Relative times of planting (RTP)**	**2021**	**2022**	**Mean**
Abontem + Zamzam	M2WBC	0.29	0.34	**0.32**
	SIM	0.49	0.36	**0.93**
	C2WBM	0.25	0.40	**0.33**
Opeaburo + Zamzam	M2WBC	0.44	0.34	**0.39**
	SIM	0.40	0.41	**0.41**
	C2WBM	0.44	0.28	**0.36**
Omankwa + Zamzam	M2WBC	0.30	0.26	**0.28**
	SIM	0.38	0.77	**0.58**
	C2WBM	0.26	0.43	**0.35**
Sole Abontem	-	0.32	0.38	**0.35**
Sole Opeaburo	-	0.42	0.27	**0.35**
Sole Omankwa	-	0.28	0.39	**0.34**
Season		*LSD(0.05)=NS*		
Varietal combination (VC)		*LSD(0.05)=NS*		
RTP		*LSD(0.05)= 0.12*	(p=<.0001)	
Variety x RTP		*LSD(0.05)= NS*		
Variety x Season		*LSD(0.05)= NS*		
RTP x Season		*LSD(0.05)= NS*		
Variety x RTP x Season		*LSD(0.05)= NS*		

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

4.4 Cowpea Phenology

4.4.1 Percentage plant establishment

Table 4.7 shows the results of the percentage plant establishment of cowpea. The Percentage plant establishment did not differ among varietal combinations, relative times of planting nor varietal combination x relative times of planting interactions for both seasons. However, the percentage plant establishment was significant in seasons and it was slightly higher in the 2022 major season than the 2021 minor season. The percentage plant establishment of cowpea ranged from 65.34 – 69.89 % and 54.01 – 88.64 % for the minor and major seasons respectively, among the intercrops. The sole cowpea had 66.66% and

79.26 % (Table 4.7). Sole cowpea recorded the highest percentage plant establishment for the 2021 period. However, cowpea planted 2 weeks before Opeaburo intercropped had the lowest percentage plant establishment for the 2021 minor cropping season. For the 2022 major cropping season, cowpea planted 2 weeks after Opeaburo had the greatest percentage plant establishment.

Table 4.7: Percentage plant establishment of cowpea as influenced by variety and relative times of planting (RTP) for 2021 minor and 2022 major cropping seasons.

Treatment		**Percentage plant establishment (%)**		
Varietal combination (VC)	**Relative times of planting (RTP)**	**2021**	**2022**	**Mean**
Omankwa + Zamzam	M2WBC	67.61	54.01	**60.81**
	SIM	67.89	70.74	**69.32**
	C2WBM	66.30	84.94	**75.62**
Opeaburo + Zamzam	M2WBC	68.46	88.64	**78.55**
	SIM	66.47	79.54	**73.01**
	C2WBM	65.34	86.36	**75.85**
Abontem + Zamzam	M2WBC	65.62	67.61	**66.62**
	SIM	68.18	84.94	**76.56**
	C2WBM	69.89	87.50	**78.70**
Sole cowpea	-	79.26	66.66	**72.96**
Season		*LSD(0.05)=6.08*		(p=<.0001)
Varietal combination (VC)		*LSD(0.05)=NS*		
RTP		*LSD(0.05)= NS*		
Variety x RTP		*LSD(0.05)= NS*		
Variety x Season		*LSD(0.05)= NS*		
RTP x Season		*LSD(0.05)= NS*		
Variety x RTP x Season		*LSD(0.05)= NS*		

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

4.4.2 Days to 50% flowering

The results of days to 50% flowering of cowpea for 2021 minor and 2022 major cropping seasons are shown in Table 4.8. Days to 50% flowering for cowpea intercropped with Abontem ranged from 41.00 – 42.25%, cowpea intercropped with Opeaburo ranged from

41.75 – 42.50, cowpea intercropped with Omankwa ranged from 40.50 – 42.50%. The days to 50% flowering for sole cowpea ranged from 40.75 – 41.50% for both cropping seasons. Days to 50% flowering was similar for both seasons. There were no significant interactions for the days to 50% flowering. There were however, significant effects of varietal combination and relative times of plangting main effects. Cowpea planted with Abontem and Omankwa flowered earlier than that intercropped with Opeaburo. Cowpea planted 2 weeks before maize flowered later than cowpea planted 2 weeks after maize and cowpea and maize planted simultaneously.

4.4.3 Days to 50% podding

Results in Table 4.2 shows days to 50% podding of cowpea for the 2021 minor and 2022 major cropping seasons. Days to 50% podding for cowpea intercropped with Abontem ranged from 45 - 46, cowpea intercropped Opeaburo ranged from 47 – 48%, while intercropped with Omankwa ranged from 46 – 48%, and for the sole cowpea, it ranged from 46 - 47 for both cropping seasons. Days to 50% podding was similar for both seasons. Except for varietal combination effects on days to 50% podding of cowpea, no significance (P>0.05) differences were observed in season, relative times of planting (RTP), season x variety interaction, season x relative times of planting (RTP), variety x relative times of planting (RTP) interaction nor season x variety x relative times of planting (RTP) interaction.

Table 4.8: Days to 50% flowering and days to 50% podding of cowpea as influenced by variety and relative times of planting (RTP) for 2021 minor and 2022 major cropping seasons.

Treatment		**Days to 50% flowering**			**Days to 50% podding**		
Varietal combination (VC)	**Relative times of planting (RTP)**	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**
Abontem + Zamzam	M2WBC	41.75	42.25	**42.00**	45.75	45.50	**45.63**
	SIM	41.75	41.00	**41.38**	45.25	46.25	**45.75**
	C2WBM	42.00	41.50	**41.75**	45.50	45.75	**45.63**
Opeaburo + Zamzam	M2WBC	42.50	41.75	**42.13**	47.50	46.00	**46.75**
	SIM	42.50	42.50	**42.50**	46.75	47.50	**47.13**
	C2WBM	42.50	42.50	**42.50**	47.50	46.75	**47.13**
Omankwa + Zamzam	M2WBC	40.50	42.50	**41.50**	46.00	47.50	**46.75**
	SIM	41.75	40.75	**41.25**	47.25	46.00	**46.63**
	C2WBM	42.50	41.75	**42.13**	47.50	47.25	**47.38**
Sole Cowpea	-	41.50	40.75	**41.13**	47.25	46.25	**46.75**
Season	*LSD(0.05)=NS*				*LSD(0.05)=NS*		
Varietal combination (VC)	*LSD(0.05)=0.51*		(p=0.0004)		*LSD(0.05)=0.74*		(p=0.0004)
RTP	*LSD(0.05)= 0.51*		(p=0.0350)		*LSD(0.05)= NS*		
Variety x RTP	*LSD(0.05)= NS*				*LSD(0.05)= NS*		
Variety x Season	*LSD(0.05)= NS*				*LSD(0.05)= NS*		
RTP x Season	*LSD(0.05)= NS*				*LSD(0.05)= NS*		
Variety x RTP x Season	*LSD(0.05)= NS*				*LSD(0.05)= NS*		

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

4.5 Cowpea Growth

4.5.1 Plant height

Figures 4.3a and 4.3b show result of the plant height of cowpea and their intercrops from 21 DAP to 63 DAP for the growing seasons. The height of the cowpea increased throughout the entire period from 21 DAP to 63 DAP for both seasons. There were significant difference recorded among the treatments means for the 2021 growing season. However, for the 2022 growing season, no significant difference was observed among the treatment means. Cowpea planted 2 weeks before maize had the tallest height in the 2021 growing period compared with the other treatments. For the 2022 growing season, Cowpea and Abontem maize planted simultaneously had the tallest height compared with the other intercrops and the sole cowpea.

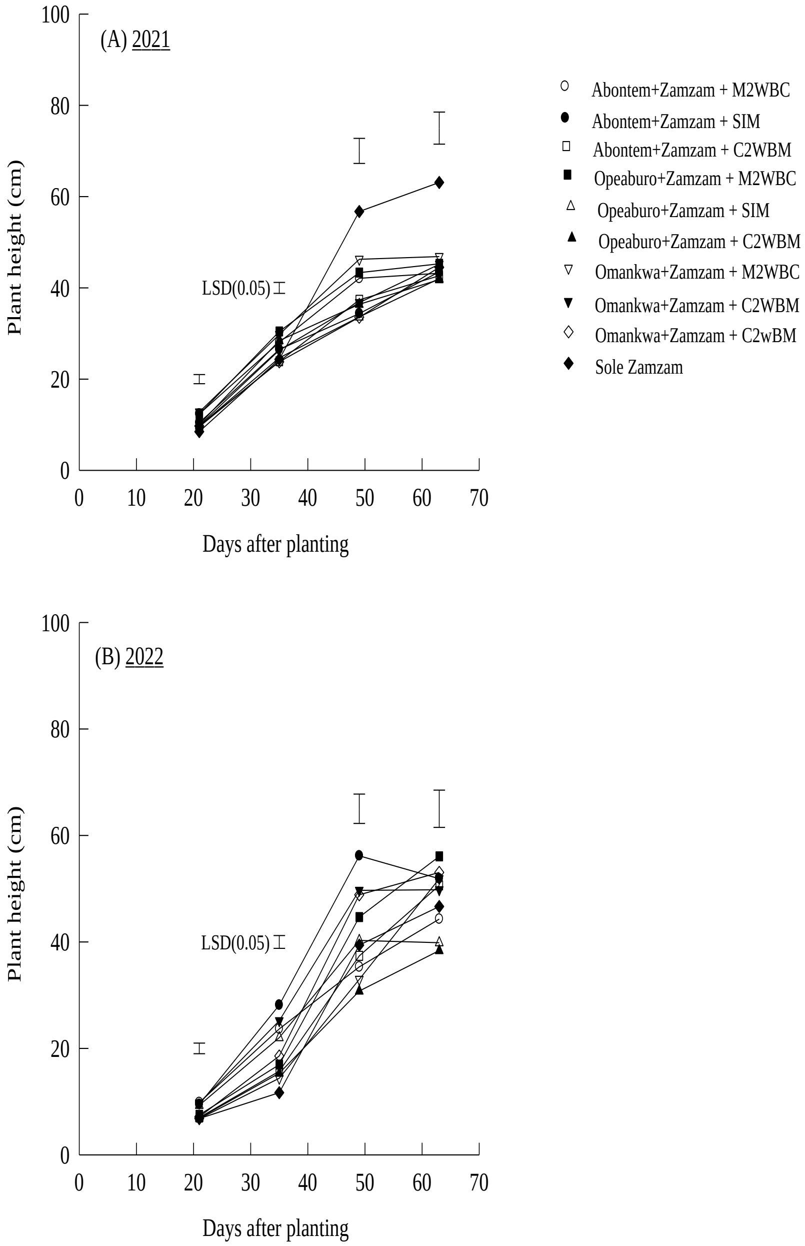

Fig. 4.3. Plant height of cowpea as influenced by varietal combination and relative times of planting in maize + cowpea intercrop at Mampong during 2021 and 2022 growing seasons.

4.5.2 Dry matter

Results in Tables 4.9 and 4.10 show dry matter accumulation of cowpea and its intercrops from 35 DAP to 63 DAP for 2021 minor cropping season and 2022 major season. Generally, in the 2021 minor season, the sole cowpea showed the highest trend in dry matter accumulation followed by Abontem planted 2 weeks before cowpea. The cowpea dry matter accumulation with cowpea intercropped with Opeaburo and Omankwa were similar cowpea at relative times of planting 1 (RTP1) for the season of 2021.

Table 4.9: Dry matter of cowpea as influenced by variety and relative times of planting (RTP) for 2021 minor cropping seasons.

Treatment		**Dry matter (g)**		
		Days after planting (DAP)		
Varietal combination (VC)	**Relative times of planting (RTP)**	**35**	**63**	**Mean**
Abontem + Zamzam	M2WBC	46.67	466.66	**256.67**
	SIM	38.11	366.12	**202.12**
	C2WBM	30.69	471.22	**250.96**
Opeaburo + Zamzam	M2WBC	18.80	343.61	**181.21**
	SIM	28.57	441.27	**234.92**
	C2WBM	28.81	321.47	**175.14**
Omankwa + Zamzam	M2WBC	21.66	330.09	**175.88**
	SIM	26.08	481.57	**253.83**
	C2WBM	30.75	458.76	**244.76**
Sole Cowpea	-	250.89	979.20	**615.05**
LSD ($p \leq 0.05$)		**41.35**	**216.12**	

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

Table 4.10: Dry matter of cowpea as influenced by variety and relative times of planting (RTP) for 2022 major cropping seasons.

Treatment		Dry matter		
		Days after planting (DAP)		
Varietal combination (VC)	**Relative times of planting (RTP)**	**35**	**63**	**Mean**
Abontem + Zamzam	M2WBC	112.54	495.60	**304.07**
	SIM	75.61	223.34	**149.48**
	C2WBM	55.23	972.38	**513.81**
Opeaburo + Zamzam	M2WBC	172.39	1005.03	**588.71**
	SIM	66.83	246.76	**156.80**
	C2WBM	223.04	1253.27	**738.16**
Omankwa + Zamzam	M2WBC	177.10	776.18	**476.64**
	SIM	29.25	366.94	**198.10**
	C2WBM	88.83	454.69	**271.76**
Sole Cowpea	-	174.53	1834.36	**1004.45**
LSD ($p \leq 0.05$		**41.35**	**216.12**	**128.74**

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

4.6 Yield and yield components of cowpea

4.6.1 Number of plants harvested

Table 4.11 shows results on number of plants harvested for cowpea for 2021 minor and 2022 major cropping seasons. The number of cowpea plants harvested for Abontem intercropped with cowpea ranged from 46.00 – 72.25, cowpea intercropped with opeaburo ranged from 48.75 – 79.5, Omankwa intercropped with cowpea ranged from 45.75 – 73.75, whereas the sole cowpea ranged from 59.50 – 73.00 for both seasons. Sole cowpea recorded the highest number of plants harvested (73.00) for cowpea for the 2021 minor cropping season whereas for the 2022 major cropping season, Opeaburo planted 2 weeks before cowpea had the highest number of cowpea plants harvested (79.50) in the two seasons (Table 4.11). The least number of plants harvested (48.00) for cowpea for the 2021 minor season was recorded by Abontem intercropped with cowpea when Abontem was planted 2 weeks before cowpea. Variety, relative times of planting (RTP), season x variety interaction, season x relative times of planting interaction, variety x relative times of planting (RTP) interaction nor season x variety x relative times of planting (RTP) did not differ significantly between treatment means for 2021 minor and 2022 major cropping seasons.

4.6.2 Number of pods per plant

Table 4.11 shows results on number of pods per plant of cowpea for 2021 minor and 2022 major cropping seasons. Significant ($P \leq 0.05$) differences existed between the treatment means of the seasons and relative times of planting (RTP).Variety, season x variety interaction, season x relative times of planting interaction, variety x relative times of planting (RTP) interaction nor season x variety x relative times of planting (RTP) did not differ significantly between treatment means for 2021 minor and 2022 major cropping seasons. The number of pods per plant for Abontem intercropped with cowpea ranged from 5.98 – 14.35, Opeaburo intercropped with cowpea ranged from 5.25 – 16.50, Omankwa intercropped with cowpea ranged from 4.28 – 18.85, whereas the sole cowpea ranged from 14.45 – 21.85 for both seasons. Sole cowpea recorded the highest number of pods per plant (14.45 and 21.85) for the 2021 minor cropping season and the 2022 major cropping season, respectively. Among the intercrops cowpea planted 2 weeks before Omankwa had the highest number of pods per plant for both seasons (Table 4.11). The least number of pods per plant (4.28) for cowpea for the 2021 minor season was recorded by Omankwa planted 2 weeks before cowpea, while for the 2022 major cropping season, the least number of pods per plant (9.88) was recorded by Abontem planted 2 weeks before cowpea.

Table 4.11: Number of plants harvested and number of pods per plant of cowpea as influenced by variety and relative times of planting (RTP) for 2021 minor and 2022 major cropping seasons.

Treatment		Number of plants harvested per plot			Number of pods per plant		
Varietal combination (VC)	**Relative times of planting (RTP)**	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**
Abontem + Zamzam	M2WBC	52.75	46.00	**49.38**	5.98	9.88	**7.93**
	SIM	59.25	55.75	**57.50**	9.58	11.60	**10.59**
	C2WBM	48.00	72.25	**60.13**	9.25	14.35	**11.80**
Opeaburo + Zamzam	M2WBC	48.75	79.50	**64.13**	5.25	16.50	**10.88**
	SIM	55.75	69.50	**62.63**	7.85	11.00	**9.43**
	C2WBM	57.50	75.50	**66.50**	9.36	10.70	**10.03**
Omankwa + Zamzam	M2WBC	45.75	55.25	**50.50**	4.28	15.25	**9.77**
	SIM	58.75	73.75	**66.25**	9.33	13.35	**11.34**
	C2WBM	59.25	69.25	**64.25**	10.22	18.85	**14.54**
Sole Cowpea	-	73.00	59.50	**66.25**	14.45	21.85	**18.15**

Season	*LSD(0.05)=5.79*	(p=<.0001)	*LSD(0.05)=2.05*	(p=<.0001)
Varietal combination (VC)	*LSD(0.05)=NS*		*LSD(0.05)=NS*	
RTP	*LSD(0.05)= NS*		*LSD(0.05)= 2.51*	(p=0.0062)
Variety x RTP	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
Variety x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
RTP x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
Variety x RTP x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

4.6.3 Number of seeds per pod

Results in Table 4.12 shows the number of seeds per pod of cowpea for 2021 minor and 2022 major cropping seasons. The number of seeds per pod for Abontem intercropped with cowpea ranged from 9.65 – 12.39, Opeaburo intercropped with cowpea ranged from 8.65 – 11.5, Omankwa intercropped with cowpea ranged from 8.68 – 11.13, whereas the sole cowpea ranged from 10.9 – 11.53 for both seasons (Table 4.12). Abontem maize planted 2 weeks before cowpea had the highest number of seeds per pod (11.83) for cowpea for the 2021 minor cropping season whereas for the 2022 major cropping season, Abontem maize and cowpea planted simultaneous had the highest number of seeds per pod (11.60) for cowpea (Table 4.12). The least number of seeds per pod (8.65) for the 2021 minor season was recorded by cowpea and Opeaburo maize planted simultaneous while for the 2022 major cropping season, the least number of seeds per pod (10.15) was recorded by cowpea planted 2 weeks after Abontem maize. Significant ($P \leq 0.05$) differences existed between the treatment means of the seasons. Variety, relative times of planting (RTP), season x variety interaction, season x relative times of planting interaction, variety x relative times of planting (RTP) interaction nor season x variety x relative times of planting (RTP) did not differ significantly between treatment means for 2021 minor and 2022 major cropping seasons. For contrast, no significant difference was observed between the treatment means for both cropping seasons. Generally, the 2022 major cropping season recorded the highest number of seeds per pod than 2021 minor season (Table 4.12).

4.6.4 100 – Seed weight

Table 4.16 shows results of 100-seed weight for cowpea in 2021 minor and 2022 major cropping seasons. The 100-seed weight for Abontem intercropped with cowpea ranged from 10.62 g – 17.00 g, Opeaburo intercropped with cowpea ranged from 10.94 g – 17.75 g, Omankwa intercropped with cowpea ranged from 10.31 g – 17.50 g, whereas the sole cowpea ranged from 17.25 g – 17.75 g for both seasons (Table 4.12). Sole cowpea had the highest 100-seed weight (17.75 g) for the 2021 minor season followed by cowpea planted 2 weeks after Abontem maize (12.39 g) whereas for the 2022 major cropping season, cowpea and Opeaburo maize planted simultaneous had the highest 100-seed weight (17.75 g) for cowpea (Table 4.12). The least 100-seed weight (10.31 g) for the 2021 minor season was recorded by Omankwa maize planted 2 weeks after cowpea while for the 2022 major cropping season, the least 100-seed weight (11.23 g) was recorded by cowpea and Abontem maize planted simultaneous. Significant ($P \leq 0.05$) differences existed between the treatment means of the seasons x variety interaction. Season, ariety, relative times of planting (RTP), season x variety interaction, season x relative times of planting interaction, variety x relative times of planting (RTP) interaction nor season x variety x relative times of planting (RTP) did not differ significantly between treatment means for 2021 minor and 2022 major cropping seasons. For contrast, no significant difference was observed between the treatment means for both cropping seasons. The 2022 major cropping season recorded the highest 100-seed weight of cowpea compared to the 2021 minor season (Table 4.12).

Table 4.12: Number of seeds per pod and 100-seed weight of cowpea as influenced by variety and relative times of planting (RTP) for 2021 minor and 2022 major cropping seasons.

Treatment		Number of seeds per pod			100 - Seed weight (g)		
Varietal combination (VC)	**Relative times of planting (RTP)**	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**
Abontem + Zamzam	M2WBC	11.83	10.15	**10.99**	12.39	11.23	**11.81**
	SIM	9.65	11.60	**10.63**	10.66	16.25	**13.46**
	C2WBM	9.80	11.34	**10.57**	10.62	17.00	**13.81**
Opeaburo + Zamzam	M2WBC	9.85	10.45	**10.15**	12.27	17.25	**14.76**
	SIM	8.65	11.00	**9.83**	11.45	17.75	**14.60**
	C2WBM	10.70	11.15	**10.93**	10.94	16.75	**13.85**
Omankwa + Zamzam	M2WBC	10.50	10.68	**10.59**	12.23	17.50	**14.87**
	SIM	10.35	11.13	**10.74**	11.76	15.00	**13.38**
	C2WBM	8.68	10.83	**9.76**	10.31	17.25	**13.78**
Sole Cowpea	-	10.90	11.53	**11.22**	17.75	17.25	**17.50**

Season	*LSD(0.05)=0.63*	(p=0.0021)	*LSD(0.05)=NS*
Varietal combination (VC)	*LSD(0.05)=NS*		*LSD(0.05)=NS*
RTP	*LSD(0.05)= NS*		*LSD(0.05)= NS*
Variety x RTP	*LSD(0.05)= NS*		*LSD(0.05)= NS*
Variety x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*
RTP x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*
Variety x RTP x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

4.6.5 Pod yield

The results for pod yield of cowpea grown in intercrop or sole crop are shown in Table 4.13. Pod yield ranged from 201.73 – 592.20 kg ha^{-1} for Abontem intercropped with cowpea, 206.18 – 630.90 kg ha^{-1} for Opeaburo intercropped with cowpea, 256.35 – 64.65 kg ha^{-1} for Omankwa intercropped with cowpea, whereas for sole cowpea, it ranged from 552.65 – 676.58 kg ha^{-1}. The highest pod yield (325.54 kg ha^{-1}) for the 2021 minor season was recorded by Omankwa intercropped with cowpea at relative times of planting 3

(RTP3) whereas for the 2022 major cropping season, sole cowpea recorded the highest pod yield (676.58 kg ha^{-1}) followed by cowpea planted 2 weeks after Omankwa maize (641.65 kg ha^{-1}). The least pod yield (201.73 kg ha^{-1}) for the 2021 minor season was recorded by cowpea planted 2 weeks after Abontem maize while for the 2022 major cropping season, the least pod yield (301.22 kg ha^{-1}) was recorded by cowpea planted 2 weeks after Abontem maize. Significant ($P \leq 0.05$) differences existed between the treatment means of the seasons. Variety, relative times of planting (RTP), season x variety interaction, season x relative times of planting interaction, variety x relative times of planting (RTP) interaction nor season x variety x relative times of planting (RTP) did not differ significantly between treatment means for 2021 minor and 2022 major cropping seasons. For contrast, no significant difference was observed between the treatment means for both cropping seasons. The 2022 major cropping season recorded the highest pod yield of cowpea compared to the 2021 minor season (Table 4.13).

4.6.6 Grain yield

The results for grain yield of cowpea grown in intercrop or sole crop are shown in Table 4.13. Grain yield ranged from 81.53 – 398.25 kg ha^{-1} for Abontem intercropped with cowpea, 107.02 – 405.25 kg ha^{-1} for Opeaburo intercropped with cowpea, 116.06 – 408.25 kg ha^{-1} for Omankwa intercropped with cowpea, whereas for sole cowpea, it ranged from 346.50 – 450.75 kg ha^{-1}. The highest grain yield (346.50 kg ha^{-1}) for the 2021 minor season was recorded by sole cowpea followed by cowpea planted 2 weeks after Abontem maize whereas for the 2022 major cropping season, sole cowpea recorded the highest pod yield (450.75 kg ha^{-1}) followed by cowpea and Opeaburo maize planted simultaneous (405.25 kg ha^{-1}). The least grain yield (81.53 kg ha^{-1}) for the 2021 minor season was recorded by cowpea and Abontem maize planted simultaneous while for the 2022 major cropping season, the least grain yield (116.41 kg ha^{-1}) was recorded by cowpea and Abontem maize planted simultaneous. Significant (P≤0.05) differences existed between the treatment means of the seasons. Variety, relative times of planting (RTP), season x variety interaction, season x relative times of planting interaction, variety x relative times of planting (RTP) interaction nor season x variety x relative times of planting (RTP) did not differ significantly between treatment means for 2021 minor and 2022 major cropping seasons. For contrast, no significant difference was observed between the treatment means for both cropping seasons. The 2022 major cropping season recorded the highest pod yield of cowpea compared to the 2021 minor season (Table 4.13).

Table 4.13: Pod yield and grain yield of cowpea as influenced by variety and relative times of planting (RTP) for 2021 minor and 2022 major cropping seasons.

Treatment		**Pod yield (kg ha^{-1})**			**Grain yield (kg ha^{-1})**		
Varietal combination (VC)	**Relative times of planting (RTP)**	**2021**	**2022**	**Mean**	**2021**	**2022**	**Mean**
Abontem + Zamzam	M2WBC	261.67	301.22	**281.45**	136.41	116.41	**126.41**
	SIM	201.73	519.63	**360.68**	81.53	354.00	**217.77**
	C2WBM	311.77	592.20	**451.99**	126.46	398.25	**262.36**
Opeaburo + Zamzam	M2WBC	206.18	518.40	**362.29**	117.77	330.75	**224.26**
	SIM	262.73	630.90	**446.82**	107.02	405.25	**256.14**
	C2WBM	270.20	437.83	**354.02**	118.70	257.75	**188.23**
Omankwa + Zamzam	M2WBC	256.35	641.65	**449.00**	116.06	376.50	**246.28**
	SIM	295.45	589.33	**442.39**	121.99	387.75	**254.87**
	C2WBM	325.54	611.90	**468.72**	126.35	408.25	**267.30**
Sole Cowpea	-	552.65	676.58	**614.62**	346.50	450.75	**398.63**

Season	*LSD(0.05)=66.60*	(p=<.0001)	*LSD(0.05)=42.20*	(p=<.0001)
Varietal combination (VC)	*LSD(0.05)=NS*		*LSD(0.05)=NS*	
RTP	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
Variety x RTP	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
Variety x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
RTP x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	
Variety x RTP x Season	*LSD(0.05)= NS*		*LSD(0.05)= NS*	

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

4.6.7 Shelling percentage

The results of shelling percentage of cowpea for 2021 minor and 2022 major cropping seasons are shown in Table 4.14. Shelling percentage ranged from 37.29 – 69.40% for Abontem intercropped with cowpea, 33.51 – 64.23% for Opeaburo intercropped with cowpea, 37.24 – 65.68 for Omankwa intercropped with cowpea, whereas for sole cowpea, it ranged from 60.38 – 66.65. The highest shelling percentage (60.38%) for the 2021 minor season was recorded by sole cowpea followed by cowpea planted 2 weeks after Opeaburo maize whereas for the 2022 major cropping season, cowpea and Abontem maize planted simultaneous had the greatest shelling percentage (69.40%). The least shelling percentage (33.51%) for the 2021 minor season was recorded by cowpea and Opeaburo maize planted simultaneous while for the 2022 major cropping season, the least shelling percentage (39.02) was recorded by cowpea planted 2 weeks after Abontem maize. Significantly ($P>0.05$), no differences existed between the treatment means of the seasons, variety, relative times of planting (RTP), season x variety interaction, season x relative times of planting interaction, variety x relative times of planting (RTP) interaction nor season x variety x relative times of planting (RTP) did not differ significantly between treatment means for 2021 minor and 2022 major cropping seasons. Also, no significant ($P>0.05$) difference was observed between the treatment means for both cropping seasons of contrast. The shelling percentage recorded in 2022 major cropping season was higher compared to the 2021 minor cropping season (Table 4.14).

Table 4.14: Shelling percentage of cowpea as influenced by variety and relative times of planting (RTP) for 2021 minor and 2022 major cropping seasons.

Treatment		Shelling percentage (%)		
Varietal combination (VC)	**Relative times of planting (RTP)**	**2021**	**2022**	**Mean**
Abontem + Zamzam	M2WBC	47.63	39.02	**43.33**
	SIM	39.32	69.40	**54.36**
	C2WBM	37.29	68.18	**52.74**
Opeaburo + Zamzam	M2WBC	48.40	59.63	**54.02**
	SIM	33.51	64.23	**48.87**
	C2WBM	44.20	61.23	**52.72**
Omankwa + Zamzam	M2WBC	45.70	59.50	**52.60**
	SIM	41.18	64.50	**52.84**
	C2WBM	37.24	65.68	**51.46**
Sole Cowpea	-	60.38	66.65	**63.52**
Season		*LSD(0.05)=NS*		
Varietal combination (VC)		*LSD(0.05)=NS*		
RTP		*LSD(0.05)= NS*		
Variety x RTP		*LSD(0.05)= NS*		
Variety x Season		*LSD(0.05)= NS*		
RTP x Season		*LSD(0.05)= NS*		
Variety x RTP x Season		*LSD(0.05)= NS*		

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

4.7 Land Equivalent Ratio (LER)

The 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 cowpea intercropping. In the 2021 growing season, maize planted 2 weeks before cowpea (Abontem + Zamzam) recorded the highest land equivalent ratio of 1.19 (119 %) followed by maize and cowpea planted simultaneously (1.13 %). Simultaneous (Table 4.1.5) planting of Opeaburo + Zamzam gave a lesser land equivalent ratio of 0.59 (59 %). In the 2022 growing season, simultaneous planting of Opeaburo + Zamzam recorded the highest land equivalent ratio of 1.84 (184 %) followed by cowpea planted 2 weeks before maize (Abontem + Zamzam) and maize planted 2 weeks before cowpea (Opeaburo + Zamzam) with land equivalent ratio of 1.68 (168 %) and 1.59 (159 %) respectively (Table 4.15). Maize planted 2 weeks before cowpea (Abontem + Zamzam) gave a lesser land equivalent ratio of 1 (100 %). LER was not significant among the varietal combinations, relative times of planting nor varietal combination x relative times of planting interactions. Similarly, there was no significant difference between the two seasons for LER (Table 4.15).

Table 4.1: Land equivalent ratio (LER) of maize and cowpea as influenced by variety and relative times of planting for 2021 minor and 2022 major cropping season.

Treatment		**LER**		
Varietal combination (VC)	**Relative times of planting (RTP)**	**2021**	**2022**	**Mean**
Abontem + Zamzam	M2WBC	0.87	1	**0.87**
	SIM	1.19	1.18	**1.19**
	C2WBM	0.94	1.68	**0.94**
Opeaburo + Zamzam	M2WBC	0.97	1.59	**0.97**
	SIM	0.59	1.84	**0.59**
	C2WBM	1.02	1.19	**1.02**
Omankwa + Zamzam	M2WBC	1.1	1.54	**1.10**
	SIM	1.13	1.18	**1.13**
	C2WBM	1.09	1.61	**1.09**

RTP= Relative times of planting, LSD= Least significant difference, SIM= Maize and cowpea planted simultaneously, M2WBC = Maize planted two weeks before cowpea, C2WBM = Cowpea planted two weeks before maize.

CHAPTER FIVE: DISCUSSION

5.1 Phenology of Cowpea and Maize

The results of percentage plant establishment for cowpea, varied from 65.34% to 69.89% in the minor season and 54.01% to 88.64% in the major season among the intercrops. These variations suggest that the choice of intercrop and the timing of planting can significantly impact cowpea establishment (Aliyu *et al.,* 2023). The sole maize, however, exhibited a slightly higher percentage plant establishment, ranging from 66.66% to 79.26%, implying that monocropping might have certain advantages over intercropping in terms of initial plant establishment. This support work done by Bitew & Abera (2019). A notable finding is the highest percentage plant establishment recorded in plots with sole cowpea for the 2021 season. This highlights the potential of sole cropping for maximizing cowpea establishment, at least in the observed year.

In the 2022 major cropping season, Opeaburo maize planted 2 weeks before cowpea exhibited the greatest percentage plant establishment for cowpea. This suggests that specific combinations of intercrops and planting times may lead to enhanced cowpea establishment, emphasizing the need for seasonal and intercropping dynamics. Maize planted 2 weeks before cowpea may have coincided with optimal environmental conditions for cowpea growth. According to Gavrilescu (2021), this could include factors such as favorable temperatures, adequate rainfall, and suitable soil moisture levels, all of which contribute to successful plant establishment. Interestingly, the analysis indicates no significant differences among varietal combinations, relative times of planting, or their interactions for both seasons. The season emerges as a significant factor, with slightly higher percentage plant establishment observed in the 2022 major season compared to the 2021 minor season. This seasonality effect could be attributed to various climatic, environmental, or agronomic factors that influence plant growth and establishment (Fatima *et al.*, 2020). The results reveals a range in the days to 50% flowering across different cowpea varieties when intercropped. The observed variations emphasize the significant influence of cowpea variety on the timing of flowering. The similarity in days to 50% flowering for both the 2021 minor and 2022 major cropping seasons suggests a consistent flowering response of cowpea to varying seasonal conditions. This agrees with findings by Fatima *et al.* (2020). This consistency is crucial for farmers, indicating that the crop maintains a relatively stable growth pattern across different cropping periods.

The results reveals variability in the days to 50% podding with the cowpea when intercropped with maize. Similar to the findings for flowering, the days to 50% podding were similar for both the 2021 minor and 2022 major cropping seasons. This suggests a consistent podding response of cowpea to varying seasonal conditions. The significant difference observed in the days to 50% podding highlights the importance of variety selection when aiming for specific podding timelines. Khatun *et al.* (2021) noted that, varieties may exhibit different growth rates or responses to environmental conditions, impacting the timing of pod development. Notably, a difference was recorded between intercrops and sole cowpea, suggesting that intercropping influenced the days to 50% podding. This difference may be attributed to competition for resources between cowpea and other crops when intercropped, potentially affecting the growth and podding timelines.

For maize, Opeaburo maize planted 2 weeks after cowpea recorded the highest percentage plant establishment in the 2021 minor season, while Abontem maize planted 2 weeks before cowpea had the least. In the 2022 major cropping season, Abontem maize planted 2 weeks before cowpea had the highest percentage plant establishment, whereas sole

Opeaburo had the least. These variations highlight the influence of intercropping practices and the relative timing of planting on maize establishment. The percentage plant establishment was slightly higher in the 2022 major season compared to the 2021 minor season. This seasonal difference could be influenced by varying environmental conditions, temperature, or other factors that may have favored maize establishment during the 2022 major season (Fatima *et al.*, 2020).

The days to 50% tasseling varied among the maize varieties, with Abontem ranging from 48 to 51 days, Opeaburo from 48 to 49 days, and Omankwa from 48 to 52 days for both seasons. Sole crops of Abontem, Opeaburo, and Omankwa also exhibited variability in days to 50% tasseling, with Opeaburo generally having the earliest tasseling. A significant difference was observed between the treatment means of variety and relative times of planting. This agrees with the work done by Adhikari *et al.* (2021). This indicates that both the choice of maize variety and the timing of planting significantly influenced the days to 50% tasseling. No difference was observed between the contrast means of Intercrops vs. Sole, suggesting that, on average, intercropping did not significantly affect the days to 50% tasseling compared to sole cropping. Opeaburo consistently showed the earliest days to 50% tasseling among the maize varieties. Opeaburo may possess genetic traits that promote early tasseling. Li *et al.* (2021) stated that, these traits could include early maturity genes or other genetic factors that influence the developmental stages of the maize plant.

The days to 50% silking varied among the maize varieties, with Abontem ranging from 53 to 57 days, Opeaburo from 53 to 55 days, and Omankwa from 53 to 57 days for both seasons. Sole crops of Abontem, Opeaburo, and Omankwa also exhibited variability in days to 50% silking, with Opeaburo generally having the earliest silking. The earliest day to 50% silking might be due to genetic differences. This agrees with earlier finding by Ige *et al.* (2019). A significant difference was observed between the treatment means of variety and relative times of planting. This suggests that both the choice of maize variety and the timing of planting significantly influenced the days to 50% silking. Opeaburo consistently showed the earliest days to 50% silking among the maize varieties. Nelimor *et al.* (2020) indicated that this characteristic could be advantageous for farmers aiming for an early maturation cycle.

5.2 Growth of Cowpea and Maize

For cowpea, the data indicates a general increase in plant height throughout the entire period from 21 DAP to 63 DAP for the 2021 minor season. This growth trend is expected as plants typically undergo significant vegetative growth during this period. Omankwa maize planted 2 weeks before cowpea showed the highest increase in plant height throughout the growing period. This suggests that the specific combination of Omankwa maize planted 2 weeks before cowpea had a positive influence on plant height. The differences in growth trends among varieties and intercropping timings highlight the importance of selecting appropriate combinations for optimal growth (Stomph *et al.*, 2020). The sole cowpea exhibited the highest trend in plant height between 49 DAP and 63 DAP. This could be attributed to the absence of competition for resources in sole cropping, allowing the cowpea plants to utilize nutrients and space more efficiently (Namatsheve *et al.*, 2021). Gaikwad *et al.* (2022) indicated that, the observed differences in growth patterns among intercropping strategies could be influenced by factors such as competition for nutrients, light, and space between cowpea and other crops. Abontem maize and cowpea planted simultaneous showed the highest increase in plant height throughout the growing period. This suggests that the specific combination of Abontem maize and cowpea planted simultaneous had a positive influence on plant height. The observed differences in growth patterns may be influenced by various factors, including nutrient availability, light exposure, and competition for resources among cowpea and other crops in the intercropping system (Gaikwad *et al.*, 2022).

The increasing trend in dry matter from 35 DAP to 63 DAP is indicative of the ongoing physiological and vegetative growth of cowpea during this period. According to Anjum *et al.* (2107), as the crop progresses through its developmental stages, there is a natural tendency for an accumulation of dry matter, reflecting enhanced photosynthetic activity, nutrient uptake, and overall plant growth. The ranking of planting systems based on dry matter content provides insights into how different intercropping affect the overall biomass production of cowpea (Sanfo *et al.*, 2023). The sole cowpea exhibiting the highest trend in dry matter suggests that, in this particular season, intercropping might have led to some level of competition for resources, affecting the overall dry matter accumulation. Abontem maize planted 2 weeks before cowpea, however, displayed a notable dry matter accumulation, indicating a potentially favorable interaction between these crops at that particular planting time. The specific mention of Opeaburo maize planted 2 weeks after cowpea as having a high dry matter content highlights the importance of timing in intercropping systems. The relative times of planting play a crucial role in determining resource availability and competition between crops. This result suggests that, for the 2022 major cropping season, planting cowpea planted 2 weeks before Opeaburo maize led to a synergistic relationship, contributing to increased dry matter accumulation in cowpea.

For maize, the consistent increase in plant height from 21 DAP to 77 DAP reflects the natural growth progression of maize plants during this period. The differences in plant height between maize varieties could be attributed to genetic variation. The variations in plant height observed in this study confirm the findings by Bhadru *et al.* (2020). The observation that sole Omankwa exhibited the highest trend in plant height suggests that Omankwa is a variety that is particularly suited for achieving tall and vigorous maize plants. Plant height is an important agronomic trait that can have implications for overall crop productivity. According to Pedersen *et al.* (2022), taller plants often have more biomass, which can contribute to higher yield potential. This variability could be attributed to genetic differences, environmental conditions, and the complex interactions between maize and the intercropped cowpea. The observation that sole Opeaburo exhibited the highest trend in plant height suggests that, for the 2022 major cropping season, Opeaburo is a variety well-suited for achieving tall and robust maize plants. Genetic traits, including height potential, play a significant role in determining the overall stature of maize plants (Liu *et al.,* 2021).

The observed increase in the number of leaves per plant from 21 DAP to 63 DAP aligns with the typical growth trajectory of maize during its vegetative phase. Sprangers *et al.* (2020) stated that, during this period, maize plants undergo active leaf initiation and expansion, contributing to an increase in the overall leaf count. The slight decrease observed at 77 DAP might be indicative of the transition to the reproductive phase, where energy is redirected towards reproductive structures rather than vegetative growth. Omankwa maize planted 2 weeks before cowpea exhibiting the highest trend suggests that, in the context of the 2021 minor cropping season, this particular combination resulted in optimal conditions for leaf initiation and growth. Different planting schedules can lead to variations in resource competition and complementarity between crops (Bitew *et al.,* 2021). The success of Omankwa maize planted 2 weeks before cowpea and Abontem maize and cowpea planted simultaneous suggests that careful consideration of planting times can enhance leaf development and, by extension, overall vegetative growth. According to Lusk *et al.* (2019), the number of leaves per plant is a crucial determinant of canopy development and light interception. A higher leaf count generally contributes to a more efficient capture of sunlight, essential for photosynthesis and biomass production (Umesh *et al.,* 2023). The observed trends in leaf development have implications for the ability of maize plants to harness solar energy and convert it into plant biomass. As stated by Mendes *et al.* (2020), seasonal variations, weather conditions, and other environmental factors can influence plant growth patterns. Omankwa maize planted 2 weeks after cowpea exhibiting the highest trend suggests that, for the 2022 major cropping season, this particular combination resulted in optimal conditions for leaf initiation and growth.

5.3 Yield and yield components of Cowpea and Maize

For cowpea, the range of the number of plants harvested for cowpea across different varieties and intercropping indicates variability in the performance of these treatments. The significant differences observed between treatment means indicate that intercropping and relative times of planting had a substantial impact on the number of plants harvested. Cowpea planted 2 weeks before cowpea Opeaburo maize recorded the highest number of plants harvested for the 2022 major cropping season. The combination of Opeaburo maize and cowpea planted simultaneous may have facilitated efficient use of soil nutrients, water, and sunlight, contributing to enhanced plant growth thereby producing higher number of plants harvested. The sole cowpea consistently recorded a relatively high number of plants harvested, indicating its robust performance across both cropping seasons. The notable finding that the 2022 major cropping season recorded a higher number of plants harvested than the 2021 minor season indicates the influence of seasonal variations on crop performance. Kumar (2020) noted that, weather conditions, temperature, and other environmental factors can impact crop growth and yield. The higher yield in the 2022 major cropping season may be attributed to more favorable conditions during that period.

The significant differences observed between treatment means of number of pods per plant indicate that intercropping and relative times of planting had a substantial impact on the number of pods per plant. Cowpea 2 weeks before Omankwa maize recorded the highest number of pods per plant for the 2022 major cropping season. The combination of Omankwa maize planted 2 weeks after cowpea may have facilitated better use of soil nutrients, water, and sunlight, promoting increased pod formation. This agrees with work done by Parker (2015). The sole cowpea consistently recorded a relatively high number of pods per plant, indicating its robust performance across both cropping seasons. The notable finding that the 2022 major cropping season recorded a higher number of pods per plant than the 2021 minor season indicates the influence of seasonal variations on cowpea pod production. The lack of significant differences in season x variety interaction suggests that while there are seasonal variations, the response of varieties to different seasons may not be significantly different.

The significant differences observed between treatment means of number of seeds per pod indicate that intercropping and relative times of planting had a substantial impact on the number of seeds per pod. Abontem maize and cowpea planted simultaneous recorded the highest number of seeds per pod for the 2022 major cropping season. This suggests a positive interaction between Abontem and cowpea at that specific planting time, resulting in an increased seed yield per pod. The consistent high performance of Abontem maize planted 2 weeks before cowpea in the 2021 minor cropping season and Abontem maize and cowpea planted simultaneous in the 2022 major cropping season suggests that these combinations were particularly well-suited for maximizing the number of seeds per pod. Sun *et al.* (2021) indicated that, the intercropping system may have enhanced the overall efficiency of resource use, including soil nutrients, water, and sunlight. Efficient resource utilization can positively impact reproductive development, leading to an increased number of seeds per pod (Dass *et al.*, 2022). The 2022 major cropping season recording a higher number of seeds per pod than the 2021 minor season indicates the influence of seasonal variations on cowpea seed production. The lack of significant differences in season x variety interaction suggests that while there are seasonal variations, the response of varieties to different seasons may not be significantly different. The significant differences observed in relative times of planting indicate that the timing of planting had a significant influence on the number of seeds per pod MacMillan & Gulden, 2020).

The range in 100-seed weight across different varieties and intercropping indicates significant variability in cowpea seed size. The significant differences observed between treatment means indicate that intercropping and relative times of planting had a substantial impact on the 100-seed weight. Opeaburo maize and cowpea planted simultaneous recorded the highest 100-seed weight for the 2022 major cropping season. Proper timing of planting (RTP2) may have minimized competition for resources between Opeaburo and cowpea, allowing each crop to access essential nutrients and energy for optimal seed development without hindering the other. This support findings by Widyati *et al.* (2022). The sole cowpea consistently recorded a relatively high 100-seed weight, indicating its robust performance across both cropping seasons. The variation in performance between Abontem maize planted 2 weeks before cowpea in the 2021 minor season and Opeaburo maize and cowpea planted simultaneous in the 2022 major season illustrates the impact of both variety and intercropping on seed weight. The finding that the 2022 major cropping season recorded a higher 100-seed weight than the 2021 minor season indicates the influence of seasonal variations on cowpea seed size. The significant differences observed in relative times of planting indicate that the timing of planting had a significant influence on the 100-seed weight. Abontem maize planted 2 weeks before cowpea recorded the least 100-seed weight for the 2022 major cropping season. This highlights the importance of selecting optimal planting times to maximize seed weight (Vogel *et al.* 2021).

The significant differences observed between treatment means of pod yield indicate that intercropping and relative times of planting had a substantial impact on pod yield. Omankwa maize planted 2 weeks after cowpea recorded the highest pod yield for the 2021 minor season, suggesting a positive interaction between. The sole cowpea consistently recorded a relatively high pod yield, indicating its robust performance across both cropping seasons. The variation in performance between Omankwa maize planted 2 weeks after cowpea in the 2021 minor season and sole cowpea in the 2022 major season illustrates the impact of both variety and intercropping on pod yield. The finding that the 2022 major cropping season recorded a higher pod yield than the 2021 minor season indicates the influence of seasonal variations on cowpea productivity. According to Parwada *et al.* (2016), seasonal variations in temperature, rainfall, and other climatic factors can significantly impact cowpea growth and productivity. The 2022 major cropping season may have experienced more favorable climate conditions, such as optimal temperatures and sufficient rainfall, promoting better cowpea development and higher pod yields. The significant differences observed in relative times of planting indicate that the timing of planting had a significant influence on pod yield. Abontem maize planted 2 weeks before cowprea recorded the least pod yield for the 2021 minor season. This highlights the importance of selecting optimal planting times to maximize pod yield (Vogel *et al.* 2021).

The grain yield of cowpea varied significantly when grown in intercrop with different crops. The variability in yields among intercropped cowpea suggests that the choice of companion crops and their relative times of planting can impact cowpea productivity. Brooker *et al.* (2015) stated that, intercropping is known to influence plant-plant interactions, resource competition, and nutrient availability. The observed differences may be attributed to the varying abilities of companion crops to complement or compete with cowpea for resources such as sunlight, water, and nutrients (Mugi-Ngenga *et al.*, 2023).

Sole cowpea recorded the highest grain yield in both the 2021 minor season and the 2022 major cropping season. This suggests that, at least for the varieties and conditions studied, sole cropping was more favorable for maximizing cowpea grain yield. Justes *et al.* (2021) stated that, sole cropping allows for unrestricted access to resources by the focal crop, eliminating competition with other species. The higher yields in sole cowpea indicate that, under the given conditions, intercropping did not provide a yield advantage. The relative times of planting had a significant impact on cowpea grain yield. The highest yield for the 2021 minor season occurred maize planted 2 weeks before cowpea, while for the 2022 major cropping season, maize and cowpea planted simultaneous resulted in the highest yield. The timing of planting can influence crop growth and development. The observed differences in yield based on RTP suggest that there may be specific windows during which cowpea interacts more favorably with the companion crops. The 2022 major cropping season recorded a higher grain yield compared to the 2021 minor season. Seasonal variations, including climatic conditions and temperature fluctuations, can significantly impact crop growth and yield (Parwada *et al.*, 2016). The observed increase in grain yield in the 2022 major cropping season may be attributed to more favorable environmental conditions.

The variability in shelling percentage may be attributed to the influence of intercropping on factors such as competition for resources, planting density, and environmental conditions. Sole cowpea, having a more consistent shelling percentage range, suggests that intercropping dynamics might introduce additional variability (Mogale, 2022). Abontem maize and cowpea planted simultaneous had the least shelling percentage in the 2022 major cropping season. Relative times of planting can affect the synchrony of crop development and maturity. According to Nderi (2020), variability in shelling percentage across different timings may be attributed to differences in growth stages and developmental rates of the cowpea and companion crops. Shelling percentage was higher in the 2022 major cropping season compared to the 2021 minor season, indicating a seasonal effect. Seasonal variations, including weather conditions, temperature, and other environmental factors, can influence the physiological processes of crops. The higher shelling percentage in the 2022 major cropping season may be attributed to more favorable conditions during the shelling process.

For maize, the number of plants harvested for maize varied across different cropping conditions and varieties. Abontem intercropped with cowpea ranged from 19.50 to 39.50 plants, indicating a substantial range in productivity. Similar variability was observed for Opeaburo and Omankwa intercropped with cowpea, as well as for sole cropping of each variety. As stated by Khonde *et al.* (2018), the observed variability in the number of plants harvested can be attributed to factors such as competition for resources, planting density, and interactions between maize and cowpea in intercropping systems. These factors may lead to differences in growth, development, and overall productivity. According to Ezeaku *et al.* (2015), the differences in the number of plants harvested at different planting times may be attributed to variations in the stages at which maize and cowpea interact, affecting overall productivity. The statistical analysis revealed significant differences between treatment means of variety and season, indicating that the choice of variety and the specific cropping season had a significant impact on the number of plants harvested. According to Masa *et al.* (2017), varietal characteristics, including growth habits and competitive abilities, can influence plant density and overall yield. Additionally, seasonal variations in weather conditions and environmental factors may contribute to differences in plant growth and productivity. The general trend indicates that the 2022 major cropping season recorded a higher number of plants harvested than the 2021 minor season. Seasonal variations in temperature, rainfall, and other environmental factors can impact crop growth and yield (Ahmad *et al.*, 2021). The observed increase in the number of plants harvested in the 2022 major cropping season may be attributed to more favorable conditions during that period.

The observed variability in cob diameter may be influenced by factors such as competition for resources, planting density, and interactions between maize and cowpea in intercropping systems. According to Chukwudi *et al.* (2022), variability in environmental conditions, nutrient availability, and water stress can also contribute to differences in cob size. Differences in cob diameter at different planting times may be attributed to variations in the stages at which maize and cowpea interact, affecting overall cob development. According to Ahmad *et al.* (2021), seasonal variations in temperature, rainfall, and other environmental factors can impact crop growth and cob development. The observed differences in the widest cob diameter between seasons and varieties may be attributed to these environmental factors.

The cob length for maize exhibited variability across different intercropping conditions and sole cropping for each variety. The observed variability in cob length may be influenced by factors such as competition for resources, planting density, and interactions between maize and cowpea in intercropping systems (Nyande *et al.,* 2023). According to Chukwudi *et al.* (2022), variability in environmental conditions, nutrient availability, and water stress can also contribute to differences in cob size. Differences in cob length at different planting times may be attributed to variations in the stages at which maize and cowpea interact, affecting overall cob development. The observed differences in the longest cob length between seasons and varieties may be attributed to these genetic factors and variations in environmental conditions.

The 100-seed weight for maize exhibited variability across different intercropping conditions and sole cropping for each variety. Aredo *et al.* (2021), stated that, variability in 100-seed weight may be influenced by factors such as competition for resources, planting density, and interactions between maize and cowpea in intercropping systems. Variability in environmental conditions, nutrient availability, and water stress can also contribute to differences in seed weight (Chukwudi *et al.*, 2022). The 100-seed weight varied based on the relative times of planting. Differences in seed weight at different planting times may be attributed to variations in the stages at which maize and cowpea interact, affecting overall seed development.

Grain yield exhibited considerable variability across different intercropping conditions and sole cropping for each variety. The observed variability in grain yield can be attributed to factors such as competition for resources, planting density, and interactions between maize and cowpea in intercropping systems (Aredo *et al.,* 2021). Chukwudi *et al.* (2022), indicated that, variability in environmental conditions, nutrient availability, and water stress can also contribute to differences in grain yield. The grain yield varied based on the relative times of planting. Silva *et al.* (2020), stated that, differences in grain yield at different planting times may be attributed to variations in the stages at which maize and cowpea interact, affecting overall grain development.

Harvest index exhibited considerable variability across different intercropping conditions and sole cropping for each variety. Salama *et al.* (2022), opined that, variability in harvest index can be attributed to factors such as competition for resources, planting density, and interactions between maize and cowpea in intercropping systems. According to Koundinya *et al.* (2021), variability in environmental conditions, nutrient availability, and water stress can also contribute to differences in the harvest index. Differences in harvest index at different planting times may be attributed to variations in the stages at which maize and cowpea interact, affecting overall harvest development (Aredo *et al.,* 2021).

5.4 Productivity (LER) of the Intercrop Systems

The Land equivalent ratio (LER) is defined as the total land area required under sole cropping to give yields obtained in the intercropping (Ennin *et al.,* 2001). According to Mohammed (2019), LER indicates the magnitude of sole cropping required to produce the same yield on a unit of intercropped land. In the 2021 growing season, maize planted 2 weeks before cowpea (Abontem + Zamzam) recorded the highest land equivalent ratio of

1.19 (119 %) followed by maize and cowpea planted simultaneously (1.13 %). Simultaneous planting of Opeaburo + Zamzam gave a lesser land equivalent ratio of 0.59 (59 %). In the 2022 growing season, simultaneous planting of Opeaburo + Zamzam recorded the highest land equivalent ratio of 1.84 (184 %) followed by cowpea planted 2 weeks before maize (Abontem + Zamzam) and maize planted 2 weeks before cowpea (Opeaburo + Zamzam) with land equivalent ratio of 1.68 (168 %) and 1.59 (159 %) respectively (Table 4.15).

Maize planted 2 weeks before cowpea (Abontem + Zamzam) gave a lesser land equivalent ratio of 1 (100 %). 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. Factors such as temperature and rainfall might have a significant impact on crop growth and yield. The lower LER 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). The advantage of intercrops with LER (1.19 and 1.84) over the sole crops 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. According to Mei *et al.* (2021), land equivalent ratios (LER) of more than 1 imply that the intercrops had a yield advantage over the sole crops. An LER of 1.19 and 1.84 respectively indicates that if planted in pure stands, the yield produced in the total intercrop would have required 19 % and 84 % more land, while an LER of 0. 13 indicates that the yield produced in the total intercrop was only 13 % of that of the same amount of land as pure stands planted. This support findings by Mohammed (2019).

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

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

Phenology of cowpea and maize:

- For cowpea phenology, sole cowpea and cowpea planted 2 weeks before Opeaburo maize promoted higher percentage plant establishment, Omankwa and Abontem maize and cowpea planted simultaneous had the earliest days to 50% flowering, whereas Abontem maize planted 2 weeks after cowpea and when planted simultaneously with cowpea gave the earliest day to 50% podding.
- For maize phenology, Opeaburo maize planted 2 weeks after cowpea and Abontem maize planted 2 weeks before cowpea enhanced percentage plant establishment while sole Opeaburo enhanced early tasseling and silking.

Vegetative growth of cowpea and maize:

- For vegetative growth of cowpea, cowpea planted 2 weeks after Omankwa maize and cowpea and Abontem maize planted simultaneously enhanced higher plant height, Sole cowpea and cowpea planted 2 weeks after Opeaburo maize gave higher number of branches, while sole cowpea gave the higher dry matter.
- For maize vegetative growth, sole Omankwa and sole Opeaburo gave higher plant height while Omankwa maize planted 2 weeks before cowpea and Omankwa maize and cowpea planted simultaneous enhanced the number of leaves of maize plant.

Yield and yield components of cowpea and maize:

- For yield and yield components, cowpea planted 2 weeks before Abontem maize and Abontem maize and cowpea planted simultaneous enhanced number of plants harvested, number of seeds per pod, pod yield, grain yield, and shelling percentage, while sole cowpea enhanced number of pods per plant and 100-seed weight.

- For yield and yield components of maize, Abontem maize planted 2 weeks before cowpea and Abontem maize and cowpea planted simultaneous had the highest number of plants harvested, 100-seed weight, and harvest index. Sole Omankwa and sole Opeaburo enhanced cob diameter and cob length while Omankwa planted 2 weeks after cowpea gave the highest maize grain yield.

Productivity (LER) of the Intercrop Systems:

- For both maize and cowpea land equivalent ratio (LER), maize planted 2 weeks before cowpea (Abontem + Zamzam) and simultaneous planting of Opeaburo + Zamzam recorded the highest land equivalent ratio for 2021 and 2022 growing seasons, respectively.

6.2 Recommendations for further/future studies

Based on the experimental results, it is recommended that:

- Abontem maize planted 2 weeks before cowpea and Abontem maize and cowpea planted simultaneous are recommended for farmers who prefer intercropping cowpea and maize sole cowpea or sole maize.
- The study could be tested in different agroecological zones such as Sudan Guinea and Coastal Savannah.
- The intercrop systems should be varied, for instance 1week or 10 days instead of the 2 weeks before or after.

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