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

# GROWTH AND YIELD RESPONSE OF MAIZE *(Zea mays* L.) TO INTEGRATED NUTRIENT MANAGEMENT OF CHICKEN MANURE AND INORGANIC FERTILIZER IN DIFFERENT AGROECOLOGICAL ZONES OF GHANA

**VERONICA ASAMOAH**

**MASTER OF PHILOSOPHY CROP SCIENCE**
**(AGRONOMY)**

**2024**

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**VERONICA ASAMOAH**
**(8181970001)**

**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)**

**JULY, 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.

**CANDIDATE’S NAME: Veronica Asamoah**

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).

**Prof. (Mrs.) Margaret Esi Essilfie:**

**(PRINCIPAL SUPERVISOR)**

Signature…………………………………….

Date…………………………..……………

**Dr. Eliezer Bortei Borketey-La:**

**(CO-SUPERVISOR)**

Signature…………………………………….

Date…………………………..……………

# ACKNOWLEDGMENT

I would like to express my heartfelt gratitude to the many individuals who have contributed to the completion of this postgraduate programme. First and foremost, I am deeply thankful to my thesis supervisors, Prof. (Mrs.) Margaret Esi Essilfie and Dr. Eliezer Bortei Borketey-La for their unwavering support, guidance, and expertise throughout this thesis writing. Your mentorship and dedication to my academic growth have been invaluable, and I am truly fortunate to have had the opportunity to work under your supervision.

I wish to acknowledge the support of my husband, Jacob Osman whose unwavering belief in my abilities and continuous encouragement have been a constant source of inspiration. Furthermore, I want to express my gratitude to all my family and friends for their innumerable support and effort for the success of this work. Lastly, I want to acknowledge the countless scholars, researchers, and writers whose work has paved the way for my research. Your contributions to the field have been invaluable.

To all those mentioned and the countless others who have played a role, however small, in the completion of this thesis, I extend my heartfelt thanks. Your contributions have been crucial to the success of this endeavour.

# DEDICATION

This thesis is dedicated to the Almighty God for seeing me through successfully in completing this programme.

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| | |
|---|---|
| CSIR-CRI | Council for Scientific and Industrial Research of Crops Research Institute |
| HSD | Honestly Significant Difference |
| CV | Coefficient of variation |
| DAP | Days after planting |
| CGR | Crop growth rate |
| RGR | Relative growth rate |
| CM | Chicken manure |
| NPK | nitrogen, Phosphorus, and Potassium |
| RCBD | Randomized Complete Block Design |
| kg | Kilogram |
| Ha | hectare |

# ABSTRACT

Two field experiments were conducted at two different locations at Asante Mampong in the Mampong municipal during the minor season in 2019 (September – November 2019) and at Damongo in the West Gonja district during the major season in 2019 (Nay – July 2019). The objective was to determine the effect of integrated nutrient management of chicken manure and inorganic fertilizer on growth and yield of maize in different agroecological zones of Ghana. The experimental design used for the study was a 2 x 5 factorial experiment arranged in randomized complete block design (RCBD) with three replications. The factors were two maize varieties (Abontem and Obatanpa) and four fertilizer rates and the control (without amendment). The fertilizer treatments were: 3 t/ha chicken manure (CM), 250 kg/ha NPK (15:15:15), 1.5 t/ha CM + 125 kg/ha NPK, 2.25 t/ha CM + 62.5 kg/ha NPK, and Control (without amendment). The results showed that Abontem maize variety was earliest to tassel, silk and to mature. Similarly, Abontem produced the greatest number of leaves per plant, dry root weight, highest cobs per plot, longest cob length, and highest seeds per cob. However, the highest plant height and grain yield was recorded by Obatanpa maize variety. For fertilizer application, the combination of 1.5 t/ha Chicken manure + 125 t/ha kg/ha NPK fertilizer was superior in yield. Generally, Asante Mampong outperformed Damongo in terms of maize growth and yield. It is therefore recommended that, farmers should cultivate Abontem maize variety with the application of 1.5 t/ha CM + 125 kg/ha NPK fertilizer for optimum maize growth and yield.

# CHAPTER ONE: INTRODUCTION

## 1.1 Background of the Study

Maize (*Zea mays* L.) has been cultivated in Ghana over several centuries after the crop was introduced into the country in the late 16th century. According to the Food and Agricultural Organization (FAO, 2020), maize tops as the most widely and consumed cereal crop in Ghana and the cultivation of the crop has been increasing since 2015. Other studies (MiDA, 2010; MoFA, 2012) also rank maize as the most important cereal produced and consumed in Ghana. In developing countries, maize is a chief source of carbohydrate in the diet of humans and the crop forms significant portions of livestock feed in the developed economies (Poole *et al*., 2021). The production of maize is not limited to Ghana but globally. It serves as staple for majority of people living in different parts of the world (Darfour & Rosentrator, 2016). The crop accounts for more than half (over 50%) of total cereal production in Ghana with an annual yield reported at approximately 1.1% (Marfo-Ahenkora, 2020).

According to Angelucci (2012), maize thrives well in the northern savannah, transitional, forest and coastal savannah agroecological zones of Ghana. The Eastern, Ashanti, and the then Brong Ahafo regions account for more than 80% of Ghana's total maize production with the then Northern, Upper East and Upper West regions making up for the remaining 20% (Angelucci, 2012). Total production of maize in the past three years in Ghana have been reported at 2,011 MT, 2,303 MT and 2,000 MT for the years 2017; 2018 and 2019 respectively (Knoema, 2020). Similarly, the FAO (2020) in its country brief in April 2020 reported that the production of maize for 2018 and 2019 in Ghana were 2,306 MT and 2,759 MT respectively. According to Wongnaa & Awunyo-Vitor (2019), the major agro-ecological zones that support the cultivation of maize in Ghana are Coastal Savannah, Forest, Transition, and Guinea Savannah Zone of Ghana. The International Food Policy Research Institute (IFPRI) and the Ministry of Food and Agriculture (MoFA) have also reported average yield of maize at 1.73 ton/ha and 1.92 ton/ha respectively (Andam *et al.,* 2017; MoFA, 2012). Also, sub-Saharan Africa records an average maize yield of 1.9 t/ha in 2018, whereas the average maize yield of 3.8 t/ha in Brazil, and 3.6 t/ha in Mexico during the same period (Mbarushimana, 2019). The average maize yield in Ghana has been estimated at 1.5 t/ha (Tetteh & Nurudeen, 2015). However, achievable yield of maize in Ghana has been estimated at 6.0 t/ha (Bawa, 2021). It is, therefore, clear that actual maize yield in Ghana is way below the yield potential of the varieties being grown.

A number of factors have been associated to the low yield of maize in Ghana. These include drought since maize production is predominantly rain-fed in Ghana, low level of soil nutrient (especially nitrogen and phosphorus), pest and diseases (Adu *et al.,* 2014). Kanton *et al.,* (2016) also affirmed that the fertility of the soils plays a key role in the productivity of crops. Farmers in sub-Saharan African have identified low soil fertility as the major hindrance to increased and stable productivity and production of cereals (Raimi *et al.,* 2017). Some soil related challenges in the regions include loss of soil organic matter, depletion of plant nutrient, high water infiltration, and low water-holding capacity of soils (Bawa, 2021). The manipulation of climate factors affecting crop productivity remain a difficult challenge, hence, it is most prudent to focus attention on improving the fertility of soil. Applying organic manures to soils aims at improving the organic matter content, water retention and infiltration, and the available soil water content (Raimi *et al.,* 2017). Fertilizers (both organic and inorganic) help to improve soil fertility, plant growth and productivity.

## 1.2 Problem Statement and Justification

Agriculture is a very predominant activity in Ghana. According to Bationo *et al*. (2018), 57.1 percent of the total land area of the country are suitable for agriculture. Thus, 13,628,179 ha of arable lands in Ghana support the cultivation of various food and cash crops. Land productivity, however, has been found to be way below the ideal level. Average crop yields have been found to be 20-60 percent below achievable yields. Other studies (FAO-RAF, 2000; Fuglie and Rada, 2012; Kanton *et al.* 2016) have discussed the low agricultural land productivity in not just Ghana, but the entire sub-Saharan African region. Most soils of the country are inherently low in fertility coupled with the failure to replace depleted nutrients after crop harvest. The issue of nutrient depletion is widespread across all agroecological zones of Ghana and nitrogen and phosphorus have been identified as the most deficient nutrients amongst all other crop nutrients (Bationo *et al*., 2018).

The use of both organic and inorganic fertilizers helps to increase soil productivity and yield. Studies have shown that numerous crops positively respond to organic manures. Kanton *et al,* (2016) also stated that the application of NPK to maize gives a very good response compared to manure. But the combination of both NPK and manure (inorganic plus organic) gives a significant increase in yield, seven-fold increase compared to fields with no treatment. Jjagwe *et al*. (2020) also found out that the growth parameters and yield of maize increase significantly with the use of both organic and inorganic fertilizers. In spite of the low soil fertility, low yield, and high yield potential of maize with the use of organic and inorganic fertilizers, application across the various agroecological zones is very low. The use of fertilizer in sub-Saharan Africa (SSA) in general has been found to be low compared to other regions of the world (Bationo *et al.* 2012). Considering the fact that SSA has the fastest growing world population (Bationo *et al.* 2012), improving soil fertility to increase yield and crop productivity would serve better. Tetteh *et al.* (2015) reiterated that the use of fertilizer in Ghana is low. Rahman *et al.* (2019) also found that fertilizer use and soil quality index among other factors affect the yield of maize in Northern Ghana. As efforts have been put in promoting the use of fertilizers by government and other stakeholders, literature on the effect of organic and inorganic fertilizers on the growth and yield of maize in Mampong in the Ashanti region and Damongo in the Savannah region of Ghana is limited. Soil fertility is a crucial factor that interplays in the growth and yield of both food and cash crops. Organic fertilizer such as chicken manure improves soil structure which increases water holding capacity and enhance nutrient exchange for plant growth.

The activities of bacterial on chicken manure during decomposition also helps in the release of nitrogen and phosphorus. Again, inorganic fertilizer such as NPK (15:15:15) is known to supply nutrients that are ready made for plant use. They supply nutrients which enhances vegetative growth and fruit formation. Furthermore, a good combination of organic fertilizer and inorganic fertilizer are known to reduce the deficiency of many secondary and micronutrients in the soil. Additionally, the two maize varieties were chosen for this study because Abontem is extra-early (75 – 80 days) and Obatanpa medium-early (105 – 110 days) maturing varieties, drought tolerant, and has high yield potential. These qualities make them versatile varieties, especially in this era of climate change. The application of poultry manure in combination with inorganic fertilizers will increase the grain yield of these maize varieties in the forest Savannah transitional and Guinea Savannah agroecological zones of Ghana. Obatanpa maize variety, a quality protein maize (QPM), is excellent for enhanced nutrition and health of humans while Abontem is good for poultry and livestock feed. Additionally, Abontem is yellow dent, drought and striga tolerant while Obatanpa is white dent with high protein content. All these qualities or attributes motivated the researcher to choose these two maize varieties (Obatanpa and Abontem) for the study. Moreover, this study would provide the hardly available knowledge on the effects of chicken manure and NPK fertilizer on the growth and yield response of selected maize varieties in the forest-savannah transition and Guinea Savannah zones of Ghana.  The findings of this study would, therefore, help farmers to know the effect of the application of different rates, and combinations of chicken manure and NPK fertilizer to soil and growth and yield of maize. This would inform them on the possible combinations that would enhance crop growth and yield. Finally, stakeholders such as Government and Non-Governmental Organizations (NGOs) that offer farmer support programmes through integrated nutrient management would also find the findings of this study beneficial. This study, therefore, seeks to examine the growth and yield response of two maize varieties (*Obatanpa* and *Abontem*) to different rates of organic and inorganic fertilizers in Mampong and Damongo, both located in different agroecological zones of Ghana.

## 1.3 Objectives of the study

### *1.3.1 Main objective*

The main objective of the study was to improve growth and yield of maize varieties by using nutrient management of chicken manure and inorganic fertilizer.

### *1.3.2 Specific objectives*

The specific objectives were to:

(i) Determine the effect of chicken manure and inorganic fertilizer NPK (15:15:15) on soil physical and chemical properties.

(ii) Evaluate the effect of chicken manure and inorganic fertilizer NPK (15:15:15) on phenology and growth of *Obatanpa* and *Abontem* maize varieties.

(iii) Examine the effectiveness of chicken manure and NPK (15:15:15) on physiological growth parameters of maize.

(iv) Assess the interactive effect of variety and soil amendments on yield and yield components of maize.

# CHAPTER TWO: LITERATURE REVIEW

## 2.1 Origin and distribution

Maize (*Zea mays L.*) is believed to have originated from Mexico and Central America which were formally called Mesoamerican (Yang *et al*., 2023). It belongs to the tribe Maydae from the family of Poaceace. According to Oxford dictionary, the term ‘maize’ is derived from the Taino language from the word ‘mahiz’. In English speaking countries maize is popularly known as ‘corn’. In some countries, the word ‘corn’ is used for local staple, while it is also use for any cereal in some other countries. Most researchers are of the view that the first domestication of maize occurred in the valley of Tehuacan of Mexico (Yang *et al*., 2023). Pollen grains of maize as old as 80,000 years have been identified from Mexico City, however, archaeological records advocate that domestication of maize is at least 6,000 years old (Hossain *et al.*, 2016).  Again, a study by Yang *et al*. (2023) revealed that domestication of a single maize in Southern Mexico took place about 9,000 years ago rather than the multiple independent domestication models.

Many studies have shown that maize was domesticated from the *Z. mays* ssp. Parviglumis. However, this contradict the observation that cultivars of maize which are closely related to parviglumis are found in the highlands of Mexico, though parviglumis is commonly prevalent to the mid-to lowlands. Distribution of maize was initially slow across America for over thousand years. However, after Columbus discovered the new world, rapid distribution occurred in the past 510 years (Zhong *et al*., 2021). Maize strives in a short-day condition. However, the insertion of CACTA-like transposon in the ZmCCt expression has made adaptation under long day condition possible (Zhong *et al*., 2021). This insertion process has aid in the distribution of maize from its centre of origin to survive in different photoperiodic environment around the world.

## 2.2 Botany

Maize *(Zea mays)* is a tall, monoecious annual grass varying in height from 1 to 4 meters and above. It produces large, narrow, and opposing leaves. The leaves alternate along the length of the solid stem. Botanically, every plant has root, stem, and flowers. The maize plant has a simple stem of nodes and internodes. At each internodes a pair of leaves is projected. A maize plant has between 8 to 21 leaves. The leaves are linear with an obvious vein at the middle and can grow from 30 cm to 100 cm in length. The maize plant has flowers (male and female inflorescences) which are positioned separately in the plant. The male flower is known as *tassel* while the female flower is the *ear.* The ear is the modified spike and there may be 1 to 3 per maize plant. The maize grains which are known as kernels are sheathed in husks and aggregate 30 to 1,000 per ear. Depending on the variety, the kernel can be white, purple, yellow, red, or black (Zhong *et al*., 2021).

## 2.3 Nutritional value

The nutritional quality of maize has been said to be poor due to its lack of two essential amino acids, namely; tryptophan and lysine. The deficiency of these amino acids in maize inhibits its protein contents. However, discovery of opaque-2 gene has revolutionized the research on improving the nutritional quality of maize. This has therefore resulted in the production of the present-day ‘quality protein maize’ (QPM) (Chaudhary *et al.*, 2014). The level of zein or prolamin has also been reduced by 50% while increasing the level of tryptophan and lysine double. Maize is naturally rich with carotenoids including beta-carotene, zeaxanthin lutein, and cryptoxanthin which have different health benefits extending from normal vision maintenance to oxidative stress lowering. This has been revealed in a study by Colombo *et al.* (2021) that source of micronutrients and phytochemicals such phenolics and carotenoids present in yellow and orange maize, anthocyanins present in blue, purple and black maize, phlobaphenes present in red maize and other insoluble and soluble dietary fibre aid in preventing diseases. Many efforts have also been made in developing maize fortified with iron, zinc and provitamin. A concentration. Bailey *et al*. (2015) and Rautiainen *et al.* (2016) have revealed that more than 2 billion people in Africa, Asia, and Latin America suffer from deficiencies of micronutrient that usually lead to retarded physical growth, impaired cognitive development, pregnancy complications, reduced work and income earning ability and risk of morbidity and mortality. This initiated the development of improved cultivars and has resulted in QPM rich in two essential amino acids; orange maize which is fortified with provitamin A (Maqbool *et al.*, 2021) and high zinc enhanced maize ((Andersson *et al.,* 2017). The improvement in the higher content of tryptophan and lysine, kernel zinc and provitamin A have been successful as a result of conventional breeding.

## 2.4 Uses

Maize is a staple crop for most Ghanaians and Africans. It plays a significant role in the livestock and poultry industry. This is because maize forms more than 65% of feed used in the livestock and poultry industry (Dei, 2017). Again, maize has the highest dietary energy value with low variability from year to year among cereal used for feeding domestic birds (Moss *et al.*, 2020). It has been established that there are over five hundred industrial products obtained from industrial processing of maize, usually from the main end-products of processing of starch and nutritive sweeteners (Sangwan *et al*., 2014). It is also an essential ingredient in the manufacture of alcoholic beverages such as maize beer and whiskey. Furthermore, the crop is used for the preparation of corn flakes, maltodextrins, corn oil, and corn syrup.

## 2.5 Varieties

Varieties of maize grown in Ghana include; "*Obatanpa, Omankwa, Aburotia, Dobidi, Mamaba, Dadaba* and *Okomasa"* In addition, extra-early maturing and quality protein maize varieties tolerant of drought and resistant to weeds have been released to farmers. They are Golden Jubilee, *"Aziga"* (meaning big egg in Ewe), *"Etuto-Pibi"* (meaning father's child in Gonja) and *"Akposoe"*. Badu-Apraku *et al.* (2014) reported that nearly 80% of the farmers in Africa predominantly grow local maize varieties because they can recycle seeds for many seasons, whilst about 20% grow improved varieties, often in addition to the local varieties. Farmers prefer *Omankwa* because they can be grown in both seasons since they are drought tolerant and serve as a risk management strategy since the short rainy season is generally unreliable and be able to survive despite the odds of harsh environment, including *Striga hermontica,* low soil fertility and drought (Badu-Apraku *et al.,* 2014). They however, assert that this has been through expansion of land under maize cultivation rather than productivity.

Studies have shown that improved crop varieties (ICV) are one of the strategies to increase agricultural productivity. This, therefore, shows low adoption of improved crop varieties by Ghanaian farmers. Another research has confirmed that just 35% of agricultural land in Africa are assigned for ICV (Danso-Abbeam *et al.,* 2017). In Ghana, the Crops Research Institute of Ghana (CRI) and Savannah Agricultural Research Institute (SARI) under the Council for Scientific and Industrial Research (CSIR) have developed and released many improved maize varieties (IMV) for cultivation by farmers across the country. These varieties have been developed to different and specific ecological zones in the country. They have distinct features such as short maturity periods and improved yields which help in solving problem of hunger and low-income farmers. The improved maize varieties have been improved to provide better nutritional benefits when consumed by livestock or human. Regardless of the IMVs released by CSIR, economically attainable yield is low. For instance, the national average yield stands at 1.9 t/ha while trials at on-farm suggests attainable yield of 4 to 6 t/ha for the crop (Danso-Abbeam *et al*., 2017). Some improved maize varieties developed by CSIR are shown in Table 2.1.

**Table 2.1: Some varieties of maize release and registered in Ghana**

| **Variety** | **Character** | **Value and use** | **Preferred Ecology** |
|---|---|---|---|
| Golden Crystal | Yellow dent/flint<br>105 – 110 days maturity period | Suitable for poultry and livestock feed | All ecologies in Ghana |
| Obatanpa | White dent,<br>105 – 110 days maturity period | QPM, excellent for enhanced nutrition and health of humans | All ecologies in Ghana |
| Mamaba | White flint,<br>105 – 110 days maturity period | QPM, excellent for enhanced nutrition and health of humans | All ecologies in Ghana |
| Dadaba | White flint,<br>105 – 110 days maturity period but drought tolerant | QPM, excellent for enhanced nutrition and health of humans | All ecologies in Ghana |
| Cida-ba | White flint,<br>105 – 110 days maturity period but drought tolerant | QPM, excellent for enhanced nutrition and health of humans | All ecologies in Ghana |
| Dodzi | White dent/flint,<br>80 – 85 days maturity period | Useful to break hunger gap before main harvest | Guinea and Sudan Savannah |

| Variety | Character | Value and use | Preferred Ecology |
|---|---|---|---|
| CSIR- Golden Jubliee | Yellow dent/flint, 105 – 110 days maturity period | QPM, suitable for livestock and poultry production (high carotene enhance yellow colour of egg yolk, reduction in fish meal when added to feed), excellent for enhanced nutrition and health of humans | Forest and forest transition zones |
| CSIR – Aziga | Yellow flint and dent, 105 – 110 days maturity period | QPM, suitable for livestock and poultry production (high carotene enhance yellow colour of egg yolk, reduction in fish meal when added to feed), excellent for enhanced nutrition and health of humans | Forest and forest transition zones |
| Ewul-boyu | Days to 50 Anthesis (58-60), days to 50% silking (61-62), cream silk colour, white flint/dent, 1000 grain weight (384.8 g), 110 days maturity period | Excellent seed quality, good yield across many locations, medium maturity, drought tolerant, resistant to logging and diseases, potential yield (5.4 t/ha) | Guinea and Sudan savannah, transitional zone |
| CSIR – Abontem | Drought and striga tolerant, yellow flint 75 – 80 days maturity period. | QPM yellow, good for poultry and livestock, potential yield (4.7 t/ha) | Most suitable for the Guinea and Sudan savannah |

***Source:*** *CSIR, 2020.*

## 2.6 Production estimate of maize in Ghana

Pauw (2022) reported that support from the government of Ghana in terms of fertilizer, provision of improved seeds, extension services and marketing, in addition to favourable rains has benefitted crop yield in the country. They attested that although maize faced some challenges including flood and attack of Fall Armyworm (FAW), the total cereal output was estimated at 4.6 million tonnes, which is above average level. Out of this figure, maize alone contributed 3 million tonnes. In 2019, maize contributed 2.9 million tonnes as against the total average of 4.4 million tonnes output of cereal in the country. This, therefore, shows a percent change of 5.5% (Pauw, 2022). Despite the increase in maize production, 2020/21 marketing year forecast has revealed that the country is said to import above-average level of 1.7 million tonnes of maize in 2021. This is due to local traders' aim of replenish their stocks.

**Table 2.2: Maize Production Estimate in Ghana**

| YEAR | VALUE (kg/ha) | CHANGE, % |
|---|---|---|
| 2020 | 3,000 | 3.45 |
| 2019 | 2,900 | 25.76 |
| 2018 | 2,306 | 14.67 |
| 2017 | 2,011 | 16.78 |
| 2016 | 1,722 | 1.77 |
| 2015 | 1,692 | -3.97 |
| 2014 | 1,762 | -0.11 |
| 2013 | 1,764 | -9.54 |
| 2012 | 1,950 | 15.80 |
| 2011 | 1,684 | -10.04 |

***Source**: FAO/GIEWS Country Cereal Balance Sheet (2021).*

## 2.7 Climatic and soil requirements

### *2.7.1* Climatic requirements

Maize is grown between latitude 58°N and latitude 40°S in tropical, subtropical and temperate areas. *Zea mays* is a warm weather crop that can tolerate high temperatures and intense sunlight but is very sensitive to cool temperatures as it is not acclimatized to low temperatures (Hama & Mohammed, 2019). Hence, it cannot thrive in an area with an average daily temperature below 19°C or where the average temperature during summer time is below 23°C (Boateng, 2013). This implies that maize can tolerate most climatic conditions but thrives better under warm sunny conditions where there is sufficient moisture. Maize yields are significantly affected when the temperature is about 32°C. Again, in temperate areas, frost is a major challenge as it can negatively affect maize at every growth stage. Thus, for maize to thrive in temperate areas, about 120 to 140 days of no frost is needed (Boateng, 2013). Furthermore, from temperatures of 5°C to 7°C, photo-inhibition sets in, damaging the physiology of the maize plant as a result of the reduced photosynthetic activities. Since photosynthesis is the main factor for the growth of maize, short days and excess clouds usually reduce the yields of maize.

Even though maize is considered to be a water-efficient crop, significant amounts of water is required if the aim is to achieve high yields. In temperate regions, 500 to 600 mm of water is needed during the season but up to about 900 mm might be required under irrigation in tropical climates (Boateng, 2013). In rain-fed conditions, which is the most common among farmers in Africa, evenly distributed rainfall and stored soil water is required for maize cultivation. In maize production, water demand increases steadily, from germination to vegetative growth phase. According to Hama & Mohammed (2019), high yields of maize mean high water demand. The authors further stated that the required amount of water for 10 tonnes of maize to be achieved in a season is typically around 500 mm. Therefore, in order to achieve high yields, this minimum quantity of water should be supplied to be utilized by the maize crop.

### *2.7.2 Soil requirement*

Even though maize thrives in most soils, it requires well drained sandy loam, loamy and silty clay soils with a pH of 5.7 to 7.5 for optimum yields. The maize crop, however, cannot survive under compact clayey and sandy soils. The top soil has to be deep (at least 1m) and fertile, with high water holding capacity. Therefore, soils with high depth and good amounts of organic matter which can store plant-available moisture are preferred for maize cultivation (Hama & Mohammed, 2019). The most relevant soil property in maize production is the soil water storage, which is determined by the texture and structure of the soil. Meanwhile, in Ghana, traditional agricultural practices have been used in growing maize over the years, which disturb the soil structure. For instance, the basic form of tillage for maize production in Ghana is seasonal ploughing of the soil, which is sometimes supplemented by other practices such as burning of crop residues, harrowing and fertilizer application, among others.

To some extent, these practices have impact on the soil structure and soil composition due to the disturbance and compaction they cause on the soil (Atakora *et al.,* 2014). Furthermore, the topsoil become susceptible to wind and water erosion, leading to loss of organic matter but less water retention. Ultimately, these conventional agricultural practices lead to infertile soils which result in poor maize yields. Evidently, most soils in Ghana are low in fertility. For instance, studies have shown that the soils of major maize production areas in Ghana have low total nitrogen (<0.2%), organic carbon (<1.5%), available phosphorus (<10 ppm) and exchangeable potassium (<100 mg/kg) (Atakora *et al.*, 2014; Adu, 1995). Atakora *et al.* (2014) again found that most soils in Ghana are shallow with manganese and iron compressions. Despite the low fertility of soils in most areas in the country, soil fertility management is rarely practiced by farmers. FAO (2005) reported that application of fertilizer in Ghana is around 8 kg/ha, while nutrient depletion is estimated to be between 40 to 60 kg of nitrogen, phosphorus and potassium per hectare. Sufficient soil moisture is needed for good yields under rain-fed agriculture such that the maize crop can depend on the moisture stored around the root zone to overcome any water deficit caused by erratic rainfall. Thus, the ability of a soil type to hold water for a few weeks during dry periods of the season is the main determining factor of the soil potential to achieve high yields of maize. Sandy soils have low moisture holding capacity while loam and clay have high water holding capacities. Sandy soils hold less than 5% water over a soil depth of 1m while loamy and clayey loam soils can hold about 20% of their volume in 1m of depth (Hama & Mohammed, 2019). Soil moisture is necessary because, every millimetre of water utilized by the maize crop can result in about 10 to 16 kg of grains.

Furthermore, to achieve a yield of at least three tonnes per ha, the maize crop requires at least 250 litres of water, especially if the soil lacks moisture (ARC-Grain Crops Institute, 2003). In terms of soil nutrients, maize requires huge amounts of nitrogen, which is mostly applied as a top dressing when the crop is about 25 to 30 cm high. The nutrients extracted by a yield of 4 tonnes of grain per hectare was estimated at 200 kg of nitrogen per hectare, 80 kg $P_2O_5$ per hectare and 160 kg $K_2O$ per hectare (Hama & Mohammed, 2019). For optimum yields, at least a similar amount of these nutrients should be applied to the soil. That notwithstanding, soil analysis is needed in order to determine the exact quantity of nutrients to be applied on the soil. Also, either organic or inorganic fertilizers or both can be incorporated into the soil to ensure adequate supply of nutrient for the maize crop.

## 2.8 Propagation of maize

Maize is an allogamous plant that is propagated via seed which is produced mainly through cross pollination. Cell or tissue culture techniques can be employed to propagate calli and reproduce tissues or plants asexually, however, these techniques are very difficult for maize. Hence, maize is not reproduced asexually but rather through the use of seeds as planting material. According to the Agricultural Research Council (ARC) Grain Crops Institute (2015), planting depth of maize can vary from about 5 cm to 10 cm based on the soil type and the planting date. It is recommended for a shallower planting depth on heavy soils, than in sandy soils. Moreover, in maize production, the plant population per unit area is considered more essential than the specific row width. In wider rows ranging from about 1.5m to 2.1m, yields are often low or medium, wind erosion and weeds are major problems.

On the other hand, in narrow rows of about 0.9 m to 1 m, yields are quite higher, and weeds are controlled better under such conditions (Hama & Mohammed, 2019). According to Baijukya *et al.* (2020), the recommended plant population for maize production is between 37,000 to 54,000, depending on the environmental constraints as well as the variety used. Higher maize population is recommended when there is sufficient moisture throughout the growing season, coupled with good agricultural practices such as weed control. On the other hand, low population is recommended under dry conditions, for instance, dry conditions are susceptible to drought. Furthermore, it is recommended that the shorter the maize variety, the higher the plant population, and vice versa (Baijukya *et al.,* 2020). Table 2.3 shows the recommended spacing of maize under different conditions.

**Table 2.3 Recommended plant population of maize under different conditions**

| Rainfall condition | Maize type | Inter row spacing (cm) | Intra row spacing (cm) | Plant(s) per hill | Expected population/ha |
|---|---|---|---|---|---|
| Low rainfall (semi-arid areas) | All varieties | 90 | 30 | 1 | 37,000 |
| | | 90 | 60 | 2 | 37,000 |
| High rainfall (sub humid and humid areas | Tall varieties | 75 | 30 | 1 | 44,444 |
| | | 75 | 60 | 2 | 44,444 |
| | Short varieties | 75 | 25 | 1 | 53,333 |
| | | 75 | 50 | 2 | 53,333 |

***Source**: (Baijukya et al. 2020).*

## 2.9 Agronomic practices

### *2.9.1 Fertilizer application*

In order to achieve the potential yield of a crop, there is the need for the supply of sufficient and balanced nutrients to the crop. Incorporating organic manure with chemical fertilizer has been found to give better yields of maize (Geng *et al*., 2019). The exact amount of fertilizer required for different plots depend on the fertility status of the soil, past cropping history and the maturity period of the seed. It is advisable to apply fertilizer doses based on the results from a soil analysis of the plot. Geng *et al*. (2019) recommends that about 150 to 180 kg of nitrogen, 70 to 80 kg of phosphorus and 60 to 80 kg of potassium should be applied per hectare, depending on the soil fertility status, maturity period of the seed and the soil type. The timing of the application of the nutrients is equally important if the aim is to achieve high yields of maize. Generally, maize is very sensitive to nutrients, and as previously stated, the application rate is dependent on the nutrient status of the soil, the soil type and the seed type. Maize utilizes different nutrients at different stages of its growth cycle. For instance, total potassium is required for uptake at about 2 weeks after anthesis, while nitrogen and phosphorus are taken until the crop reaches physiological maturity. Phosphorus and potassium are quite stable, hence, may stay in the soil for a longer period when they are applied. However, nitrogen is very mobile, thus, it can either be taken up by the maize crop after application or lost through processes such as volatilization and leaching, among others. Therefore, for nitrogen application, split application is recommended, since over application at one stage of the crop's life might waste the nitrogen. Geng *et al.* (2019) recommended that phosphorus should be applied 100% as a basal dose at the time of planting; 40% as basal dose at planting, another 40% at 5 to 6 leaf stage and 20% at tassel emergence for potassium. For nitrogen, Geng *et al.* (2019) recommended 10% as basal dose at planting time, 20% at 2 to 3 leaf stage, 40% at 5 to 6 leaf stage, 20% at tassel emergence stage as side dressing, and 10% at the silk browning stage as side dressing.

### *2.9.2 Weed control*

Weeds are very detrimental in maize production as they compete with maize for nutrients, soil moisture, light and space which can reduce yields by about 50%. Furthermore, weeds can harbour pests and diseases. Therefore, weed management must be done properly and at the appropriate time in order to achieve higher yields. Maize is mostly susceptible to weed competition at its early growth stage. Hence, to achieve high yields, weeds should be controlled early, between two to four weeks after planting, before they outgrow the maize plants (Nunes *et al.*, 2018). Also, planting immediately after land preparation can help to minimize weeds competition. In situations where weed pressure is significantly high and time becomes a factor of concern, other means of weeding such as herbicides application must be considered. Weeds can be controlled better, cheaper, faster, less laboriously when herbicides are used. In general, the type of herbicide to be used is dependent on the type of weeds present on the field. Atrazine is a selective and broad-spectrum herbicide for maize production, which can be applied to control weeds as a pre-emergent. It can be sprayed within three days after planting at a rate of 1 to 1.5 kg per hectare. It can control both narrow and broad leaves with the exception of *Cyperus* and *Cynodont* spp (Geng *et al.*, 2019). Atrazine can keep the soil weed-free for at least one month. Glyphosate and Paraquat are the two most popular post emergence herbicides used. Nunes *et al.* (2018) recommends that Glyphosate should be applied one to two weeks before planting while Paraquat can be combined with Pendimethalin and applied right after planting. Paraquat eliminates any living weeds on the field whiles the Pendimethalin suppresses the growth of any pre-emerging weed. It is recommended that pre-emergent herbicides should be applied before the maize seedlings and weeds start emerging on the field. Also, it is important for moisture to be available when herbicides are applied to enhance intake by the weeds. The maize plant can suppress weed growth by itself during its later stages of life where it has developed canopies. Manual weeding is also necessary and recommended, when some weeds are still remaining on the plot after spraying.

### *2.9.3 Pest and disease control*

Another significant challenge in maize farming in Ghana is pests and diseases. Without effective management, pests and diseases can lead to total crop failure in extreme cases. Major pests of maize production in Ghana are fall armyworms, stem borers and grasshoppers. Major diseases include bacteria blight, maize streak, and rust. Nunes *et al.* (2018) reported that there is the need to identify the common pests and diseases available in the area, and plant resistant or tolerant varieties. For effective control of pests and diseases, planting must be done early to avoid high pest pressure that occur when planting is delayed; scouting must be done as early as the maize seedlings start emerging, to be able to monitor the level of infestation and apply the necessary controls to avoid economic losses. In situations where pests and diseases infestation are significant, judicious use of pesticides is highly recommended.

### 2.10 Harvesting and storage

Harvesting of maize should be done immediately after the grains dry, at a moisture content of 15% or less (Danso *et al*., 2017). Delaying harvesting can result in lodging of cobs and stalk and attack by birds and other pests. In dry areas such as the Savannah, maize grains can be left on the field to dry before harvesting is done. The crop can be harvested when it is spotted that the cobs have started dropping. In the Forest and Transition zones, it might still be raining when the maize matures. Thus, the maize should be harvested as soon as possible (if possible after two to three days of no rains) and dried.

Maize ears can be stored in outdoor cribs. Maize can also be shelled and kept in sacks or other containers indoors. Maize must be well dried, dehusked and shelled well before it is stored. If maize is to be stored for long, for instance, more than three months, the moisture content should be below 11%. This can help minimize aflatoxin production, which can be toxic for consumption (Adu *et al.*, 2014). Debris, insects and other unwanted materials should be removed before maize is stored. Bagged maize should be packed on pallets, away from the floor and in well-ventilated rooms. Again, insecticides may be used to protect maize grains if storage length will be long. Atelic 25 E.C and Aluminium phosphide are common types of insecticides used to protect maize grains.

## 2.11 Effect of organic and inorganic fertilizers on Soil physical and chemical properties

The application of fertilizer and management of soil nutrients are major elements that influence high yield and desired grain quality (Kakar *et al.,* 2020). Studies show that the application and different combinations of organic and inorganic fertilizers have significant influence on the physical and chemical properties of soil. According to Kumar *et al.* (2019), overuse of inorganic fertilizers leads to pollution of soil, air, and water through leaching, destruction of the physical properties of soil as well as destruction to biodiversity (which have the potential to improve soil physical property). To remedy this, incorporation of organic fertilizers has been proposed by researchers for improved soil properties, both physical and chemical, and the general nutrition of soil. Mader *et al.* (2012) asserted that the application of organic fertilizers like saw dust, animal manure, and others, or the combination of both organic and inorganic fertilizers, could alternatively reduce the overutilization of fertilizers from organic sources and improve soil fertility as well as the physical and chemical properties.

The authors further odserved that compared to inorganic fertilizers, organic fertilizers maintain soil quality, increases the organic matter content of soil, and improve the physical and chemical soil properties through decomposition of organic substances found in organic fertilizers. In support of this argument are other studies by Kakar *et al. (*2019) who observed that organic matter improves soil biodiversity, plant growth regulators, and soil nutrients. Ogun Wole *et al.* (2010) studied the effect of organic and inorganic soil amendments on soil physical and chemical properties in the savanna agro ecosystem of West Africa. The study observed that organic and inorganic input practices that involve incorporation of *C. pascuorum* will enhance the aggregate stability of soil and reduce erosion by wind. It was further observed that soil organic matter (enhanced through use of organic fertilizers) act as important bonding agents for soils that have low contents of clay. Ogun Wole *et al.* (2010) concluded that input management by use of organic and inorganic fertilizers improves macro-aggregate stability of soils and fairly enhance the stability of soil mean weight diameter. Furthermore, physical properties of soil such as soil bulk is reduced by incorporation of crop residue, while at the same time, improves soil porosity. Incorporation of crop residue in the organic and inorganic input management practices was also found to enhance soil organic concentrations sequestration in soil, as well as improved soil fertility status. Ogundijo *et al.* (2014) conducted an experiment to analyze the effect of integrated application of organic and inorganic fertilizers on Soil Organic Carbon (SOC), nitrate-nitrogen, ammonium-nitrogen, pH and exchangeable cations using poultry manure at the rate of (0, 5 and 10 t $ha^{-1}$) and NPK 20-10-10 fertilizer (0 and 120 kg $ha^{-1}$). The test crop used was maize, and it was planted for two seasons.

No treatment was applied at the commencement of the second season. The findings revealed that application of 10 t $ha^{-1}$ poultry manure and 120 kg $ha^{-1}$ NPK fertilizer improved SOC significantly ($P \leq 0.05$) as much as 55.05 % over the control and 36.29% over the sole application of 120 kg $ha^{-1}$ NPK. It was also found that the application of organic manure improved $NO^{-}_{3}$ – N of the soil. The incorporation of poultry manures also increased the compositions of Ca, Na, Mg in both years and pH at harvest in 2010. The study generally recommended the combined application of 10 t $ha^{-1}$ of poultry manure with 120 kg $ha^{-1}$ NPK 20-10-10 for improved soil fertility. According to research conducted by Boateng *et al.* (2006) on the effect of poultry manure on the growth and yield of maize, it was disclosed that the application of poultry manure increases soil N by more than 53%, with a significant increase in exchangeable cations. Considering the studies (Kakar *et al.*,

2019) and others cited, it is evident that improved practices of organic and inorganic fertilizers have the potential to significantly improve the physical properties of soil such as porosity, aeration, biodiversity, organic matter content (hence, water holding capacity), as well as soil physical bonding and stability. Moreover, chemical properties such as Ca, Na, Mg and other essential chemical elements are improved through proper combinations of fertilizer from both organic and inorganic sources.

### 2.12 Effect of Chicken Manure on Growth and Yield of Maize

Maize is a nutrient demanding crop; therefore, the supply of nutrients must be adequate and balanced during growth of the crop (Adekiya *et al.* 2020). The study asserted that maize demands large amounts of N for better growth and yield, therefore, the use of poultry manure (PM) with urea fertilizer could be very beneficial. With reference to Boateng *et al.* (2016) who postulated that Pm has the potential to increase soil N by over 53%, it could be argued that PM could increase maize yield significantly when applied in the right amount. Boateng *et al.* (2016) posited that poultry manure is cheap, readily available all-season round, environmentally friendly, has significant residual effect, and the general ability to improve soil structure relative to organic fertilizers. This makes it very essential in improving maize growth and yield.

Adeyemo *et al.* (2019) assessed the effects of poultry manure on organic matter contents, soil infiltration, and the performance of maize on two contrasting degraded alfisols in southwestern Nigeria. The PM was incorporated into the soil by use of hoes and shovels two weeks before planting. The application of the poultry manure was repeated at 4 weeks and 8 weeks from the initial application. The findings revealed that poultry manure application had a significant impact on yield parameters of maize including fresh shoot biomass, dry shoot biomass, cob weight, dry grain weight, wet grain weight and 1000 grain weight irrespective of different soil types. The findings revealed an increasing linear trend under manure rate of 4–10 mg/ha which increased maize shoot biomass significantly. The application rate of 6 mg/ha poultry manure achieved the highest fresh shoot biomass, while 8 mg/ha increased dry shoot biomass in both soil types. Furthermore, the cob and grain yield were significantly increased by poultry manure application compared with the control. The difference in outcome was attributed to the availability of more nutrients by poultry manure throughout the growing season.

The increases were also attributed to improvement in soil properties such as reduction in bulk density, improved infiltration rates and SOM signifying better aggregate stability, nutrient release, and availability of moisture. Compared to the control (0 mg/ha), manure rate at 2 mg/ha, 4 mg/ha, 6 mg/ha, 8 mg/ha, and 10 mg/ha increased cob weight by 19, 85, 98, 100, and 127% in clay loam soil type (Adeyemo *et al.* 2019). For cob weight, increases by 12%, 77%, 96%, 97%, and 113%, respectively, were recorded for sandy clay loam. In addition to the above, the recorded increases in the clay loam soil type in fresh and dry grain weight were 17%, 67%, 70%, 78%, and 109% and 51%, 98%, 87%, 99%, and 214%, respectively; while the increase recorded in fresh and dry grain weight for SCL soil type were 12%, 54%, 67%, 78%, and 89% and 11%, 26%, 41%, 50%, and 79%, respectively (Adeyemo *et al.* 2019). Finally, 10 mg/ha manure application rate increased cob weight, wet grain weight, and dry grain weight/cob by 127%, 109%, and 214%, respectively, in the CL and 113%, 89%, and 79%, respectively, for SCL soil type. Another study in the semi-deciduous rain forest zone of Ghana by Boateng *et al.* (2016) on the effect of poultry manure application on maize (*Zea mays*) growth and yields on a Ferric Acrisol soil revealed that poultry manure is a valuable fertilizer and could be used as a suitable alternative to inorganic fertilizers in the forest zone of Ghana. The various treatments of poultry manure yielded higher values for height, leaf area index and biomass. The 4 t PM/ha rate produced yield of 2.07 t/ha maize grain, an outcome that is not statistically different from recorded averages of inorganic fertilizer rates of (2.29 t/ha) and 6 t pm/ha (2.60 t/ha). Findings from the application of 6 t PM/ha and 8 t PM/ha rates was not statistically significant. Similarly, split application of 4 t PM/ha (thus, 2 × 2 t PM/ha) and 2 t PM/ha + 30-20-20 kg NPK/ha achieved similar biomass and yield of maize grain as the 4 t PM/ha. As previously discoursed, the application of PM resulted in more than 53% increases of N levels.

### 2.13 Effect of Inorganic Fertilizer and Chicken Manure on Yield of Maize

The effects of inorganic fertilizers and PM on maize growth and yield have been extensively researched. Adekiya *et al.* (2020) analyzed the effects of different rates of poultry manure and split applications of urea fertilizer on soil chemical properties, growth, and yield of maize in selected agricultural states in Nigeria. The findings from the study disclosed that the application of PM and N (urea), either applied once at the onset of planting or split-applied improves the chemical properties of soil, growth and yield of maize. The results from the study further revealed that the combined application of N fertilizers and PM led to a higher yield in maize, compared with their sole forms. It was found that the application of 60 +30 + 30 + 8 $t$ ha$^{-1}$ PM or 4 $t$ ha$^{-1}$ PM treatments revealed that highest growth and yield of maize. For better maize growth and yield, the study recommended a 60 + 30 + 30 + 4 $t$ ha$^{-1}$ PM, and the application of N according to plant growth and the pattern of uptake, after the initial application of PM.

A study on the effects of integrated chicken manure and inorganic fertilizers on growth and yield of hybrid maize in Malawi revealed findings similar to that of Adekiya *et al.* (2020). The maximum maize girth and height were achieved from the combinations of CM and 22.5 kg N, a quarter of the endorsed application rate for inorganic fertilizer. There was no statistically significant effect of increasing the rate of application for inorganic fertilizer on maize growth. The fertilizer treatment combination of 4 t ha$^{-1}$ chicken manure and 90 kg N ha$^{-1}$ resulted in the maximum grain yield value of 6.3 t ha$^{-1}$. Mahmood *et al.* (2017) studied the effect of organic and inorganic manures on maize through experimental research in an agronomic research farm, University of Agriculture Faisalabad, Pakistan. Results from the study revealed that application of chemical fertilizers alongside organic manures substantially improves the yield of maize. It has been shown therefore, that the right combinations of both organic and inorganic fertilizers such as Poultry manure and N improve yield of maize.

# CHAPTER THREE: MATERIALS AND METHODS

## 3.1 Experimental Location

The field experiment was conducted at two different locations, Asante Mampong and Damongo in the Mampong Municipality and West Gonja District, respectively. In Asante Mampong, it was conducted at the university research farm, Akenten Appiah-Menka of Skills Training and Entrepreneurial Development (AAMUSTED), Mampong Campus.

In Damango, the experiment was carried out at the Agricultural College farm (AGRA farm).

### *3.1.1 Description of Experimental Location, climatic and soil conditions for Asante Mampong*

Asante Mampong is the capital of the Mampong Municipal of the Ashanti Region of Ghana. Asante Mampong is located between latitude 6°30’N to 9°45’N, and falls in the Forest-Savanna Transitional Zone of Ghana. The Municipal is a low-lying area in the south and undulating getting to the northern part. The highest point of the Municipal is around 2400 m above sea level with the lowest being 135 m above sea level. The escarpment of the Municipal extends the Kintampo-Bisa ranges. The drainage of the area consists of the rivers including Sene, Afram and Sasebonso (GSS, 2014). The mean rainfall received in the Mampong Municipal per annum is approximately 1270 mm. The Municipality also experiences two rainy seasons in a year with the major rains starting around early April and ending in July, whiles the minor rains occur in September and end in November. There is a short dry spell experience in August. The dry season begins in December and continues till March in the subsequent year. The mean temperature in a year is about 27$^{o}$ C. However, this mean temperature usually varies from 22 to 30$^{o}$ C (GSS, 2014). The soil at the experimental site is the Savanna Ochrosol derived from the Voltarian Sandstone and belongs to the Bediase Soil Series (Asiamah, 1998). It is classified as Chromic Luvisol according to FAO/UNESCO classification (FAO/UNESCO, 1988). It is reddish in colour, sandy-loam in texture, deep and free from stones and pebbles, and contains some appreciable amount of organic matter. Human activities such as production of charcoal, bush fires and lumbering have negatively affected the vegetation in the Municipal with the north-eastern area being degraded into a Savannah land.

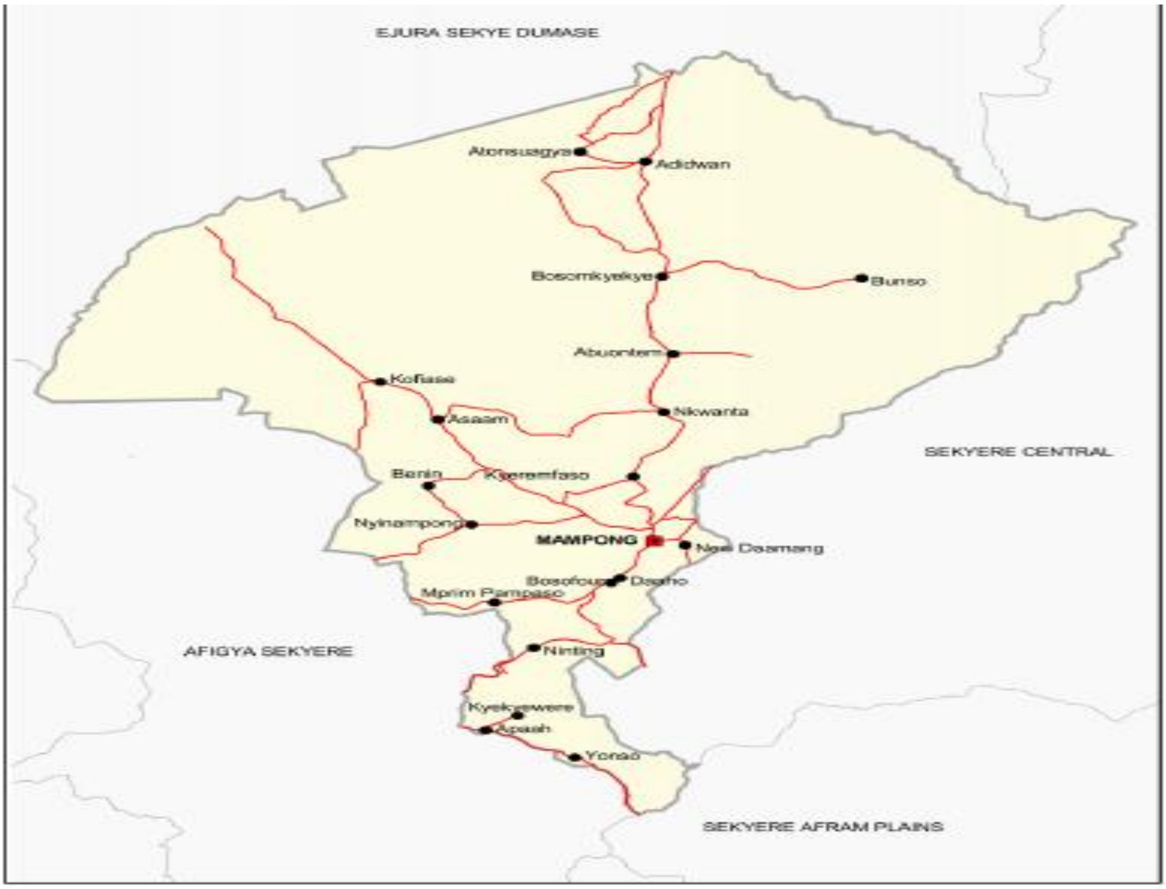
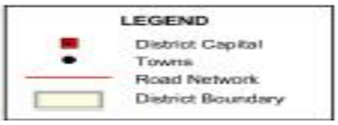


**Figure 3.1: District map of Mampong Municipal. Source: GSS, 2014)**



### *3.1.2 Description of Experimental Location, climatic and soil conditions of Damango*

Damongo is the capital of the West Gonja District, which is located at the western part of Tamale, the Northern Regional capital. Geographically, Damongo lies at longitude -1.81884 and latitude 9.08296 (GEODATOS, 2020). The district occupies a total land area of about 4715 square kilometres (GSS, 2014). Again, Damongo is bounded to the west by Sawla-Tuna-Kalba and Bole Districts, to the south by Central Gonja District, to the north-west by Wa East District and to the east by North Gonja District. The topography of Damongo is mostly undulating and has altitudes between 150 to 200 meters above sea level. The Damongo Escarpment which lies at the northern part of the Damongo is the only high land in the district. The Mole River from the north of the district joins the White Volta River to the east of Damongo and joins the Black Volta in the Central Gonja District around Tuluwe which is located in the Savanna region. Damango falls in the Guinea Savannah agroecological zone of Ghana.

The temperature of Damongo is usually high with the maximum temperatures recorded during the dry seasons (March and April). The average annual temperature in the area is $30^{o}$ C. The temperatures are lowest between December and January in the District. The Harmattan winds characterise the dry seasons of the district which is dusty, dry and very cold in the morning but hot at noon. There is high soil moisture deficit due to the extremely high evaporation in the area. The rainfall pattern of the district is unimodal with a mean rainfall of about 1,144 mm per annum (MoFA, 2020). Again, the rainfall pattern in the area is uneven, which starts during the latter part of April and ends late in October. Rains in Damongo are stormy and heavy with rains of 300 mm per hour (GSS, 2014). There are frequent floods and increasing erosion in the area due to the heavy downpours.

The rocks in the West Gonja District which includes Damango are mostly of Voltaian gold. The Alluvial Formations have sandstones and mudstones. The western part of the district capital is constituted with granite material which has low fertility. That notwithstanding, there are rich alluvial sandy deposits occurring at the Damongo and Kenikeni Forest Reserves. Due to the Voltaian Formation of the area, underground water utilization is restricted. The extreme western part of Damongo is composed of granitic material of low fertility. Rich alluvial sandy deposits occur around Damongo and the Kenikeni Forest Reserves.

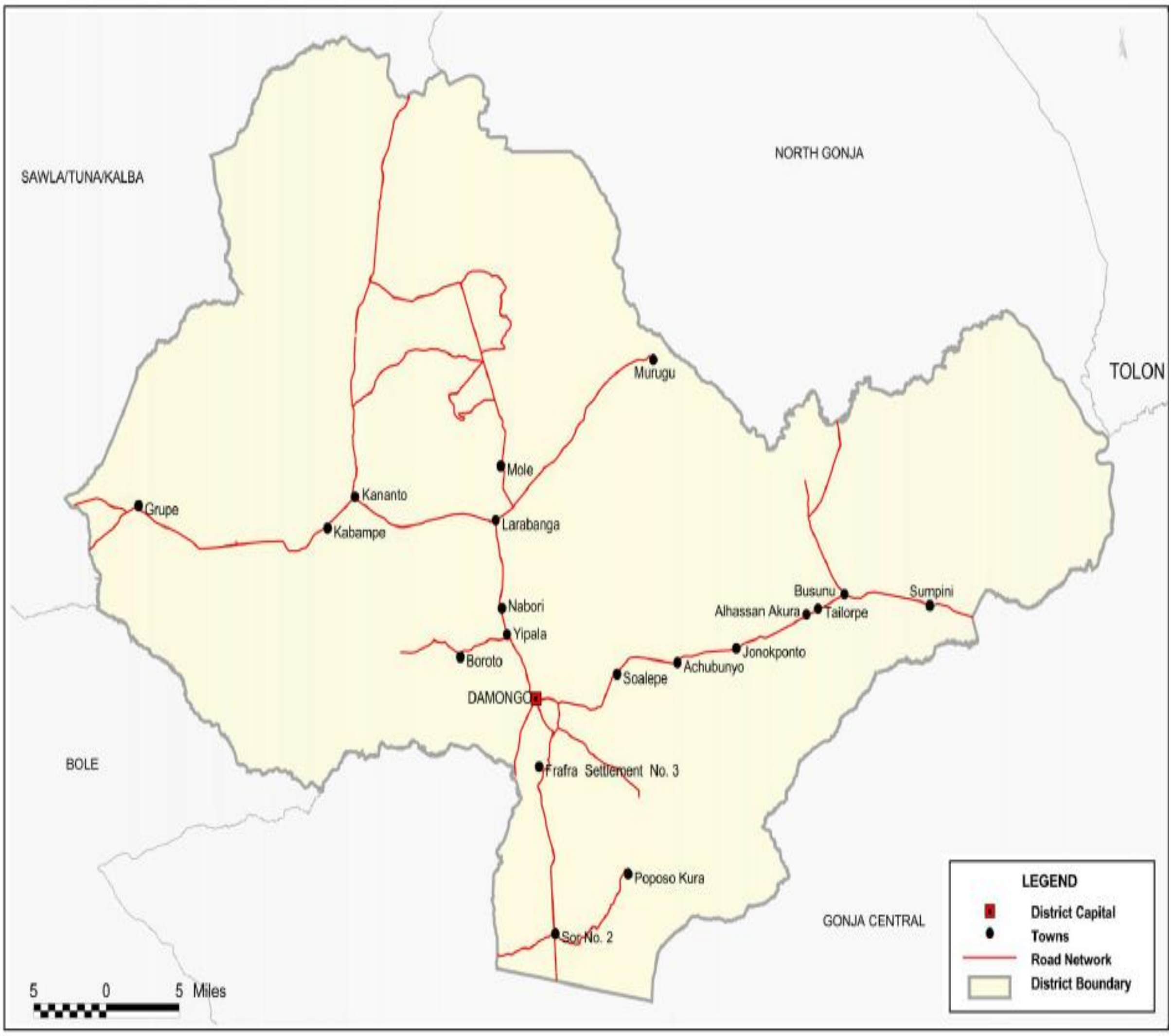


**Figure 3.2 District Map of West Gonja District. Source: GSS (2014)**

## 3.2 Experimental Design and Treatments

The experimental design used for the study was a 2 x 5 factorial experiment arranged in randomized complete block design (RCBD) with three replications. The factors were; four different fertilizer rates (chicken manure and NPK fertilizer) plus the control (without amendment) imposed on two varieties of maize. In all, there were ten treatments as shown in Table 3.1 below.

**Table 3.1 Details of fertilization treatments**

| Treatment | Variety | Fertilizer rate |
|---|---|---|
| $T_1$ | Abontem | 3 t/ha chicken manure (CM) |
| $T_2$ | Abontem | 250 kg/ha NPK (15:15:15) |
| $T_3$ | Abontem | 1.5 t/ha CM + 125 kg/ha NPK ($\frac{1}{2}$ CM + $\frac{1}{2}$ NPK) |
| $T_4$ | Abontem | 2.25 t/ha CM + 62.5 kg/ha NPK ($\frac{3}{4}$ CM + $\frac{3}{4}$ NPK) |
| $T_5$ | Abontem | No fertilizer (control) |
| $T_6$ | Obatanpa | 3 t/ha CM |
| $T_7$ | Obatanpa | 250 kg/ha NPK (15:15:15) |
| $T_8$ | Obatanpa | 1.5 t/ha CM + 125 kg/ha NPK ($\frac{1}{2}$ CM + $\frac{1}{2}$ NPK) |
| $T_9$ | Obatanpa | 2.25 t/ha CM + 62.5 kg/ha NPK ($\frac{3}{4}$ CM + $\frac{3}{4}$ NPK) |
| $T_{10}$ | Obatanpa | No fertilizer (control) |

## 3.3 Cultural/Management/Agronomic Practices

### *3.3.1 Chicken Manure preparation*

The chicken manure used for the Asante Mampong experiment was obtained from deep litter system from the poultry farm at AAMUSTED, Mampong campus and heaped under shade for two weeks. Similarly, the chicken manure used for the Damongo experiment was obtained from deep litter system from the poultry farms located in Damongo and heaped under shade for two weeks. Chicken manure decomposition was done on 4th May to 19th May in Damongo, and in Mampong, it was done on 3rd August to 17th August, 2020. The chicken manure in both cases was covered with a polythene sheet to aid further decomposition.

### *3.3.2 Field layout and land preparation*

A total field size of 37.0 m × 18.4 m (680.8 $m^2$) was demarcated at both sites, stumps were removed, ploughed and harrowed thereafter lined and pegged. Each experimental plot measured 3.2 m x 4.8 m. The gap left between plots was 1 m whereas between blocks was 2 m.

### *3.3.3 Chicken manure application*

Chicken manure was applied to plots according to treatment and incorporated into the soil. This was left for one week before planting was done.

### *3.3.4 Planting Materials and Planting*

The planting materials used for both experiments were two varieties of maize, '*Abontem*' and '*Obatanpa*', developed and released by the Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI). Both maize varieties were obtained from CSIR-CRI, Kumasi. The selection of these maize varieties was based on their characteristics as described in Table 2.1. Each experimental plot measured 3.2 m wide x 4.8 m long (15.36 $m^2$). Three seeds per stand was sown. This was done on 21st September, 2019 for the minor season at Mampong and 15th May 2019 for the major season at Damongo. The seeds were sowed in rows at the depth of 4 - 5 cm. The planting distance was 80 cm between rows x 40 cm within rows. Each experimental plot contained four (4) rows with (24) plants per row. Seedling emergence started four (4) days after sowing and one week later refilling was done. Seedlings were thinned to two plants per hole at eight (8) days after emergence. There were forty-eight (48) plants in the harvest area (two middle rows) per plot.

### *3.3.5 Weed control*

A pre-emergence herbicide was used to control the weeds before sowing and after ploughing. Weed control was done by hoeing and hand pulling at 3, 6 and 9 weeks after planting. This was done to minimise competition for soil nutrient, space and other essential growth resources.

### *3.3.6 Fertilizer Application*

NPK fertilizer was applied to the maize plants two weeks after planting according to treatment. Sulphate of ammonia was applied six weeks after planting as top-dressing by using side placement method of application to maize plants. Sulphate of ammonia was applied to NPK (15:15:15) treated plots at the rate of 192g, 96 g and 48g for full NPK, half NPK and one fourth NPK treatments, respectively.

### *3.3.7 Pest and Disease control*

Incidence of pest and disease was monitored periodically by frequent visit to the experimental Sites to check for disease such as rust, early leaf spot and late leaf spot and pest such as cartapillar, fall army worm, stem borer. Insecticide Bypel 1 (Pr Gv: Bt) *Bacillus thuringiensis* (16000/N/mg) per knapsack was applied four weeks after planting using CP 15 (15 litre) knapsack sprayer on the maize to control fall army worm.

## 3.9 Data Collected

### *3.9.1 Soil sampling*

The soil at the experimental sites were sampled at 0 - 25 cm depth prior to planting, bulked, and sub-sampled from each experimental unit prior to application of inorganic fertilizer. The soil samples were air dry, sieved through 2.00 mm and 0.05 mm mesh for physical and chemical analysis. The soil analysis was done at the Soil Research Institute, Kwadaso in Kumasi to estimate the amount of nutrient content present as well as physical and other chemical properties of the soil. This was done for each experimental site before planting and after harvesting.

### *3.9.2 Phenological data*

#### *3.9.2.1 Percentage plant establishment*

The percentage plant establishment was estimated at 30 days after planting as the percentage of seedlings in the two harvestable rows have established and was expressed over the number of seedlings expected and the mean recorded.

#### *3.9.2.2 Days to 50% tasseling*

This was estimated when 50% of the plants in the two harvestable rows have tasselled from the day of planting and the mean estimated.

#### *3.9.2.3 Days to 50% silking*

This was estimated when 50% of the plants in the two harvestable rows have formed silks from the day of planting and the mean recorded.

#### *3.9.2.4 Days to 50% maturity*

This was determined as the number of days when plants within the harvestable rows have fully matured and undergone senescence from the day of planting of maize seeds to maturity and the mean recorded.

### *3.9.3 Vegetative growth data*

#### *3.9.3.1 Plant height*

Plant height was measured from four randomly selected and tagged plants in the two harvestable rows. The plant height was measured from the base of the plant at soil level to the apical part of the stem at 30 days after planting and every two weeks interval and the mean estimated.

#### *3.9.3.2 Stem diameter*

The diameter of the plant was measured with Vernier calliper from the base of the stem on four randomly selected tagged plants from the two middle rows from 30 days after planting and at every two weeks interval and the mean estimated.

#### *3.9.3.3 Number of leaves per plant*

The total number of leaves per plant was counted from four randomly selected and tagged plants in the two harvestable rows at 30 days after planting and at every two weeks interval and the mean estimated.

#### *3.9.3.4 Root dry weight*

Four plants were randomly selected from the two border rows. They were then uprooted and separated into shoot and root, and later 200 g were enveloped for the determination of dry weight using electronic weighing scale by putting them in an oven at 70 ºC till constant temperature. The root dry weight was taken at 30 days after planting and every fourteen days interval up to 72 days after planting.

### *3.9.4 Physiological growth parameters*

Data were calculated on crop growth rate (CGR) and relative growth rate (RGR) to see their impact on maize at both Mampong and Damongo. In order to determine total dry weight from 30 days after planting to harvesting time. Samples were oven dried at 75°C for 72 hours and the mean dried weight was determined by using an electronic weighing scale. Total dry weight was used to determine crop growth rate and relative growth rate as indicated in the formulas below (Aliabadi *et al.,* 2008).

RGR = $\frac{Ln\,W2-Ln\,W1}{T2-T1}$, Where RGR=relative growth rate; $LnW_2 - LnW_1$ = Natural logarithm of dry matter variations; $T_2 - T_1$ = Time variations as day

CGR =$\frac{W2-W1}{T2-T1}$ x $\frac{1}{GA}$, Where CGR=Crop growth rate; $W_2 - W_1$ = Dry matter variations; $T_2 - T_1$ = Time variations as day.

### *3.9.5 Yield and Yield components*

#### *3.9.5.1 Number of plants harvested*

The total number of plants harvested per plot from the two harvestable rows were counted at harvest and the mean estimated.

#### *3.9.5.2 Cob Diameter*

The diameter of five randomly selected cobs harvested from the two harvestable rows per plot was measured with Vernier callipers from the widest part of the cob after dehusking and the mean estimated.

#### *3.9.5.3 Cob length*

The lengths of five randomly selected cobs after harvest and dehusking from the two middle rows per plot were measured using a meter rule from the base to the tip of the cob and the mean estimated.

#### *3.9.5.4 100 - seed weight*

The 100 - seed weight was determined by weighing hundred (100) seeds randomly selected from mature shelled cobs within the two middle rows per plot using electronic weighing scale and the mean estimated.

#### *3.9.5.5 Number of filled cobs per plot*

The total number of filled cobs per plot from the two central rows was counted after harvest and the mean estimated.

#### *3.9.5.6 Number of unfilled cobs per plot*

The total number of unfilled cobs per plot from the two central rows was counted after harvest and the mean estimated.

#### *3.9.5.7 Number of seeds per cob*

The total number of seeds per cob on five randomly selected plant from the two central rows was counted after shelling at harvest and the mean estimated.

#### *3.9.5.8 Grain yield*

Grains from plants in the two middle rows per plot were removed by manual grain remover after harvest. The grains were weighed with an electronic weighing scale and their grain yields per plot estimated.

### 3.10 Data Analysis

The data collected was analysed in GenStat Release 11.1 (2008) using Analysis of Variance (ANOVA). Means which differed significantly were separated using the Tukey’s Honestly Significant Difference (HSD) at 5% level of significance (P = 0.05).

# CHAPTER FOUR: RESULTS

## 4.1 Physico-chemical properties of soil and manure at the experimental sites

### *4.1.1 Physico-chemical properties of the soil at the experimental site before planting and after harvesting in Asante Mampong and Damongo*

Table 4.1 shows physico-chemical properties of the soil at the experimental site before planting and after harvesting in Asante Mampong and Damongo. At Asante Mampong, the pH was 5.05 which was higher compared to the 4.75 pH at Damongo. Soil at Asante Mampong recorded the highest Phosphorus (P) value of 12.70 mg/kg compared to the least value of 4.10 mg/kg at Damongo (Table 4.1). The results also showed Nitrogen (N), Potassium (K), Calcium (Ca), Magnesium (Mg), and Sodium (Na) to be higher in Asante Mampong than those at Damongo. Similarly, with exchangeable acidity and percengtage organic carbon, Asante Mampong had the higher values compared to those in Damongo (Table 4.1). However, for percentage organic matter, soil at Damongo recorded the highest value of 1.50 compared to the least value of 0.74 recorded in Asante Mampong.

For initial particle size analysis, Damongo generally recorded the highest % sand and % clay values than to Asante Mampong. However, % silt was higher in Asante Mampong than in Damongo. For final particle size analysis, Asante Mampong had the highest % sand whereas for % clay and % silt, soil in Damongo recorded the highest. The soils at the two locations were found to be sandy loam (Table 4.1).

### *4.1.2 Final physical and chemical analysis of fertilizer treated plots*

Table 4. 2 presents results of final soil plus manure physical and chemical analysis. The 250 kg/ha NPK had similar pH value (5.83 and 5.29 respectively) at both Asante Mampong and Damongo. No fertilizer (Control) recorded the highest value for phosphorus (12.70 mg/kg) at Asante Mampong, while at Damongo the highest phosphorus value (32.75 mg/kg) was recorded by $0.75\ t/ha$ Chicken manure 62.5 kg/ha $NPK$ + Soil. For Nitrogen, $0.75\ t/ha$ CM + 62.5 kg/ha $NPK$ had the highest at Asante Mampong while 250 kg/ha NPK + Soil had the highest Nitrogen at Damongo. Generally, $0.75\ t/ha$ CM + 62.5 kg/ha $NPK$ had the highest potassium level at both locations. Calcium was higher in No fertilizer (Control) at Asante Mampong whereas at Damongo, 1.5 t/ha Chicken manure $+125\ kg/ha\ NPK$ + Soil gave the highest rate of calcium. Manganese was higher in No fertilizer (Control) at Asante Mampong while at Damongo, it was higher in 250 kg/ha NPK. Generally, Sodium (Na) was higher in 3 t/ha CM soils at both locations (Table 4.2).

**Table 4.1: Initial soil chemical analysis, and initial and final soil physical properties of soils atAsante Mampong and Damongo.**

| **Soil Samples** | | | | **Exch. Bases (cmol/kg)** | | | | **Exch. Acidity** | | **% Org. C.** | **% Org. M.** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **pH** | **P** | **N** | **K** | **Ca** | **Mg** | **Na** | **Al** | **H** | | |
| | **($H_2O$)** | **mg/kg** | **(%)** | | | | | **(cmol/kg)** | | | |
| Mampong | 5.05 | 12.70 | 0.13 | 0.30 | 4.20 | 1.80 | 0.14 | 0.42 | 0.51 | 1.10 | 0.74 |
| Damongo | 4.75 | 4.10 | 0.03 | 0.10 | 0.50 | 0.30 | 0.12 | 0.23 | 0.34 | 0.58 | 1.50 |

| | **Initial particle size analysis** | | **Final particle size analysis** | |
|---|---|---|---|---|
| | Mampong | Damongo | Mampong | Damongo |
| % Sand | 62.70 | 77.80 | 81.00 | 70.80 |
| % Clay | 4.10 | 4.10 | 9.00 | 10.10 |
| % Silt | 33.20 | 18.10 | 10.00 | 18.06 |
| Textural class | Sandy loam | Sandy loam | Sandy loam | Sandy loam |

**Table 4.2 Chemical analysis for the fertilizer treatments after harvest**

| Fertilizer treatments | pH | Avail. P mg/kg | N (%) | Exch. Bases (cmol/kg) | | | | Exch. Acidity | | % Org. C. | % Org. M. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | K | Ca | Mg | Na | Al | H | | |
| **Mampong** | | | | | | | | | | | |
| 250 kg/ha 250 kg/ha NPK | 5.83 | 6.12 | 0.26 | 0.23 | 2.80 | 0.70 | 0.08 | 0.22 | 0.32 | 1.36 | 2.34 |
| 3 t/ha Chicken manure | 5.63 | 5.93 | 0.27 | 0.26 | 3.40 | 0.30 | 0.17 | 0.38 | 0.48 | 1.44 | 2.48 |
| 1.5 t/ha Chicken manure +125 $kg/ha\ NPK$ | 5.53 | 7.25 | 0.24 | 0.33 | 3.00 | 0.10 | 0.13 | 0.40 | 0.45 | 1.56 | 0.68 |
| 0.75 $t/ha$ Chicken manure 62.5 kg/ha $NPK$ | 5.27 | 5.92 | 0.28 | 0.33 | 2.60 | 1.10 | 0.16 | 037 | 0.39 | 1.32 | 2.27 |
| No fertilizer (Control) | 5.05 | 12.70 | 0.13 | 0.30 | 4.20 | 1.80 | 0.14 | 0.42 | 0.51 | 1.10 | 0.74 |
| **Damongo** | | | | | | | | | | | |
| 250 kg/ha 250 kg/ha NPK | 5.29 | 51.92 | 0.28 | 0.36 | 2.00 | 1.40 | 0.07 | 0.18 | 0.28 | 0.44 | 0.76 |
| 3 t/ha Chicken manure | 5.20 | 20.66 | 0.25 | 0.26 | 1.80 | 0.80 | 0.10 | 0.20 | 0.30 | 0.12 | 0.20 |
| 1.5 t/ha Chicken manure +125 $kg/ha\ NPK$ | 5.21 | 17.80 | 0.26 | 0.23 | 3.20 | 1.20 | 0.06 | 0.18 | 0.22 | 0.04 | 0.07 |
| 0.75 $t/ha$ Chicken manure 62.5 kg/ha $NPK$ | 5.24 | 32.75 | 0.24 | 0.33 | 1.80 | 1.30 | 0.05 | 0.19 | 0.28 | 0.36 | 0.62 |
| No fertilizer (Control) | 4.75 | 4.10 | 0.03 | 0.10 | 0.50 | 0.30 | 0.12 | 0.23 | 0.34 | 0.58 | 1.50 |

## 4.2 Climatic conditions at the Experimental sites

### *4.2.1 Weather conditions at Damongo*

Table 4.3 shows the weather condition for Damongo during the major rainy season in 2019. The total rainfall was 628.9 mm. The mean maximum and minimum temperatures during the 2019 main rainy season were 33.0 $^0$C and 23.7 $^0$C, respectively and were recorded in May (Table 4.3). The highest relative humidity (92.97% and 73.71%) was recorded in June while May recorded the least relative humidity (92.37% and 66.70%).

### *4.2.2 Weather conditions at Asante Mampong*

Table 4.4 illustrate the weather condition for Mampong-Ashanti during the minor rainy season in 2019. The total rainfall for this season was 561.4 mm. The mean maximum and minimum temperatures during the 2019 minor rainy season were 31.5 $^0$C and 22.9 $^0$C, respectively (Table 4.4).The highest relative humidity (96.48% and 74.23%) respectively were recorded in October and September, while the least (89.10% and 43.74%) was recorded in December during the minor rainy season.

**Table 4.3: Weather condition for Damongo during the major rainy season in 2019**

| Month | Total Rainfall (mm) | Mean Temperature ($^{0}$C) | | Relative Humidity (%) | |
|---|---|---|---|---|---|
| | | Min. | Max. | 06:00hr | 15:00hr |
| May | 101.6 | 23.7 | 33.0 | 92.37 | 66.70 |
| June | 185.5 | 22.9 | 31.3 | 92.97 | 73.71 |
| July | 184.6 | 22.5 | 29.7 | 92.67 | 73.60 |
| August | 157.2 | 23.0 | 31.3 | 92.67 | 71.34 |
| **Total** | 628.9 | | | | |

***Source: Ghana Meteorological Service, 2019.***

**Table 4.4: Weather condition for Mampong during the minor rainy season in 2019.**

| Month | Total Rainfall (mm) | Mean Temperature ($^{0}$C) | | Relative Humidity (%) | |
|---|---|---|---|---|---|
| | | Min. | Max. | 06:00hr | 15:00hr |
| September | 314.5 | 22.2 | 29.8 | 93.63 | 74.23 |
| October | 220.1 | 22.2 | 30.8 | 96.48 | 65.23 |
| November | 26.8 | 22.9 | 31.5 | 95.47 | 57.97 |
| December | 0.0 | 21.5 | 31.4 | 89.10 | 43.74 |
| **Total** | 561.4 | | | | |

***Source: Ghana Meteorological Service, 2019.***

## 4.3 Phenology

### *4.3.1 Percentage Plant Establishment*

Table 4.5 shows percentage plant establishment of maize plants as affected by Chicken manure and inorganic fertilizer during the 2019 cropping season at Damongo and Mampong. The percentage plant establishment during the 2019 cropping season for the two maize varieties (Abontem and Obatanpa) ranged from (96.6 - 97.6) and (95.0 - 97.3), respectively (Table 4.5). There was a significant (P<0.05) difference between Obatanpa and Abontem in percentage plant establishment during the 2019 cropping season (Table 4.5). Organic and inorganic fertilizer applied singly or in combination did significantly influence plant establishment across the two locations. Interactively, Obatanpa and Abontem that received 1.5 t/ha CM + 125 kg/ha NPK produced similar and low percentage plant establishment respectively than other amended and No fertilizer (Control) plots.

**Table 4.5: Percentage plant establishment of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong.**

| **Variety** | **Fertilizer** | **Percentage plant establishment** | | |
|---|---|---|---|---|
| | | **Damongo** | **Mampong** | **Mean** |
| Abontem | No fertilizer | 97.5 | 96.6 | 97.0 |
| | 250 kg/ha NPK | 97.5 | 97.5 | 97.5 |
| | 3 t/ha CM | 96.6 | 97.5 | 97.0 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 94.1 | 99.1 | 96.6 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 97.5 | 97.5 | 97.5 |
| Obatanpa | No fertilizer | 95.8 | 98.3 | 97.0 |
| | 250 kg/ha NPK | 95.8 | 97.5 | 96.6 |
| | 3 t/ha CM | 95.0 | 96.6 | 95.8 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 94.1 | 97.5 | 95.8 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 94.1 | 96.6 | 95.4 |
| | **Tukey's Hsd ($P \leq 0.05$)** | **10.84** | **6.62** | **6.06** |
| | **Mean** | **95.8** | **97.5** | **6.06** |
| | **CV (%)** | **3.5** | **2.1** | |

***Tukey's Hsd ($P \leq 0.05$); Location = 1.63 Location x Variety = 3.06***
***Location x Soil Amendments = 6.06 Location x Variety x Soil Amendments = 9.69***

### *4.3.2 Days to 50% tasseling*

Table 4.6 shows results of days to 50% tasseling of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong. The effect of site difference on days to 50 % tasseling was statistically significant (P<0.05) with an average of 1 day early tasseling at the Damongo farm site than at Mampong (Table 4.6), possibly reflecting the slower growth on the more acidic soil. There was a statistically significant (P<0.05) influence of varieties, organic and inorganic fertilizers on days to 50 % tasseling in all treatments. Obatanpa variety took more days (54 days) to tassel compared to the Abontem variety (46.4 days) in Mampong. The number of days to tasseling significantly (P<0.05) increased by an average of 3 days with application 250 kg/ha NPK. There was early tasseling in Mampong in respect to Obatanpa compared to the other when 250 kg/ha NPK was applied.

**Table 4.6: Days to 50% tasseling of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong.**

| Variety | Fertilizer | Days to 50% Tasseling | | |
|---|---|---|---|---|
| | | **Damongo** | **Mampong** | **Mean** |
| Abontem | No fertilizer | 49.0 | 47.6 | 48.3 |
| | 250 kg/ha NPK | 46.3 | 46.3 | 46.3 |
| | 3 t/ha CM | 46.3 | 45.0 | 45.6 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 47.0 | 47.6 | 47.3 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 46.6 | 45.6 | 46.1 |
| Obatanpa | No fertilizer | 59.6 | 61.6 | 60.6 |
| | 250 kg/ha NPK | 52.3 | 48.0 | 50.1 |
| | 3 t/ha CM | 57.6 | 49.0 | 53.3 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 60.6 | 51.6 | 56.1 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 54.0 | 61.6 | 57.8 |
| | **Tukey's Hsd ($P \leq 0.05$)** | **8.43** | **9.24** | **5.01** |
| | **Mean** | **51.9** | **50.4** | |
| | **CV (%)** | **11.7** | **12.3** | |

***Tukey Hsd ($P \leq 0.05$); Location = 1.35 Location x Variety = 2.53***

***Location x Soil Amendments = 5.01 Location x Variety x Soil Amendments = 8.02***

### *4.3.3 Days to 50% silking*

Table 4.7 shows days to 50% silking of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong. Abontem took a maximum of 52 days for silk production while Obatanpa took a minimum of 58 days to produce silk (Table 4.7). There was a significant difference ($P<0.05$) in terms of the number of days for silk production between the two varieties. The No fertilizer (Control) plants recorded the highest number of days (60 days) for 50% silking (Table 4.7). At Mampong, Abontem took 52 days for silk production which is one day more as recorded in Damongo while Obatanpa took 62 days in Damongo and 58 days in Mampong produce silk. Obatanpa took 4 more days to produce silk in Damongo than in Mampong (Table 4.7).

**Table 4.7: Days to 50% silking of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong.**

| Variety | Fertilizer | Days to 50% silking | | |
|---|---|---|---|---|
| | | **Damongo** | **Mampong** | **Mean** |
| Abontem | No fertilizer | 55.3 | 51.6 | 53.5 |
| | 250 kg/ha NPK | 50.3 | 55.0 | 52.6 |
| | 3 t/ha CM | 51.3 | 50.6 | 51.0 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 49.3 | 51.6 | 50.5 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 51.3 | 52.0 | 51.6 |
| Obatanpa | No fertilizer | 65.3 | 63.0 | 64.1 |
| | 250 kg/ha NPK | 60.6 | 55.0 | 57.8 |
| | 3 t/ha CM | 60.6 | 55.0 | 57.8 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 64.6 | 55.3 | 60.0 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 59.6 | 65.0 | 62.3 |
| | **Tukey's Hsd (P ≤ 0.05)** | **8.65** | **9.61** | **5.60** |
| | **Mean** | **56.8** | **55.4** | |
| | **CV (%)** | **11.2** | **9.3** | |

***Tukey Hsd (P ≤ 0.05); Location = 1.51 Location x Variety = 2.83***
***Location x Soil Amendments = 5.60 Location x Variety x Soil Amendments = 8.96***

### *4.3.4 Days to maturity*

As shown in Table 4.8 is results of days to 50% maturity of maize as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong. Abontem took 98 days to attain maturity which is not different from the case of Damongo while it Obatanpa 128 day to attain maturity. There was a significant difference (P<0.05) in terms of the days to maturity between Abontem and Obatanpa (Table 4.8). There was no significant (P<0.05) sites or seasonal effect on days to maturity. However, plants took on the average 2 more days to mature during the minor season (i.e., 115.4 days) compared to the major season (i.e., 117.2 days) for Obatanpa maize variety. The effect of varietal differences on number of days to maturity was statistically significant (P<0.05) in all experiments, with obatanpa taking on the average more days (i.e.,117.2 days) to mature compared to Abontem (i.e., 98.6 days). Plants received chicken manure matured earlier (i.e., 101 days) followed by those applied with 250 kg/ha NPK mixed with chicken manure (i.e., 108 days).

**Table 4.8: Days to 50% maturity of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong.**

| **Variety** | **Fertilizer** | **Days to 50% maturity** | | |
|---|---|---|---|---|
| | | **Damongo** | **Mampong** | **Mean** |
| Abontem | No fertilizer | 98.0 | 100.6 | 99.3 |
| | 250 kg/ha NPK | 98.0 | 100.6 | 99.3 |
| | 3 t/ha CM | 98.0 | 98.0 | 98.0 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 98.0 | 97.3 | 97.6 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 98.0 | 96.6 | 97.3 |
| Obatanpa | No fertilizer | 128.0 | 120.0 | 124.0 |
| | 250 kg/ha NPK | 128.0 | 120.0 | 124.0 |
| | 3 t/ha CM | 128.0 | 104.6 | 116.3 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 128.0 | 120.3 | 124.0 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 128.0 | 121.3 | 124.6 |
| | **Tukey's Hsd (P ≤ 0.05)** | **3.32** | **6.94** | **3.21** |
| | **Mean** | **113.0** | **107.9** | |
| | **CV (%)** | **13.5** | **9.9** | |

***Tukey Hsd (P ≤ 0.05); Location = 0.86 Location x Variety = 1.62***

***Location x Soil Amendments = 3.21 Location x Variety x Soil Amendments = 5.14***

## 4.4 Physiological Growth Parameters

### *4.4.1 Crop Growth Rate*

The results on crop growth rate (CGR) from 0-30 WAP and 90 DAP to harvest at Damongo and Mampong are presented in Tables 4.9 and 4.10 respectively. There were no significant ($P \geq 0.05$) differences between the interactive effect of variety and soil amendment on crop growth rate (CGR) at Damongo except from 60-90 DAP where the interaction between Obatanpa and 3 t/ha Chicken manure recorded significantly higher CGR (52.96 g $m^{-2}day^{-1}$) than Abontem planted on 250 kg/ha NPK amended plots (33.59 g $m^{-2}day^{-1}$) (Table 4.9). At Mampong, there were no significant ($P \geq 0.05$) differences between the interactive effect of variety and soil amendment on crop growth rate from 0-30 DAP through to 90 DAP to harvest (Table 4.10). There was a gradual increase in CGR among all treatments from 0-30 DAP to 60-90 DAP which later decreased from 90 DAP to harvest across both locations (Tables 4.9 and 4.10).

**Table 4.9: Interactive effect of variety and soil amendment on crop growth rate at Damongo**

| Treatment | Crop growth rate g $m^{-2}day^{-1}$ | | | |
|---|---|---|---|---|
| | **0-30 DAP** | **30-60 DAP** | **60-90 DAP** | **90 DAP – Harvest** |
| **Abontem** | | | | |
| *No fertilizer | 10.38 | 16.41 | 46.62ab | 26.04 |
| *250 kg/ha NPK | 7.31 | 21.35 | 33.59b | 19.74 |
| *3 t/ha CM | 9.25 | 21.35 | 34.12ab | 19.79 |
| *1.5 t/ha CM + 125 kg/ha NPK | 11.98 | 22.14 | 46.61ab | 27.59 |
| *0.75 t/ha CM + 62.5 kg/ha NPK | 8.71 | 17.71 | 38.02ab | 21.62 |
| **Obatanpa** | | | | |
| *No fertilizer | 6.61 | 20.31 | 34.38ab | 16.88 |
| *250 kg/ha NPK | 18.23 | 29.95 | 50.78ab | 28.12 |
| *3 t/ha CM | 16.86 | 27.22 | 52.96a | 25.74 |
| *1.5 t/ha CM + 125 kg/ha NPK | 10.20 | 29.17 | 46.09ab | 21.56 |
| *0.75 t/ha CM + 62.5 kg/ha NPK | 8.14 | 17.19 | 39.07ab | 20.78 |
| **Tukey's Hsd ($P \leq 0.05$)** | **NS** | **NS** | **19.01** | **NS** |
| **CV (%)** | **38.08** | **32.93** | **15.39** | **19.46** |

*V- Variety; SA- Soil amendment; DAP- Days after planting; - Interaction*

**Table 4.10: Interactive effect of variety and soil amendment on crop growth rate at Mampong**

| Treatment | Crop growth rate g m$^{-2}$day$^{-1}$ | | | |
|---|---|---|---|---|
| | 0-30 DAP | 30-60 DAP | 60-90 DAP | 90 DAP – Harvest |
| **Abontem** | | | | |
| *No fertilizer | 11.11 | 25.49 | 42.71 | 17.98 |
| *250 kg/ha NPK | 8.92 | 22.29 | 35.00 | 18.61 |
| *3 t/ha CM | 9.11 | 27.71 | 37.71 | 18.55 |
| *1.5 t/ha CM + 125 kg/ha NPK | 11.81 | 19.31 | 34.17 | 13.55 |
| *0.75 t/ha CM+ 62.5 kg/ha NPK | 13.44 | 21.11 | 36.67 | 17.95 |
| **Obatanpa** | | | | |
| *No fertilizer | 7.71 | 25.42 | 30.42 | 16.75 |
| *250 kg/ha NPK | 11.32 | 21.25 | 37.92 | 18.63 |
| *3 t/ha CM | 14.51 | 19.52 | 31.25 | 18.68 |
| *1.5 t/ha CM + 125 kg/ha NPK | 7.22 | 22.92 | 33.75 | 21.10 |
| *0.75 t/ha CM + 62.5 kg/ha NPK | 5.66 | 26.46 | 31.88 | 17.83 |
| **Tukey's Hsd (P ≤ 0.05)** | **NS** | **NS** | **NS** | **NS** |
| **CV (%)** | **32.30** | **16.24** | **21.30** | **27.72** |

*V- Variety; SA- Soil amendment; DAP- Days after planting; * - Interaction*

### *4.4.2 Relative Growth Rate*

The results on relative growth rate (RGR) from 0-30 WAP and 90 DAP to harvest at Damango and Mampong are presented in Tables 4.11 and 4.12 respectively. There were no significant (P≥ 0.05) differences between the interactive effect of variety and soil amendment on relative growth rate (RGR) across the entire period at Damango (Table 4.11). However, the highest RGR value (0.89 g m$^{-2}$/day$^{-1}$) was observed in Obatanpa maize variety planted on 1.5 t/ha Chicken manure + 125 kg/ha NPK at 0-30 DAP, whereas the least (0.02 g m$^{-2}$day$^{-1}$) was recorded by Abontem planted on 3 t/ha CM amended soils (Table 4.12). At Mampong, there were significant (P≤0.05) differences between the interactive effect of variety and soil amendment on relative growth rate from 0-30 DAP through to 60 - 90 DAP (Table 4.12). Abontem maize variety that received 3 t/ha Chicken manure recorded significantly higher RGR than same variety and Obatanpa maize variety that received 0.75 t/ha Chicken manure + 62.5 kg/ha NPK and 3 t/ha Chicken manure respectively at 0-30 DAP.

From 30-60 DAP, Obatanpa maize variety that received 0.75 t/ha Chicken manure + 125 Kg/ha NPK recorded significantly higher RGR than Abontem variety that received 250 kg/ha NPK whereas Obatanpa maize variety that received 3 t/ha CM recorded significantly higher RGR than same variety that received no amendment from 60-90 DAP (Table 4.12). However, at 90-harvest, there were no significant differences between the interactive effect of variety and soil amendment on relative growth rate. There was a decrease in RGR from 30-60 DAP to 90 DAP-harvest across both locations (Tables 4.11 and 4.12).

**Table 4.11: Interactive effect of variety and soil amendment on relative growth rate at Damongo**

| Treatment | Relative growth rate g $g^{-1}$ $m^{-2}$$day^{-1}$ | | | |
|---|---|---|---|---|
| | **0-30 DAP** | **30-60 DAP** | **60-90 DAP** | **90 DAP – Harvest** |
| **Abontem** | | | | |
| *No fertilizer | 0.74 | 0.41 | 0.22 | 0.06 |
| *250 kg/ha NPK | 0.82 | 0.55 | 0.19 | 0.03 |
| *3 t/ha CM | 0.80 | 0.55 | 0.19 | 0.02 |
| *1.5 t/ha CM + 125 kg/ha NPK | 0.82 | 0.56 | 0.14 | 0.05 |
| *0.75 t/ha CM + 62.5 kg/ha NPK | 0.78 | 0.46 | 0.17 | 0.03 |
| **Obatanpa** | | | | |
| *No fertilizer | 0.81 | 0.40 | 0.11 | 0.04 |
| *250 kg/ha NPK | 0.86 | 0.58 | 0.14 | 0.05 |
| *3 t/ha CM | 0.82 | 0.49 | 0.16 | 0.07 |
| *1.5 t/ha CM + 125 kg/ha NPK | 0.89 | 0.57 | 0.12 | 0.02 |
| *0.75 t/ha CM + 62.5 kg/ha NPK | 0.77 | 0.51 | 0.18 | 0.03 |
| **Tukey Hsd ($P \leq 0.05$)** | **NS** | **NS** | **NS** | **NS** |
| **CV (%)** | **8.98** | **18.64** | **46.78** | **48.19** |

*V- Variety; SA- Soil amendment; DAP- Days after planting; * - Interaction*

**Table 4.12: Interactive effect of variety and soil amendment on relative growth rate at Mampong**

| **Treatment** | **Relative growth rate g $g^{-1}$ $m^{-2}$$day^{-1}$** | | | |
|---|---|---|---|---|
| | **0-30 DAP** | **30-60 DAP** | **60-90 DAP** | **90 DAP – Harvest** |
| **Abontem** | | | | |
| *No fertilizer | 0.89abc | 0.42b | 0.08ab | 0.07 |
| *250 kg/ha NPK | 0.89abc | 0.39b | 0.03ab | 0.07 |
| *3 t/ha CM | 0.95a | 0.55ab | 0.03ab | 0.04 |
| *1.5 t/ha CM + 125 kg/ha NPK | 0.85bcde | 0.51ab | 0.08ab | 0.06 |
| *0.75 t/ha CM + 62.5 kg/ha NPK | 0.80de | 0.58ab | 0.13ab | 0.07 |
| **Obatanpa** | | | | |
| *No fertilizer | 0.93ab | 0.49ab | 0.01b | 0.04 |
| *250 kg/ha NPK | 0.81cde | 0.48ab | 0.12ab | 0.08 |
| *3 t/ha CM | 0.80e | 0.65ab | 0.13a | 0.04 |
| *1.5 t/ha CM + 125 kg/ha NPK | 0.90ab | 0.63ab | 0.02ab | 0.07 |
| *0.75 t/ha CM + 62.5 kg/ha NPK | 0.94ab | 0.73a | 0.02ab | 0.03 |
| **Tukey Hsd ($P \leq 0.05$)** | **0.09** | **0.30** | **0.12** | **NS** |
| **CV (%)** | **3.49** | **19.09** | **36.44** | **58.63** |

*V- Variety; SA- Soil amendment, DAP- Days after planting, * - Interaction*

## 4.5 Vegetative Growth

### *4.5.1 Plant height*

Figures 4.1 and 4.2 show plant height of the maize varieties as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong. The plant height increased linearly from 30 DAP to 86 DAP in both Damongo and Mampong locations for both Abontem and Obatanpa. Significant differences ($P<0.05$) were observed in plant height for the two varieties. Abontem was the tallest followed by Obatanpa with rapid growth. There was no significant ($P<0.05$) difference between Abontem and Obatanpa varieties in plant height in the two locations although difference exist between treatment from 30 to 58 DAP.

A significant difference exists between treatment at 72 DAPS to 86 DAPS (Figures 4.1 and 4.2). Abontem produced significantly taller plants than abontem from 72 to 86 DAPS. Similarly, there was a significant difference between treatment at 30 DAPS to 44 DAPS in Abontem in Damongo. Both varieties produced significantly taller plants from 30 DAPS to 86 DAPS in Damongo site than in Mampong (Figure 4.1 and 4.2). There was significant ($p>0.05$) difference between relative time of planting in plant height from 30 DAP to 86 DAP except from 72 DAP to 86 DAP which abontem took more days later after planting differed significantly in plant height in Damongo.

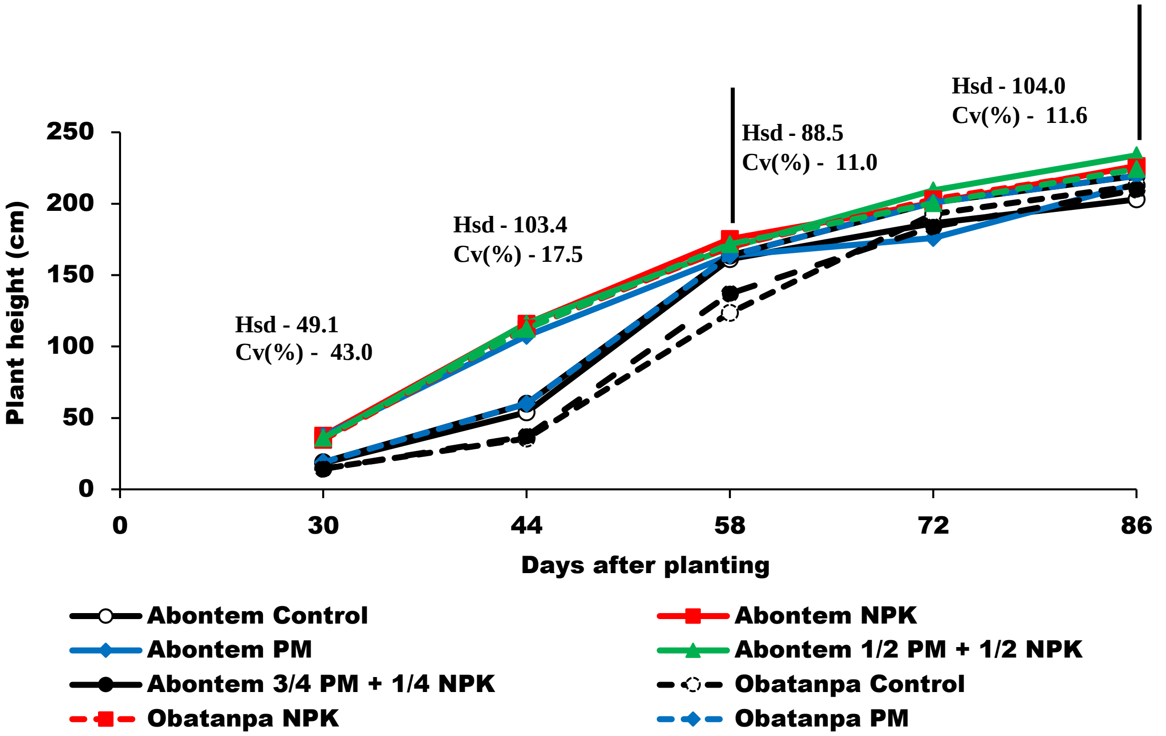


Figure 4.1: Plant height of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Damongo.

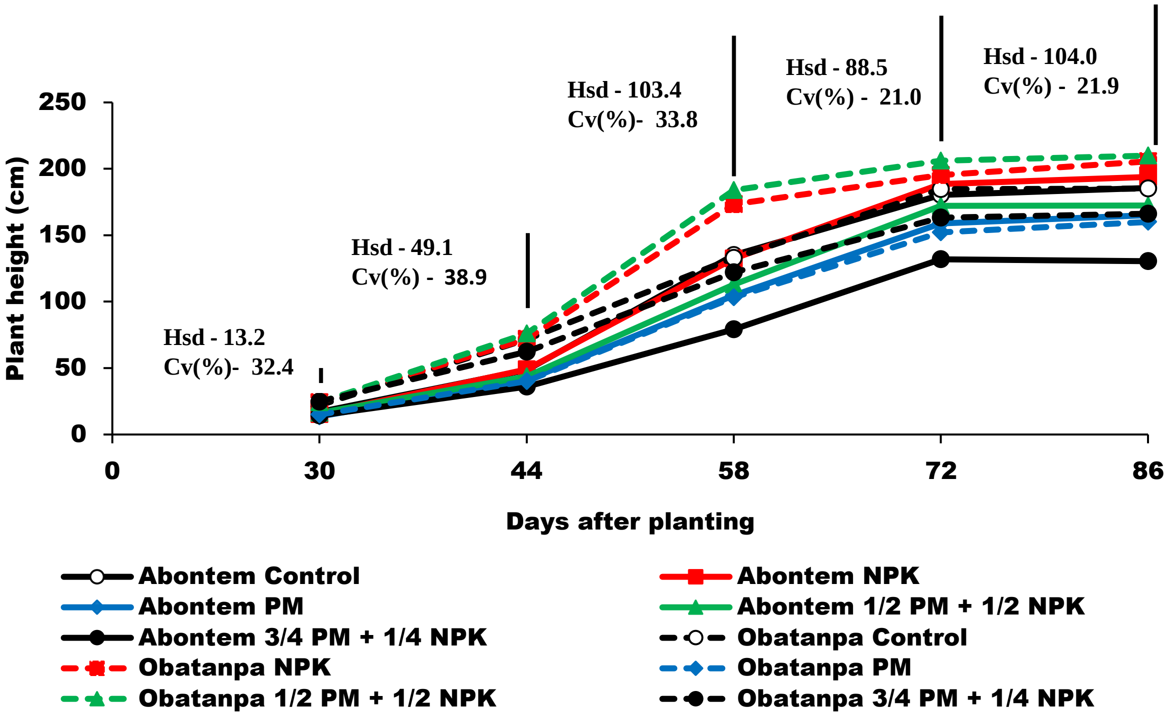


Figure 4.2: Plant height of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Mampong.

### *4.5.2 Number of leaves per plant*

Figures 4.3 and 4.4 shows results of number of leaves per plant of the maize varieties as influenced by organic and inorganic fertilizers and their combinations at Damango and Mampong. There was significant (P<0.05) difference between Abontem and Obatanpa varieties in the number of leaves per plant in the two locations from 30 to 86 DAP. The number of leaves per plant increased from 30 DAP to 86 DAP for both Abontem and Obatanpa at both Damongo and Mampong locations. Abontem produced greater number of leaves per plant than Obatanpa from 30 to 86 days of planting during the cropping seasons (Figures 4.3 and 4.4).

Obatanpa grown under 1.5 Cm + 125 kg/ha NPK and 0.75 Cm + 62.5 kg/ha NPK produced the highest number of leaves per plant after 72 and 86 days of planting than the other amended and No fertilizer (Control) plots during the cropping season (Figures 4.3 and 4.4). Both maize varieties grown on chicken manure produced the highest number of leaves per plant at 86 days of planting. Obatanpa variety produced a greater number of leaves in Damongo site than in Mampong site. Obatanpa had a significantly (P<0.05) higher number of leaves than Abontem. Generally, the soil amendments influenced the number of leaves.

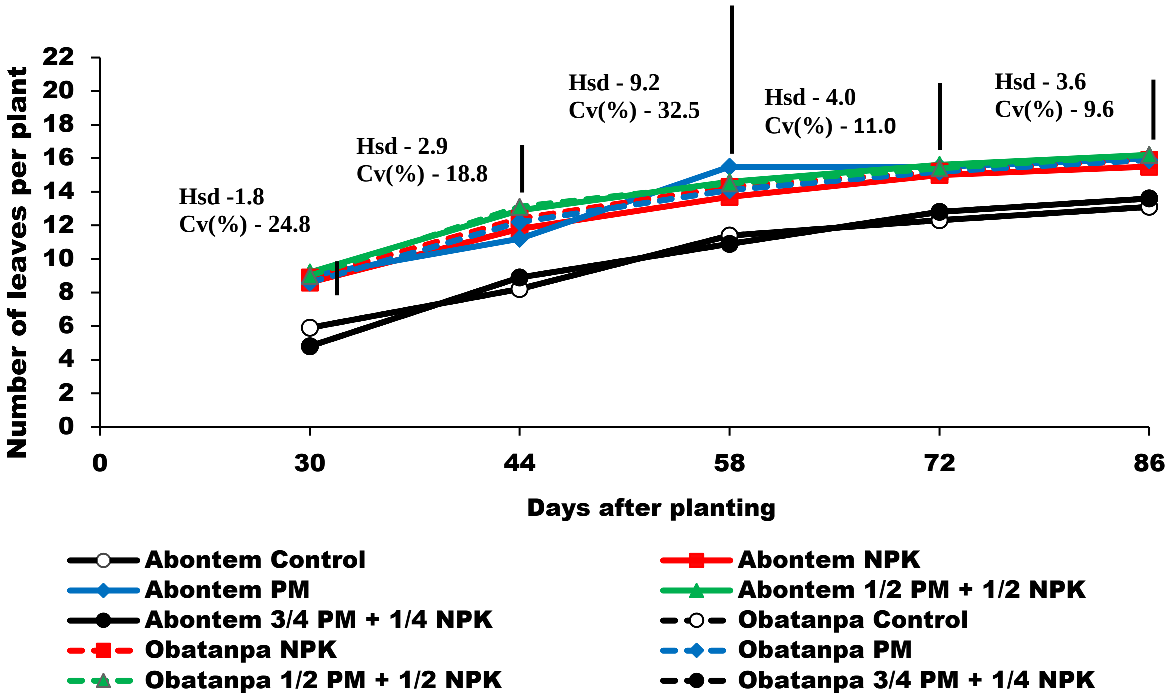


**Figure 4.3: Number of leaves per plant of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Damango.**

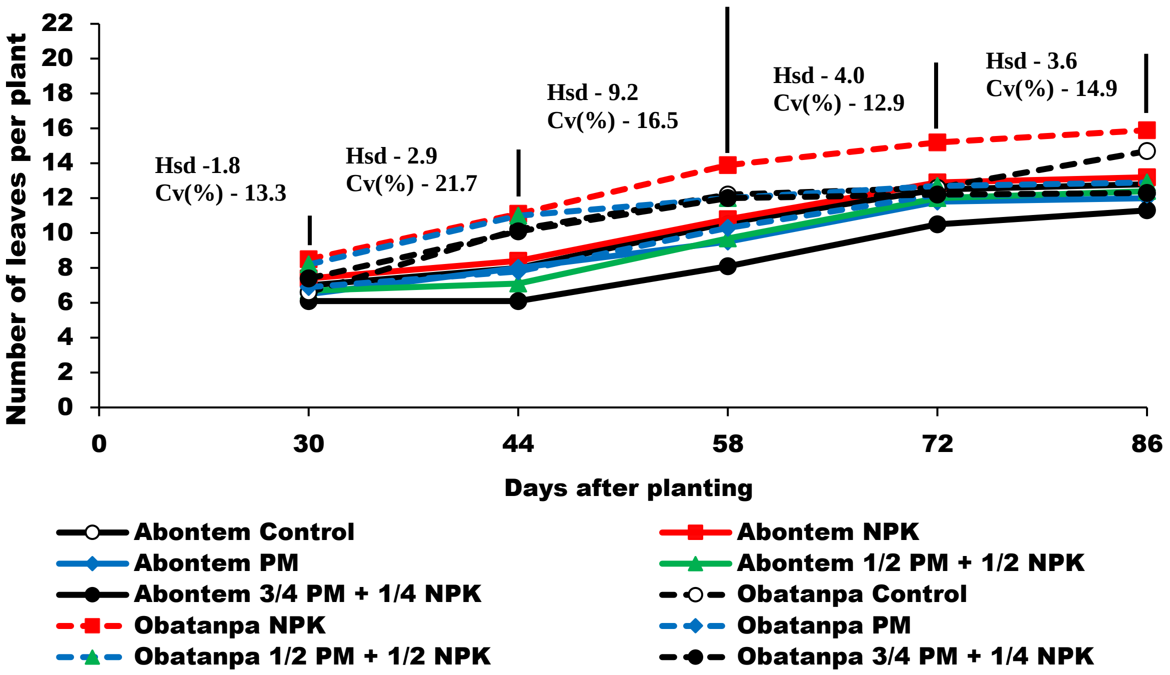


**Figure 4.4: Number of leaves per plant of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Mampong.**

### *4.5.3 Root dry weight*

Figures 4.5 and 4.6 represent results of dry root weight of the maize varieties as influenced by organic and inorganic fertilizers and their combinations at Damongo. The root dry weight was taken at 30, 60 and 90 days after planting (DAPS) at the two sites. The dry root weight increased from 30 DAP to 90 DAP at both locations for Abontem and Obatanpa. There was statistically significant ($P<0.05$) difference in root dry weight at 30 days after planting (DAPS), with 12.4% higher at Mampong (Figures 4.5 and 4.6) compared to those plants at Damongo.

Figure 4.6 showed significant varietal difference, with Abontem producing a higher average root dry weight (5.9 %) than Obatanpa. However, the varieties reacted differently to the application of 1.5 Cm + 125 kg/ha NPK, with Abontem being more responsive than Obatanpa. Generally, the application of 3 t/ha Chicken manure and 250 kg/ha NPK fertilizer significantly ($P<0.05$) increased root dry weight. There was significant increase ($P< 0.05$) in root dry weight when 250 kg/ha NPK was applied irrespective of the amount of 3 t/ha chicken manure applied. Statistically, significant ($P< 0.05$) interactive effects of 250 kg/ha NPK mineral fertilizer on root dry weight were observed. The application of inorganic 250 kg/ha NPK fertilizer significantly ($P < 0.05$) increased root dry weight by 18.3, 29.3 and 33.6 % respectively over the No fertilizer (Control). Significant differences in root dry weight at 90 days after planting (DAPS) were observed.

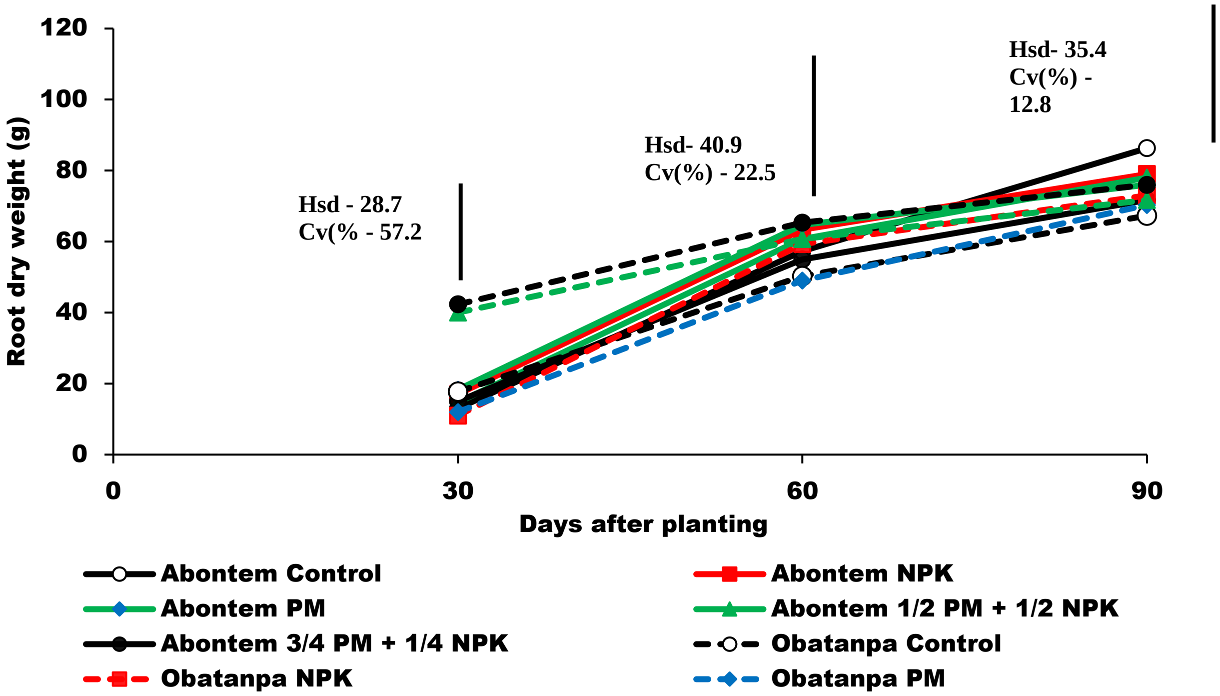


Figure 4.5: Root dry weight of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Damango.

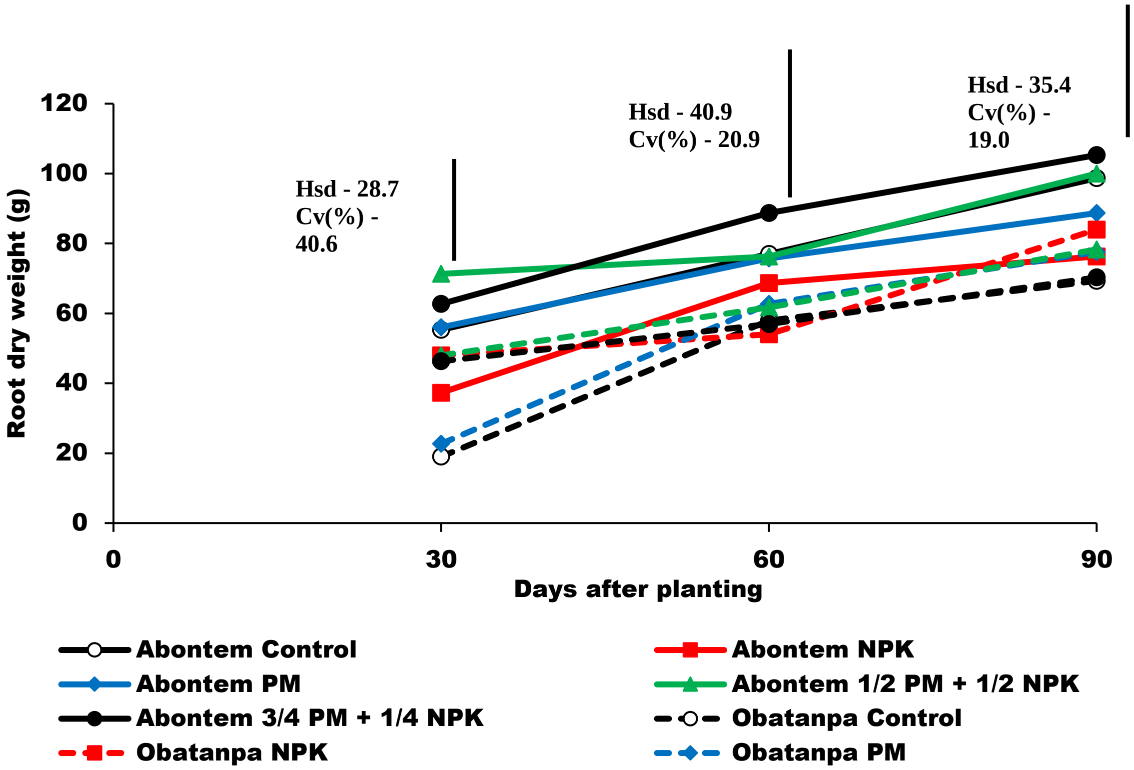


Figure 4.6: Root dry weight of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Mampong.

## 4.6 Yield and yield components

### *4.6.1 Number of plants harvested*

Table 4.10 shows number of plants harvested of Obatanpa and Abontem as influenced by organic and inorganic fertilizers and their combinations at Damango and Mampong. Overall, the results show that the Mampong site consistently produced more plants per plot than the Damongo site for both soil amendment groups. There was a significant (P<0.05) difference between the number of plants harvested per plot in Damongo and in Mampong. In terms of soil amendments, the greater effect was seen with the application of 3 t/ha chicken manure for both varieties. For Abontem, under the application of 250 kg/ha NPK, plants had lower yields compared to the treatments with the addition of organic matter (3 t/ha Chicken manure).

**Table 4.10: Number of plants harvested of the *maize varieties* as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong.**

| **Variety** | **Fertilizer** | **Number of plants harvested** | | |
|---|---|---|---|---|
| | | **Damongo** | **Mampong** | **Mean** |
| Abontem | No fertilizer | 36.3 | 37.0 | 36.6 |
| | 250 kg/ha NPK | 34.3 | 36.3 | 35.3 |
| | 3 t/ha CM | 37.0 | 38.0 | 37.5 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 34.3 | 38.3 | 36.3 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 36.0 | 38.0 | 37.0 |
| Obatanpa | No fertilizer | 35.0 | 36.6 | 35.8 |
| | 250 kg/ha NPK | 34.6 | 39.0 | 36.8 |
| | 3 t/ha CM | 35.3 | 38.3 | 36.8 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 34.3 | 38.3 | 36.3 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 37.3 | 38.0 | 37.6 |
| | **Tukey's Hsd (P ≤ 0.05)** | **7.75** | **3.82** | **4.08** |
| | **Mean** | **35.4** | **37.8** | |
| | **CV (%)** | **6.8** | **3.8** | |

***Tukey (P ≤ 0.05); Location = 1.10 Variety = 1.10 Soil Amendments = 2.45***
***Location x Variety = 2.06 Location x Soil Amendments = 4.08***
***Variety x Soil Amendments = 4.08 Location x Variety x Soil Amendments = 6.52***

### *4.6.2 Cob length*

Results of cob length of Obatanpa and Abontem as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong. There was no significant (P<0.05) differences between Obatanpa and Abontem in cob length in both study locations (Tables 4.11). Cob length of Abontem and Obatanpa was significantly influenced by 3 t/ha chicken manure plus 250 kg/ha NPK from other amended and No fertilizer (Control) plots during the cropping season. There was no significant (P<0.05) difference between amended and the No fertilizer (Control) plots in cob length during the cropping season. Abontem grown on amended and No fertilizer (Control) plots had longer cob length than Obatanpa (Table 4.11). The application of 3 t/ha Chicken manure and 250 kg/ha NPK was superior in cob length in both varieties as compared to other treatments.

**Table 4.11: Cob length of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong.**

| **Variety** | **Fertilizer** | **Cob length (cm)** | | |
|---|---|---|---|---|
| | | **Damongo** | **Mampong** | **Mean** |
| Abontem | No fertilizer | 27.6 | 27.5 | 27.6 |
| | 250 kg/ha NPK | 24.9 | 24.7 | 24.8 |
| | 3 t/ha CM | 24.7 | 25.4 | 25.1 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 27.6 | 27.6 | 27.6 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 25.8 | 26.1 | 25.9 |
| Obatanpa | No fertilizer | 18.0 | 16.1 | 17.0 |
| | 250 kg/ha NPK | 26.1 | 26.1 | 26.1 |
| | 3 t/ha CM | 27.4 | 27.3 | 27.3 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 28.8 | 29.0 | 28.9 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 16.2 | 16.0 | 16.1 |
| | **Tukey's Hsd (P ≤ 0.05)** | **6.19** | **5.96** | **3.96** |
| | **Mean** | **24.7** | **24.6** | |
| | **CV (%)** | **17.9** | **19.3** | |

***Tukey (P ≤ 0.05); Location = 1.07 Location x Variety = 2.00***
***Location x Soil Amendments = 3.96 Location x Variety x Soil Amendments = 6.34***

### *4.6.3 Cob diameter*

Results of cob diameter of Obatanpa and Abontem as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong are shown in Table 4.12. There was no significant (P>0.05) between Abontem and Obatanpa. These values were however similar to when 250 kg/ha NPK was applied alone at Mampong farm. Applications of 250 kg/ha NPK alone produced cob diameters of 4.43 (Obatanpa) and 4.23 (Abontem) all in Mampong. Mixing 0.75 t/ha Cm with 62.5 kg/ha NPK statistically out-yielded other treatments especially for Abontem.

**Table 4.12: Cob diameter of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong.**

| Variety | Fertilizer | Cob diameter (cm) | | |
|---|---|---|---|---|
| | | **Damongo** | **Mampong** | **Mean** |
| Abontem | No fertilizer | 2.77 | 4.17 | 3.47 |
| | 250 kg/ha NPK | 4.72 | 4.03 | 4.38 |
| | 3 t/ha CM | 4.59 | 3.57 | 4.08 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 4.70 | 4.37 | 4.53 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 4.80 | 4.47 | 4.63 |
| Obatanpa | No fertilizer | 2.50 | 4.17 | 3.33 |
| | 250 kg/ha NPK | 6.27 | 4.43 | 5.35 |
| | 3 t/ha CM | 4.67 | 4.00 | 4.33 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 4.53 | 4.07 | 4.30 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 4.15 | 4.37 | 4.26 |
| | **Tukey's Hsd ($P \leq 0.05$)** | **1.59** | **1.51** | **1.01** |
| | **Mean** | **4.37** | **4.16** | |
| | **CV (%)** | **25.9** | **11.6** | |

***Tukey ($P \leq 0.05$); Location = 0.27 Location x Variety = 0.51***
***Location x Soil Amendments = 1.01 Location x Variety x Soil Amendments = 1.62***

### *4.6.4 Number of filled cobs per plot*

Table 4.13 shows the results of umber of filled cobs of Obatanpa and Abontem as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong. There was a significant ($P<0.05$) difference between Obatanpa and Abontem in terms of the number of filled cobs. Obatanpa recorded 34.8 number of filled cobs against Abontem's 33.3 filled cobs at Mampong. Both varieties Abontem and Obatanpa grown under 250 kg/ha NPK differed ($P<0.05$) significantly from 0.75 t/ha Cm+ 62.5 kg/ha NPK in number of cobs per plot during the cropping season (Table 4.13). There was a significant ($P<0.05$) difference between Abontem and Obatanpa in number of filled and unfilled cobs at Damongo. Abontem under 1.5 t/ha Cm + 125 kg/ha NPK differed ($P<0.05$) significantly from chicken manure and the No fertilizer (Control) in number of cobs per plot in the same cropping season. Obatanpa grown under 250 kg/ha NPK differed ($P<0.05$) significantly from 0.75 t/ha Cm + 62.5 kg/ha NPK in number of cobs per plot during the cropping season (Table 4.13). Abontem and Obatanpa grown on amended and the No fertilizer (Control) plots did not differ significantly in number of cobs per plant during the cropping season.

**Table 4.13: Number of filled cobs per plot of maize (Obatanpa and Abontem) as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong.**

| Variety | Fertilizer | Number of filled cobs per plot | | |
|---|---|---|---|---|
| | | **Damongo** | **Mampong** | **Mean** |
| Abontem | No fertilizer | 32.6 | 34.0 | 33.3 |
| | 250 kg/ha NPK | 30.3 | 31.6 | 31.0 |
| | 3 t/ha CM | 39.0 | 34.6 | 36.8 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 29.0 | 35.3 | 32.1 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 37.67 | 31.0 | 34.3 |
| Obatanpa | No fertilizer | 38.3 | 33.0 | 35.6 |
| | 250 kg/ha NPK | 34.6 | 36.6 | 35.6 |
| | 3 t/ha CM | 30.3 | 34.6 | 32.5 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 33.0 | 34.6 | 33.8 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 36.3 | 35.0 | 35.6 |
| | **Tukey's Hsd ($P \leq 0.05$)** | **25.56** | **5.73** | **11.92** |
| | **Mean** | **34.1** | **34.0** | |
| | **CV (%)** | **23.0** | **7.5** | |

***Tukey Hsd ($P \leq 0.05$); Location = 3.21 Variety = 3.21 Soil Amendments = 7.18***
***Location x Variety = 6.03 Location x Soil Amendments = 11.92***
***Variety x Soil Amendments = 11.92 Location x Variety*Soil Amendments =19.07***

### *4.6.5 Number of unfilled cobs per plot*

Table 4.14 indicates the number of unfilled cobs per plot of maize as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong. There was no significant difference in the number of unfilled cobs between Abontem and Obatanpa at Damongo with same number of unfilled cobs (3.2). Both varieties Abontem and Obatanpa that received 250 kg/ha NPK differed (p<0.05) significantly from 0.75 t/ha Cm + 62.5 t/ha kg/ha NPK in number of unfilled cobs per plot during the cropping season (Table 4.14). There was a significant (P<0.05) difference between Abontem and Obatanpa in number of unfilled cobs at Damongo. Abontem under 1.5 t/ha Cm + 125 kg/ha NPK differed (p<0.05) significantly from chicken manure and the No fertilizer (Control) in number of cobs per plot in the same cropping season. Obatanpa under 250 kg/ha NPK differed (p<0.05) significantly from 0.75 t/ha Cm + 62.5 kg/ha NPK in number of unfilled cobs per plot during the cropping season (Table 4.14). Abontem and Obatanpa that received amended and No fertilizer (Control) did not differ significantly in number of cobs per plant during the cropping season.

**Table 4.14: Number of unfilled cobs per plot of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong.**

| **Variety** | **Fertilizer** | **Number of unfilled cobs per plot** | | |
|---|---|---|---|---|
| | | **Damongo** | **Mampong** | **Mean** |
| Abontem | No fertilizer | 3.0 | 4.0 | 3.5 |
| | 250 kg/ha NPK | 3.3 | 4.3 | 3.8 |
| | 3 t/ha CM | 3.0 | 3.6 | 3.3 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 3.6 | 4.0 | 3.8 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 3.0 | 2.6 | 2.8 |
| Obatanpa | No fertilizer | 2.3 | 3.6 | 3.0 |
| | 250 kg/ha NPK | 4.3 | 2.3 | 3.3 |
| | 3 t/ha CM | 2.3 | 3.6 | 3.0 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 3.0 | 3.6 | 3.3 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 4.0 | 3.0 | 3.5 |
| | **Tukey's Hsd (P ≤ 0.05)** | **3.69** | **4.34** | **2.71** |
| | **Mean** | **3.2** | **3.5** | |
| | **CV (%)** | **37.9** | **39.5** | |

***Tukey (P ≤ 0.05); Location = 0.73 Variety = 0.73 Soil Amendments = 1.63***
***Location x Variety = 1.37 Location x Soil Amendments = 2.71***
***Variety x Soil Amendments = 2.71 Location x Variety x Soil Amendments = 4.33***

### *4.6.6 Number of seeds per cob*

Table 4.15 indicates results of number of seeds per cob of maize varieties as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong. From these results, we can observe from the treatment that the Damongo site tends to have a higher number of seeds per cob compared to the Mampong site for Abontem variety. Similarly, for the Obatanpa variety, Damongo site has a relatively lower number of seeds per cob (409.1) compared to Mampong (428.4). There was a significant ($P<0.05$) difference between Abontem and Obatanpa varieties on the number of seeds per cob. On the soil amendments, the highest number of seeds per cob was recorded when 1.5 t/ha Chicken manure (Cm) and 125 kg/ha NPK was applied (397.0 and 468.0) for Damongo and Mampong respectively. Interactively, Abontem recorded the highest number of seeds per cob than Obatanpa during the interaction.

**Table 4.15: Number of seeds per cob of maize (Obatanpa and Abontem*)* as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong.**

| **Variety** | **Fertilizer** | **Number of seeds per cob** | | |
|---|---|---|---|---|
| | | **Damongo** | **Mampong** | **Mean** |
| Abontem | No fertilizer | 431.6 | 427.4 | 429.5 |
| | 250 kg/ha NPK | 477.3 | 421.5 | 449.4 |
| | 3 t/ha CM | 479.9 | 412.3 | 446.1 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 390.1 | 466.8 | 428.5 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 461.7 | 422.9 | 442.3 |
| Obatanpa | No fertilizer | 387.3 | 470.0 | 428.7 |
| | 250 kg/ha NPK | 396.1 | 329.6 | 362.9 |
| | 3 t/ha CM | 445.7 | 427.7 | 436.7 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 404.1 | 469.2 | 436.7 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 412.0 | 445.5 | 428.7 |
| | **Tukey's Hsd ($P \leq 0.05$)** | **166.74** | **184.52** | **117.54** |
| | **Mean** | **428.6** | **429.3** | |
| | **CV (%)** | **13.2** | **15.7** | |

***Tukey ($P \leq 0.05$); Location = 31.71 Location x Variety = 59.44***
***Location x Soil Amendments = 117.54 Location x Variety x Soil Amendments = 187.98***

### *4.6.7 Grain yield*

Results in Table 4.16 indicate grain yield of Obatanpa and Abontem as influenced by organic and inorganic fertilizers and their combinations at Damongo and Mampong. Obatanpa recorded the highest grain yield of 7.12 t $ha^{-1}$ and 6.24 t $ha^{-1}$ respectively compared to Abontem at both Damongo and Mampong. For soil amendment, 0.75 t/ha Chicken manure + 62.5 kg/ha NPK had the highest grain yield (7.55 t $ha^{-1}$) followed by 1.5 t/ha Chicken manure + 125 kg/ha NPK (7.23 t $ha^{-1}$) at Damongo. However, for soil amendment at Mampong, 1.5 t/ha Chicken manure + 125 kg/ha NPK (6.64 t $ha^{-1}$) followed by full 250 kg/ha NPK (6.58 t $ha^{-1}$). With the interactive effects, Abontem x 0.75 t/ha Chicken manure + 62.5 kg/ha NPK had the highest grain yield of 7.81 t $ha^{-1}$ at Damongo whereas at Mampong, 3 t/ha Chicken manure had the highest grain yield of 7.16 t $ha^{-1}$. The interaction between Obatanpa and 250 kg/ha NPK had the highest maize grain yield for maize (8.20 t $ha^{-1}$ and 7.42 t $ha^{-1}$ respectively) at both Damongo and Mampong (Table 4.16).

**Table 4.16: Grain yield of Obatanpa and Abontem as influenced by organic and inorganic fertilizers and their combinations at Damango and Mampong.**

| **Variety** | **Fertilizer** | **Grain yield (t ha$^{-1}$)** | | |
|---|---|---|---|---|
| | | **Damongo** | **Mampong** | **Mean** |
| Abontem | No fertilizer | 7.68 | 5.08 | 6.38 |
| | 250 kg/ha NPK | 5.73 | 7.73 | 5.73 |
| | 3 t/ha CM | 6.64 | 7.16 | 6.90 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 6.51 | 6.51 | 6.51 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 7.81 | 6.58 | 7.19 |
| Obatanpa | No fertilizer | 6.19 | 6.51 | 6.35 |
| | 250 kg/ha NPK | 8.20 | 7.42 | 7.81 |
| | 3 t/ha CM | 5.99 | 5.53 | 5.76 |
| | 1.5 t/ha CM + 125 kg/ha NPK | 7.94 | 6.77 | 7.36 |
| | 0.75 t/ha CM + 62.5 kg/ha NPK | 7.27 | 4.95 | 6.12 |
| | **Tukey's Hsd ($P \leq 0.05$)** | **4.51** | **3.23** | **2.56** |
| | **Mean** | | | |
| | **CV (%)** | **21.50** | **19.30** | |

***Tukey ($P \leq 0.05$); Location = 6.91 Location x Variety = 1.30***
***Location x Soil Amendments = 2.56 Location x Variety x Soil Amendments = 4.10***

## 4.7 Correlation analysis of growth and yield and yield components of maize for Mampong and Damongo

Table 4.17 shows results of the correlation analysis of growth and yield and yield components of maize at both Mampong and Damongo. At Mampong, grain yield was strongly and highly correlated with 100- seed weight (r=0.99). 100-seed weight was significantly correlated with cob diameter (r=0.42). Cob length was significantly correlated with stem diameter (r=0.54) and plant height (r=0.53). Stem diameter was positively and highly correlated with number of leaves per plant (r=0.81) and plant height (r=0.77). Number of leaves per plant was significantly correlated with plant height (r=0.59). At Damongo, grain yield was strongly correlated with plant height (r=0.66). Stem diameter was strongly and highly correlated with number of leaves per plant (r=0.92) while umber of leaves per plant was strongly correlated with plant height (r=0.66).

**Table 4.17: Correlation analysis of growth and yield and yield components of maize as influenced by variety and soil amendment for Mampong and Damongo.**

| **Parameters** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
|---|---|---|---|---|---|---|---|
| | | | | **Mampong** | | | |
| 1. Plant height | | 0.59*** | 0.77*** | 0.53*** | 0.16 | 0.15 | 0.04 |
| 2. Number of leaves per plant | | | 0.81*** | 0.39* | 0.15 | 0.09 | -0.03 |
| 3. Stem diameter | | | | 0.54*** | 0.20 | 0.20 | -0.10 |
| 4. Cob length | | | | | -0.08 | 0.42** | 0.12 |
| 5. Cob diameter | | | | | | -0.15 | -0.09 |
| 6. 100-seed weight | | | | | | | 0.99*** |
| 7. Grain yield | | | | | | | |
| | | | | **Damongo** | | | |
| 1. Plant height | | 0.66*** | 0.67 | 0.01 | 0.22 | -0.10 | 0.66*** |
| 2. Number of leaves per plant | | | 0.92*** | -0.13 | 0.09 | -0.17 | 0.11 |
| 3. Stem diameter | | | | -0.03 | 0.12 | -0.18 | 0.16 |
| 4. Cob length | | | | | 0.05 | -0.30 | 0.12 |
| 5. Cob diameter | | | | | | -0.06 | -0.03 |
| 6. 100-seed weight | | | | | | | -0.05 |
| 7. Grain yield | | | | | | | |

# CHAPTER FIVE: DISCUSSION

## 5.1 Effect of chicken manure and NPK fertilizer on soil physical and chemical properties

The higher pH in Asante Mampong soil than that of Damongo shows that the soil at Asante Mampong is less acidic. This higher pH could enhance the availability of certain nutrients like phosphorus, making them more accessible to plants. As stated by Kyere (2021), slightly acidic soils, like that of Asante Mampong, are often optimal for the production of a variety of crops. The lower pH suggests more acidic soil, which can limit nutrient availability and affect crop growth. According to Gurmessa (2021), acidic soils might require amendments, such as lime, to raise the pH and improve fertility.  The higher phosphorus level in Mampong soil than that of Damongo indicates better soil fertility at Asante Mampong.

Phosphorus is essential for root development and energy transfer in plants, and higher levels can lead to improved crop yields. This agrees with findings by Fathi & Afra (2023) who reported that phosphorus is essential for root development and energy transfer in plants. The lower phosphorus content suggests that the soil may need supplementation with phosphorus fertilizers to support healthy plant growth. Higher levels of nitrogen (N), potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) in Asante Mampong soil indicates more fertile soil, which can support plant growth and better crop productivity. Lower levels of these essential nutrients in Damongo suggest that the soil may be less fertile, possibly requiring fertilization to improve crop yields. Higher values of exchangeable acidity and organic carbon in Mampong suggest that the soil has a good capacity to retain and exchange nutrients, which is beneficial for long-term soil fertility and plant health whereas the lower values may indicate a reduced ability to retain nutrients, which can affect crop growth over time. Interestingly, Damongo recorded a higher percentage of organic matter compared to Asante Mampong. This higher organic matter improves soil structure, water retention, and nutrient availability, which can be advantageous for crop production. Singh *et al.* (2022) noted that the lower organic matter content may require the addition of organic materials like compost to enhance soil health and productivity. The soil at Damongo had higher percentages of sand and clay, which can affect soil drainage and water retention. According to Kyere (2021), higher sand content typically results in faster drainage but may reduce nutrient retention. Higher silt content at Asante Mampong could improve water retention and nutrient availability, making the soil more suitable for certain crops.

The final particle size analysis showed that Asante Mampong had a higher percentage of sand, which could improve drainage but may require more frequent irrigation. Both locations were found to have sandy loam soils, which are generally good for agriculture due to their balanced properties of drainage and nutrient retention. However, the slight differences in sand, silt, and clay content between the two sites suggest that they may have varying capacities for water retention and nutrient availability, influencing the types of crops that can be effectively grown at each site. The highest pH Levels by 250 kg/ha NPK + Soil can be due to balanced nutrients in NPK (nitrogen, phosphorus, potassium) which can contribute to an overall improvement in soil chemical properties, including pH. Despite not adding any fertilizer, the soil at Asante Mampong showed the highest phosphorus content which could be due to residual phosphorus in the soil from previous cropping cycles or naturally occurring phosphorus that was more readily available in the absence of added nutrients. The 2.25 t/ha Chicken Manure + 62.5 kg/ha NPK + Soil at Asante Mampong gave the highest nitrogen content and might be that chicken manure is a rich source of organic nitrogen, and when combined with NPK fertilizer, it can greatly increase the nitrogen levels in the soil, supporting vigorous plant growth. The highest nitrogen level at Damongo by 250 kg/ha NPK + Soil at Damongo could be that NPK fertilizers are designed to supply essential nutrients, including nitrogen, directly to the soil, which can lead to a significant increase in soil nitrogen levels. This support findings by Yahaya *et al.* (2023). The 0.75 t/ha Chicken Manure + 62.5 kg/ha NPK + Soil combination resulted in the highest potassium levels at both locations. Studies by Rayne & Aula (2020) indicated that chicken manure is not only rich in nitrogen but also in potassium, which is essential for plant health. According to Yahaya *et al.* (2023), the addition of NPK fertilizer further boosts potassium availability, leading to optimal levels in the soil.

No Fertilizer (Control) at Asante Mampong had the highest calcium level and could be due to the naturally occurring calcium in the soil or the possibility that the absence of other nutrients allowed for higher calcium availability. The 1.5 t/ha Chicken Manure + 125 kg/ha NPK + Soil resulted in the highest calcium content at Damongo. Chicken manure and NPK fertilizers can both contribute to increased calcium levels in the soil, which is essential for plant cell wall structure and growth (Niamat *et al*., 2019). The 3 t/ha Chicken Manure + Soil treatment resulted in the highest sodium levels at both locations. Chicken manure can contain sodium, and when applied in large quantities (3 t/ha), it can significantly increase the sodium content in the soil. Sodium, while essential in small amounts, can become problematic if levels become too high, potentially leading to soil salinity issues.

## 5.2 Effect of chicken manure and NPK fertilizer on phenology and growth of maize

The differences in percentage plant establishment during the 2019 cropping season for the two maize varieties, Abontem and Obatanpa, can be attributed to the use of organic (chicken manure) and inorganic fertilizers (NPK) which significantly influenced plant establishment. Fertilizers provide essential nutrients that support seedling growth and development. This is in line with studies by Jaswal *et al.* (2021) who stated that fertilizers provide essential nutrients for plant growth and development. However, the effectiveness of these fertilizers can vary depending on how they are applied and the specific needs of the maize varieties. The combination of organic and inorganic fertilizers (1.5 t/ha chicken manure + 125 kg/ha NPK) may not always lead to optimal plant establishment.

While these combinations can enrich the soil with a broad range of nutrients, they might also cause nutrient imbalances or soil conditions that are not ideal for seed germination and early plant growth, especially if not applied correctly. The two maize varieties, while both generally resilient, may have different nutrient requirements or tolerances to the specific soil conditions created by the fertilizers. For instance, the weather conditions at the two locations were different, and variations in temperature, rainfall, and humidity, can affect plant growth and development. Obatanpa and Abontem that received 1.5 t/ha chicken manure + 125 kg/ha NPK showed lower percentage plant establishment. This suggests that these varieties might be more sensitive to the nutrient levels or soil conditions produced by this specific fertilizer combination. The high percentage plant establishment by 1.5 t/ha Cm + 125 kg/ha NPK could be that this combination could have created conditions that were not optimal for plant establishment. For example, excessive nutrients can sometimes lead to salt stress, especially in young seedlings, reducing their ability to establish. According to Wongkiew *et al*. (2022), the application of organic fertilizers like chicken manure might lead to increased microbial activity in the soil, which could temporarily reduce the availability of nutrients like nitrogen to the plants during critical establishment phases. The statistically significant earlier tasseling by an average of 1 day difference could be attributed to the slower growth conditions at Mampong, possibly due to its more acidic soil. The maize varieties responded differently to the treatments, with the Obatanpa variety requiring more time to reach 50% tasseling compared to the Abontem variety and may suggest that Obatanpa has a slower development rate under the given conditions. This agrees with findings by Dapaah & Essilfie (2016). The application of NPK fertilizer to 250 kg/ha resulted in a significant delay in tasseling which indicates that higher nitrogen levels in the soil can extend the maize growth phase, affecting phenology.

Abontem produced silks in a maximum of 52 days, while Obatanpa took longer, with a minimum of 58 days which indicates that Obatanpa has a slower reproductive development rate compared to Abontem. The control plants, which received no fertilizer, took the longest time to reach 50% silking, with an average of 60 days suggesting that the absence of nutrient supplementation slows down the reproductive process, likely due to insufficient nutrients for optimal growth. Maize at Mampong silked earlier than Damongo which could be due to site-specific environmental conditions, such as soil acidity or microclimatic factors that affected the growth rate. The weather conditions in the two locations were different, with variations in temperature, rainfall, and humidity, which can affect plant growth and development. According to Stockdale *et al.* (2019), different locations may have different climate (temperature, rainfall, humidity, etc.) which can influence the growth and yield of crops.

Abontem reached maturity faster than Obatanpa suggesting that Obatanpa has a longer growth cycle compared to Abontem, likely due to inherent genetic differences between the varieties. The applications of fertilizers had a noticeable impact on the maturity of maize. Plants treated with chicken manure matured the earliest. This was followed by plants that received a combination of 250 kg/ha NPK and CM. The earlier maturity observed with these treatments indicates that organic inputs, particularly chicken manure, can enhance the growth and development process, likely by improving soil fertility and nutrient availability (Bhunia *et al*., 2021). Also, the weather conditions at the two locations were different, and variations in temperature, rainfall, and humidity, can affect plant growth and development thereby given Mampong advantage to mature faster than Damongo.

The significantly higher CGR recorded by the interaction between Obatanpa and 3 t/ha Chicken manure compared to Abontem on 250 kg/ha NPK amended plots from 60-90 DAP at Damango could be that organic amendments like 3 t/ha Chicken manure enhance microbial diversity and activity in the soil. This microbial activity aids in nutrient cycling, making nutrients more available to plants, and thereby positively impacting growth rates. Different plant varieties respond uniquely to soil amendments due to genetic differences. This result corroborates with Essilfie *et al.* (2023) who reported that maize plants (Obatanpa and Omankwa maize varieties) that received 10 t/ha CM and as well as 5 t/ha CM + 1.5 t/ha GB had higher CGR and RGR values than the No fertilizer (Control). The Abontem maize variety that received 3 t/ha chicken manure likely benefited from the increased nutrient availability, leading to a significantly higher RGR compared to the same variety under other amendments at 0-30 DAP at Mampong. Obatanpa variety that received combination of 0.75 t/ha Chicken manure + 62.5 kg/ha NPK and sole 3 t/ha Chicken manure at 30-60 DAP and 60-90 DAP respectively could have created an optimal nutrient balance, promoting enhanced growth rates during these growth periods. These results are in conformity with the findings of  Islam *et al.* (2019) who reported that relative growth rate (RGR) was significantly different among the maize cultivars and observed a declining trend of RGR as the crop proceeds towards maturity Throughout both locations, CGR and RGR increased from 0 - 30 WAP which later decreased from 60 - 90 WAP.

The decline in CGR and RGR could be due to the fact that as plants mature, they shift their focus from vegetative growth to reproductive growth, such as producing tassels, silks and grains. This transition might have led to the decrease in overall growth rate. Maize plants, like other annual crops, experience full remobilization of photo-assimilates throughout their growth cycle, leading to a decrease in stem dry matter accumulation. This process ultimately contributes to a decline in both Crop Growth Rate (CGR) and Relative Growth Rate (RGR).  This result is in line with Bharati (2016) who also found the maximum crop growth rate during the initial growth stage of maize and also a decreasing trend of CGR.

The linear increase in plant height from 30 days after planting (DAP) to 86 DAP at both locations indicates a steady and consistent growth pattern during this period, likely influenced by favourable growing conditions and the effects of applied fertilizers. Abontem consistently grew taller than Obatanpa, suggesting that Abontem has a more vigorous growth habit. This difference in height might be due to genetic factors that confer greater biomass accumulation in Abontem compared to Obatanpa. Both maize varieties produced significantly taller plants in Damongo than in Mampong from 30 DAP to 86 DAP. This suggests that the environmental conditions at Damongo such as temperature, rainfall, humidity, soil fertility and soil moisture availability were more conducive to plant growth. The difference in plant height between the two locations highlights the importance of site-specific factors in influencing crop development. According to Hasnain *et al*. (2020), the significant differences in plant height observed between different treatments in both varieties, suggest that the type and combination of fertilizers applied had a notable impact on plant growth. As stated by Cottney *et al.* (2022), the height differences in later stages might be attributed to the cumulative effects of nutrient availability, with certain treatments providing more sustained support for growth.

Abontem consistently produced a higher number of leaves compared to Obatanpa across both locations throughout the growth period. This indicates that Abontem has a more prolific leaf development compared to Obatanpa, potentially due to its genetic traits. The number of leaves per plant increased steadily from 30 DAP to 86 DAP for both maize varieties at both locations. This growth trend suggests that as maize plants mature, they produce more leaves, which is a common developmental pattern in maize cultivation. Obatanpa grown with a combination of 1.5 CM + 125 kg/ha NPK and 0.75 CM + 62.5 kg/ha NPK produced the highest number of leaves per plant after 72 and 86 days. This indicates that these specific fertilizer treatments were particularly effective in enhancing leaf production compared to other treatments, including the control plots with no fertilizer. Plants grown with chicken manure showed the highest number of leaves per plant which suggests that organic amendments, such as poultry manure, were beneficial in promoting leaf growth, likely due to improved soil fertility and nutrient availability. This support findings by Agbede *et al.* (2020). Obatanpa produced more leaves at Damongo site compared to the Mampong site. This indicates that site-specific factors, such as soil type, fertility, and environmental conditions, influenced the leaf production. The conditions at Damongo were likely more favourable for Obatanpa's leaf development.

The dry root weight of maize increased progressively from 30 days after planting (DAP) to 90 DAP at both sites for both varieties. This steady increase indicates that as maize plants mature, their root systems grow and accumulate more biomass. At 30 DAP, there was a significant difference in root dry weight between the sites, with Mampong plants showing 12.4% higher root dry weight compared to Damongo. This suggests that Mampong's soil or environmental conditions were more conducive to root growth early in the growing season. Among the fertilizers, 250 kg/ha NPK was particularly effective in increasing root dry weight, showing a significant improvement of 18.3% at 30 DAP, 29.3% at 60 DAP, and 33.6% at 90 DAP compared to the no fertilizer control. This indicates that high levels of NPK fertilizer are highly beneficial for root development (Agbede *et al.*, 2020). The response of the varieties to the fertilizer treatments varied, with Abontem showing a higher responsiveness to 1.5 CM + 125 kg/ha NPK compared to Obatanpa. This indicates that Abontem may utilize fertilizers more effectively or have a higher capacity for root growth under optimal fertilization conditions.

## 5.3 Effect of chicken manure and NPK fertilizer on yield and yield components of maize

Mampong consistently produced more plants per plot compared to Damongo for both soil amendment groups. This significant difference indicates that the conditions at Mampong were more favorable for plant production, which could be due to factors such as soil fertility, moisture levels, or climate. The highest number of plants harvested per plot was achieved with the application of 3 t/ha chicken manure for both maize varieties suggests that organic amendments like chicken manure were particularly effective in enhancing plant production, likely due to improved soil fertility and nutrient availability. Findings by Raza *et al*. (2022) suggested that the superior performance of chicken manure compared to NPK fertilizers highlights the importance of organic amendments in certain contexts. Singh *et al.* (2020) indicated that chicken manure not only supplies essential nutrients but also enhances soil organic content and microbial activity, which can improve plant growth and yield. Despite the interaction effects, neither sole fertilizers nor combinations of fertilizers with manure significantly influenced the number of cobs per plant. This indicates that while soil amendments can impact other growth parameters, they did not lead to significant differences in the number of cobs per plant in this study. The number of cobs per plant remained similar whether manure was applied alone, in combination with fertilizers, or no soil amendments were used (control). There was no significant difference in the number of cobs per plant between the Abontem and Obatanpa varieties at both Damongo and Mampong.

This combination likely provided optimal nutrients and improved soil conditions, promoting better cob development as indicated by Karamina & Fikrinda (2020). There was no significant difference in cob diameter between the varieties Obatanpa and Abontem. This suggests that both varieties produced cobs of similar diameter, regardless of the fertilizer treatments applied. The application of 250 kg/ha NPK alone resulted in cob diameters for Obatanpa and Abontem at Mampong which indicates that NPK fertilizer had a measurable impact on cob diameter, with Obatanpa showing slightly larger cobs compared to Abontem under this treatment. Mixing 0.75 t/ha chicken manure with 62.5 kg/ha NPK statistically outperformed other treatments, especially for Abontem. This combination produced larger cob diameters compared to other fertilizer treatments, highlighting the effectiveness of combining organic and inorganic fertilizers (Karamina & Fikrinda, 2020). The organic manure likely improved soil structure and nutrient availability, enhancing cob development. The number of filled cobs differed significantly between maize plants grown with 250 kg/ha NPK and those grown with 0.75 t/ha chicken manure plus 62.5 kg/ha NPK. This suggests that the application of 250 kg/ha NPK alone resulted in a different number of filled cobs compared to the combination of chicken manure and NPK. The combination of chicken manure and NPK appeared less effective in producing filled cobs compared to the NPK alone in this instance. Additionally, Abontem under 1.5 t/ha chicken manure plus 125 kg/ha NPK showed a significant difference from the control and other treatments, highlighting the effectiveness of this specific combination in increasing the number of filled cobs. The results highlight the varying effectiveness of different fertilizer combinations and their impact on maize productivity.

The differences in filled cobs among treatments suggest that while some combinations are more effective, others may not show significant benefits (Amoakwah *et al*., 2017). Findings Ren *et al*. (2022), suggested that optimizing fertilizer strategies for maize cultivation requires careful consideration of the type and amount of fertilizers used. At Damongo, there was no significant difference in the number of unfilled cobs between Abontem and Obatanpa, with both varieties having an average of unfilled cobs per plot. This indicates that, at this location, both varieties performed similarly in terms of producing unfilled cobs. Both varieties that received 250 kg/ha NPK showed a significant difference in the number of unfilled cobs compared to those that received 0.75 t/ha chicken manure plus 62.5 kg/ha NPK. The NPK alone resulted in fewer unfilled cobs compared to the combination with chicken manure, suggesting that the NPK fertilizer was more effective at reducing the number of unfilled cobs. At the Damongo site, Abontem exhibited a higher number of seeds per cob compared to the Mampong site. This suggests that the Damongo site conditions such as temperature, rainfall, humidity, etc were more favorable for seed development in the Abontem variety. For Obatanpa, the situation was reversed; the Mampong site had a higher number of seeds per cob compared to Damongo. This indicates that Mampong provided better conditions such as temperature, rainfall, humidity, etc for seed development in the Obatanpa variety. Abontem generally had more seeds per cob compared to Obatanpa, suggesting that Abontem may have better seed-setting capabilities or growth characteristics that lead to more seeds per cob. The application of 1.5 t/ha chicken manure and 125 kg/ha NPK resulted in the highest number of seeds per cob for both locations. Gao *et al.* (2020) indicated that the combination of organic and inorganic fertilizers was most effective in enhancing seed development in maize. The effectiveness of this combination likely stems from improved soil fertility and nutrient availability, which supports better cob development and seed setting.

Obatanpa consistently outperformed Abontem in terms of grain yield, recording highest yields at both Damongo and Mampong. This suggests that Obatanpa is a more productive variety under the given conditions, possibly due to its superior growth characteristics or better adaptation to the local environment. The 0.75 t/ha Chicken Manure + 62.5 kg/ha NPK combination yielded the highest grain output indicating that this specific ratio of organic and inorganic fertilizers was most effective at boosting maize productivity at Damongo. The 1.5 t/ha Chicken Manure + 125 kg/ha NPK combination led to the highest yield, reflecting its effectiveness in improving maize productivity at Mampong. Abontem x 0.75 t/ha Chicken Manure + 62.5 kg/ha NPK interaction produced the highest grain yield at Damongo. This indicates that Abontem, when combined with this specific fertilizer mix, achieved exceptional productivity. The 3 t/ha Chicken Manure resulted in the highest grain yield for Abontem at Mampong, highlighting the strong effect of chicken manure alone in improving yield at this site. The higher grain yield obtained in both locations might be due to well distributed rainfall pattern, appropriate temperature, suitable soil-water relationships, and efficient dry matter partitioning in maize growth and development. This is in agreement in work done by Bhattacharya & Bhattacharya (2021). The difference in optimal fertilizer treatments between Damongo and Mampong highlights the influence of local soil and environmental conditions on maize yield. This variability suggests that farmers should adapt their fertilization practices based on site-specific conditions to achieve the best results.

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

# CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

## 6.1 Conclusion

### Objective 1:

- Soil at Asante Mampong, had the highest pH and Phosphorus values compared to Damongo. Nitrogen (N), Potassium (K), Calcium (Ca), Magnesium (Mg), and Sodium (Na), Exchangeable acidity and percengtage organic carbon were higher in Asante Mampong soil than Damongo.
- For percentage organic matter, soil at Damongo recorded the highest value compared to Asante Mampong.
- For initial particle size analysis, Damongo generally recorded the highest % sand and % clay values compared to Asante Mampong.  % silt was higher in Asante Mampong than in Damongo.
- For final particle size analysis, Asante Mampong had the highest % sand whereas for % clay and % silt, soil in Damong recorded the highest.
- No fertilizer (Control) recorded the highest value for phosphorus at Asante Mampong while at Damongo the highest phosphorus value was recorded by $0.75\ t/ha$ Chicken manure 62.5 kg/ha $NPK$ + Soil.
- For Nitrogen, $0.75\ t/ha$ Chicken manure 62.5 kg/ha $NPK$ + Soil had the highest at Asante Mampong while 250 kg/ha 250 kg/ha NPK + Soil had the highest Nitrogen at Damongo.
- Generally, $0.75\ t/ha$ Chicken manure 62.5 kg/ha $NPK$ + Soil had the highest potassium level at both locations.
- Calcium was higher in No fertilizer (Control) at Asante Mampong whereas at Damongo, 1.5 t/ha Chicken manure $+125\ kg/ha\ NPK$ + Soil gave the highest rate

of calcium. Manganese was higher in No fertilizer (Control) at Asante Mampong while at Damongo, it was higher in 250 kg/ha 250 kg/ha NPK + Soil.

- Generally, Sodium (Na) was higher in 3 t/ha chicken manure + Soil at both locations.

**Objective 2:**

- Maize at Damongo tasseled earlier than at Mampong. Organic and inorganic fertilizers had influence on days to 50 % tasseling in all treatments with full 250 kg/ha NPK application recording the earliest days to 50% tasseling Abontem had earliest days to 50% tasseling than Obatanpa. There was early tasseling in Mampong in respect to Obatanpa compared to the other when 250 kg/ha NPK was applied.
- In terms of silking, Abontem had the earliest days to 50% silking compared to Obatanpa in both Mampong and Damongo. The earliest days to 50% silking was recorded in Mampong than in Damongo.
- For days to maturity, Abontem took 98 days to attain maturity which was not different from the case of Damongo while Obatanpa had 128 day to attain maturity. Obatanpa took more days to mature compared to abontem. Plants applied with Pm matured earlier (101 days) followed by those applied with 250 kg/ha NPK mixed with Pm (108 days).
- Obatanpa produced significantly taller plants than Abontem. Both varieties produced significantly taller plants from 30 DAPS to 86 DAPS in Damongo site than in Mampong.
- Abontem produced higher number of leaves per plant than Obatanpa from 30 to 86 days of planting during the cropping season. Obatanpa that received 1.5 Cm + 125

kg/ha NPK and 0.75 t/ha Cm +62.5 kg/ha NPK produced the highest number of leaves per plant after 72 and 86 days of planting than the other amended and No fertilizer (Control) plots during the cropping season. Both maize varieties grown on PM produced the highest number of leaves per plant at 86 days of planting. Obatanpa variety produced a greater number of leaves in Damongo site than in Mampong site.

- Abontem produced a higher average root dry weight than Obatanpa. Generally, the application of 3 t/ha Chicken manure and 250 kg/ha NPK fertilizer significantly increased root dry weight in the tables below. There was significant increase in root dry weight when 250 kg/ha NPK was applied irrespective of the amount than the other treatments.

**Objective 3:**

- The interaction between Obatanpa and 3 t/ha Chicken manure recorded significantly higher CGR (52.96 g $m^{-2}/day^{-1}$) than Abontem planted on 250 kg/ha NPK amended plots (33.59 g $m^{-2}/day^{-1}$) at both locations.
- The highest relative growth rate (RGR) was observed in Obatanpa maize variety that received 1.5 t/ha chicken manure + 125 kg/ha NPK at 0 - 30 DAP whereas the least was recorded by Abontem planted on 3 t/ha chicken manure amended soils at Damongo.
- At Mampong, Abontem maize variety that received 3 t/ha Chicken manure recorded significantly higher RGR than same variety and Obatanpa maize variety that received 0.75 t/ha Chicken manure + 62.5 kg/ha NPK and 3 t/ha Chicken manure respectively at 0-30 DAP.

**Objective 4:**

- Overall, the results show that the Mampong site consistently produced more plants per plot than the Damongo site for both soil amendment groups. In terms of soil amendments, the highest yield was seen with the application of 3 t/ha chicken manure for both varieties.
- Abontem and Obatanpa plants on plots amended with either sole fertilizer or fertilizer + manure did not significantly influence the number of cobs per plants.
- Obatanpa and Abontem under 3 t/ha Chicken manure (Cm) differed significantly from others and the No fertilizer (Control) in number of cobs per plot in the cropping season in the two locations. Abontem produced higher cob per plot at Damongo than Mampong under 3 t/ha chicken manure in the two locations.
- Cob length of Abontem and Obatanpa was significantly influenced by 3 t/ha chicken manure plus 250 kg/ha NPK from other amended and No fertilizer (Control) plots during the cropping season. Abontem grown on amended and No fertilizer (Control) plots had longer cob length than Obatanpa.
- Applications of 250 kg/ha NPK produced higher cob diameters of Obatanpa than Abontem in Mampong. Mixing 0.75 Cm with 62.5 kg/ha NPK statistically out-yielded other treatments especially for Abontem.
- Obatanpa recorded higher number of filled cobs against Abontem at Mampong. Both varieties Abontem and Obatanpa grown under 250 kg/ha NPK differed significantly from 0.75 t/ha Cm + 62.5 kg/ha NPK in number of cobs per plot during the cropping season. Also, there was no significant difference in the number of unfilled cobs between Abontem and Obatanpa in Damongo.
- Damongo had higher number of seeds per cob compared to the Mampong site for Abontem variety. Similarly, for the Obatanpa variety, Damongo site had a

relatively lower number of seeds per cob compared to Mampong. On the soil amendments, the highest number of seeds per cob was recorded when 1.5 t/ha Chicken manure (Cm) and 125 kg/ha NPK for Damongo and Mampong respectively. Abontem recorded the highest number of seeds per cob than Obatanpa.

- Obatanpa recorded the highest grain yield compared to Abontem at both Damongo and Mampong. For soil amendment, 1.5 t/ha Chicken manure + 125 kg/ha NPK had the highest grain yield at both Damongo and Mampong, With the interactive effects, Abontem x 0.75 t/ha Chicken manure + 62.5 kg/ha NPK had the highest grain yield at Damongo whereas at Mampong, full 3 t/ha Chicken manure had the highest grain yield. Also, Obatanpa x full 250 kg/ha NPK had the highest grain yield for maize at both Damongo and Mampong.
- At Mampong, there was a strong positive correlation between grain yield, 100-seed weight, cob diameter, cob length, stem diameter, plant height, and number of leaves per plant.
- At Damongo, there was a strong positive correlation between grain yield, plant height, stem diameter, and number of leaves per plant.

## 6.2 Recommendations

Based on the experimental results, it is recommended that:

- Farmers in Asante Mampong, can successfully cultivate maize in the soils since it had the highest pH, Phosphorus, Nitrogen (N), Potassium (K), Calcium (Ca), Magnesium (Mg), and Sodium (Na), Exchangeable acidity, percentage organic carbon, percentage organic matter, % silt, % sand.

- The combination of $2.25\ t/ha$ Chicken manure 62.5 kg/ha $NPK$ + Soil had the highest phosphorus, nitrogen, and potassium whereas 250 kg/ha NPK + Soil had the highest Nitrogen at Damongo and hence recommended.
- For farmers who want to obtain optimum yield of maize, 250 kg/ha NPK or the combination 2.25s t/ha CM with 62.5 kg/ha NPK is recommended.
- Nutrient availability and use for maize appeared to be better with the combination of the three sources of fertilizers and therefore, the study recommends the application of plant nutrients.
- The study also suggests combined application of CM and 250 kg/ha NPK on the growth and yield of maize because of its complementary effects. These positive attributes appeared to be further strengthened with the application of organic matter.
- Furthermore, owing to the spatial variability in soil nutrients in the area, site-specific recommendation of fertilizer application is suggested for efficient fertilizer use.
- Finally, the study recommends that stakeholders such as Government and Non-Governmental Organizations (NGOs) should offer farmer support programmes through integrated nutrient management to farmers to boost crop yield.
- Though the cultivars were different, they reacted similarly to N and P inorganic fertilizer application. The Obatanpa maize cultivar, however, was more responsive to inorganic fertilizer by producing higher grain yield than Abontem.

# REFERENCES

Adekiya, A. O., Ogunboye, O. I., Ewulo, B. S., & Olayanju, A. (2020). Effects of Different Rates of Poultry Manure and Split Applications of Urea Fertilizer on Soil Chemical Properties, Growth, and Yield of Maize. *The Scientific World Journal*, Vol. 2020. Article ID 4610515, 8 pages. DOI: https://doi.org/10.1155/2020/4610515.

Adeyemo, A. J., Akingbola, O. O., & Ojeniyi, S. O. (2019). Effects of poultry manure on soil infiltration, organic matter contents and maize performance on two contrasting degraded alfisols in southwestern Nigeria. *International Journal of Recycling of Organic Waste in Agriculture,* 8(1), 73-80.

Adu, G. B., Abdulai, M. S., Alidu, H., Nustugah, S. K., Buah, S. S., Kombiok, J. M., & Etwire, P. M. (2014). Recommended production practices for maize in Ghana. *CSIR-AGRA Maize production guide,* 1-18.

Adu, S.V. (1995). Soils of the Nasia basin. *Memoir No. 6. Soil Research Institute. Kumasi.*

Agbede, T. M., Odoja, A. S., Bayode, L. N., Omotehinse, P. O., & Adepehin, I. (2020). Effects of biochar and poultry manure on soil properties, growth, yield and quality of cocoyam (Xanthosoma sagittifolium Schott) grown in sandy soil. *Communications in Soil Science and Plant Analysis*, *51*(7), 932-947.12

Agegnehu, G., Amede, T., Erkossa, T., Yirga, C., Henry, C., Tyler, R., ... & Sileshi, G. W. (2021). Extent and management of acid soils for sustainable crop production system in the tropical agroecosystems: a review. *Acta Agriculturae Scandinavica, Section B—Soil & Plant Science*, *71*(9), 852-869.

Ali, L., Manzoor, N., Li, X., Naveed, M., Nadeem, S. M., Waqas, M. R., ... & Yan, J. (2021). Impact of corn cob-derived biochar in altering soil quality, biochemical status and improving maize growth under drought stress. *Agronomy*, *11*(11), 2300.

Aliabadi, F.H, Lebaschi, M.H., Shiranirad, A.H., Valadabadi, S.A.R., Hamidi, A., Daneshian, J. (2008). Effects of arbuscular mycorrhizal fungi (Glomus hoi), different levels of phosphorus and drought stress on physiological growth indices of coriander (*Coriandrum sativum* L.). 5th International Crop Sci. Congress & Exhibition. Korea p. 231.

Amoakwah, E., Arthur, E., Frimpong, K. A., & Islam, K. R. (2021). Biochar amendment influences tropical soil carbon and nitrogen lability. *Journal of Soil Science and Plant Nutrition*, *21*(4), 3567-3579.

Amoakwah, E., Frimpong, K. A., & Arthur, E. (2017). Corn cob biochar improves aggregate characteristics of a tropical sandy loam. *Soil Science Society of America Journal*, *81*(5), 1054-1063.

Andam, K. S., Johnson, M., Ragasa, C., Kufoalor, D. S. and Das Gupta, S. A. (2017). A chicken and maize situation: the poultry fed sector in Ghana. IFPRI Discussing Paper 1601, International Food Policy Research Institute (IFPRI), Washington, D. C. http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/131055

Andersson, M. S., Saltzman, A., Virk, P. S., Pfeiffer, W. H. (2017). Progress update: crop development of biofortified staple food crops under Harvest plus. *Afr. J. Food Agric. Nutr. Dev.* 17, 11905–11935. doi: 10.18697/ajfand.78. HarvestPlus05

Angelucci, F. (2012). Analysis of Incentives and Disincentives for Maize in Ghana. FAO 2012. Technical Notes Series, MAFAP, FOA, Rome.

ARC Grain Crops Institute (2003). Maize Production Guide. Directorate of Agriculture Information Service, Department of Agriculture. Pretoria-South Africa. pp 2-4.

Asfaw, M. D. (2022). Effects of animal manures on growth and yield of maize (Zea mays L.). *Journal of Plant Science and Phytopathology*, *6*(1), 033-039.

Atakora, W. K., Fosu, M., & Marthey, F. (2014). Modelling maize production towards site specific fertilizer recommendation in Ghana IITA (International Institute of Tropical Agriculture) (2009). Cereals and legumes systems, Ibadan, Nigeria.

Badu-Apraku, B., Asuboah, R. A., Fakorede, M. A. B., & Asafo-Adjei, B. (2014). Strategies for sustainable maize seed production in West and Central Africa.

Baijukya, F., Sabula, L., Mruma, S., Mzee, F., Mtoka, E., Masigo, J., ... & Swai, E. (2020). Maize production manual for smallholder farmers in Tanzania.

Bailey, R. L., West Jr, K. P., & Black, R. E. (2015). The epidemiology of global micronutrient deficiencies. *Annals of nutrition and metabolism, 66*(Suppl. 2), 22-33.

Bationo, A., Fening, J. O., & Kwaw, A. (2018). Assessment of soil fertility status and integrated soil fertility management in Ghana. *Improving the Profitability, Sustainability and Efficiency of Nutrients Through Site Specific Fertilizer Recommendations in West Africa Agro-Ecosystems: Volume 1*, 93-138.

Bationo, A., Hartemink, A., Lungu, O., Naimi, M., Okoth, P., Smaling, E., Thiombiano, L., and Waswa, B. (2012). Knowing the African soils to improve fertilizer recommendations. In Improving Soil Fertility Recommendations in Africa Using the Decision Support System for Agro technology Transfer (DSSAT); Al, K.E., Ed.; Springer: Dordrecht, The Netherlands, 2012; pp. 19–42.5

Bawa, A. (2021). Yield and Growth Response of Maize (Zea mays L.) to Varietal and Nitrogen Application in the Guinea Savanna Agro-Ecology of Ghana. *Advances in Agriculture*, *2021*, 1-8.

Bergmann, W. 1992. Nutritional disorders of plants. 2nd ed. Gustav Fischer Verlag, Jena, Germany.

Bharati, C. (2016). Chemical weed control in hybrid maize (Zea mays L.). Masters of Science in Agriculture (Agronomy). Orissa University of Agriculture and Technology, Bhubaneswar-751003

Bhattacharya, A., & Bhattacharya, A. (2021). Dry matter production, partitioning, and seed yield under soil water deficit: a review. *Soil Water Deficit and Physiological Issues in Plants*, 585-702.

Bhunia, S., Bhowmik, A., Mallick, R., & Mukherjee, J. (2021). Agronomic efficiency of animal-derived organic fertilizers and their effects on biology and fertility of soil: A review. *Agronomy*, *11*(5), 823.

Boateng, O. E. (2013). Estimation of genetic improvement of maize in Ghana under three levels of nitrogen application. Master's Dissertation. Kwame Nkrumah University of Science and Technology, Kumasi.

Boateng, S. A., Zickermann, J., & Kornahrens, M. (2006). Poultry manure effect on growth and yield of maize. *West African Journal of Applied Ecology*, 9(1).

Bonavia, D., & Grobman, A. (2014). Andean maize: Its origins and domestication. In *Foraging and farming* (pp. 456-470). Routledge.

Braimoh, A. K., and Vlek, P. l. G. (2006). Soil quality and other factors influencing maize yield in Northern Ghana. *Soil use and Management, 22*(2), 165-171.

Callo-Concha, D., Gaiser, T., & Ewert, F. (2012). *Farming and cropping systems in the West African Sudanian savanna. WASCAL research area: northern Ghana, southwest Burkina Faso and northern Benin* (No. 100). ZEF working paper series.

Celik, I., Ortas, I., and Kilic, S. (2004). Effects of compost, mycorrhiza, manure and fertilizer on some physical properties of a Chromoxerert soil. *Soil and Tillage Research* 78(1):59–67. doi: 10.1016/j.still.2004.02.012.

Chapoto, A., and C. Ragasa. (2013). *Moving in the right direction? Maize productivity and fertilizer use and use intensity in Ghana*. Washington, DC. IFPRI Discussion Paper 01314.

Chaudhary, D. P., Kumar, S., & Yadav, O. P. (2014). Nutritive value of maize: improvements, applications and constraints. *In Maize: Nutrition dynamics and novel uses* (pp. 3-17). Springer, New Delhi.

Chen, J. H. (2006). The combined use of chemical and organic fertilizers and/or biofertilizer for crop growth and soil fertility. *In International workshop on sustained management of the soil-rhizosphere system for efficient crop production and fertilizer use* (Vol. 16, No. 20, pp. 1-11). Land Development Department Bangkok Thailand.

Chen, L., Yang, H., Fang, Y., Guo, W., Chen, H., Zhang, X., ... & Cao, D. (2021). 6

Colombo, R., Ferron, L., & Papetti, A. (2021). Colored corn: An up-date on metabolites extraction, health implication, and potential use. *Molecules, 26*(1), 199.

Cottney, P., Black, L., Williams, P., & White, E. (2022). How cover crop sowing date impacts upon their growth, nutrient assimilation and the yield of the subsequent commercial crop. *Agronomy*, *12*(2), 369.

Cox, W. J., & Cherney, J. H. (2015). Field-scale studies show site-specific corn population and yield responses to seeding depths. *Agronomy journal*, *107*(6), 2475-2481.

CSIR (2011): Characteristics of maize varieties recommended to farmers and their recognize yield.

Danso-Abbeam, G., Bosiako, J. A., Ehiakpor, D. S., & Mabe, F. N. (2017). Adoption of improved maize variety among farm households in the northern region of Ghana. *Cogent Economics & Finance*, *5*(1), 1416896.

Danso-Abbeam, G., Bosiako, J. A., Ehiakpor, D. S., & Mabe, F. N. (2017). Adoption of improved maize variety among farm households in the northern region of Ghana. *Cogent Economics & Finance*, 5(1), 1416896.

Dapaah, H. K., & Essilfie, M. E. (2016). Maize varietal intercropping and productivity under rainfed conditions in a forest-savannah transition zone. *Tropical Agriculture*, *93*(2).

Darfour, B. & Rosentrater, K. A. (2016). Maize in Ghana: an overview of cultivation to processing. In *2016* ASABE Annual International Meeting (p.1). *American Society of Agricultural and Biological Engineers*.7

Davi, H., Gillmann, M., Ibanez, T., Cailleret, M., Bontemps, A., Fady, B., & Lefèvre, F. (2011). Diversity of leaf unfolding dynamics among tree species: new insights from a study along an altitudinal gradient. *Agricultural and Forest Meteorology*, *151*(12), 1504-1513.21

Dawuda, M. M., Boateng, P. Y., Hemeng, O. B., & Nyarko, G. (2011). Growth and yield response of carrot (Daucus carota L.) to different rates of soil amendments and spacing. *Journal of Science and Technology (Ghana), 31*(2). 20

Dawuda, M. M., Boateng, P. Y., Hemeng, O. B., & Nyarko, G. (2011). Growth and yield response of maize (Zea Mays) to different rates of soil amendments and spacing. *Journal of Science and Technology (Ghana), 31*(2).

Dei, H. K. (2017). Assessment of maize (Zea mays) as a feed resource for poultry. *Manafi, M. (Comp.). Poultry science. Intech Open*, 1-32.

Dennis, E. A., Anane-Sakyi, C., and Affi-Pungu, G. (1994). The effect of cow dung and mineral fertilisers on yield of dry season gardening of onion in the Upper East Region of Ghana. In Proceedings of 1st National Workshop on Food and Industrial Crops, Kumasi, Ghana. 25 – 27

Dhaliwal, S. S., Naresh, R. K., Mandal, A., Walia, M. K., Gupta, R. K., Singh, R., & Dhaliwal, M. K. (2019). Effect of manures and fertilizers on soil physical properties, build-up of macro and micronutrients and uptake in soil under different cropping systems: a review. *Journal of Plant Nutrition*, *42*(20), 2873-2900.

Djaman, K., Irmak, S., Rathje, W. R., Martin, D. L., & Eisenhauer, D. E. (2013). Maize evapotranspiration, yield production functions, biomass, grain yield, harvest index, and yield response factors under full and limited irrigation. *Transactions of the ASABE*, *56*(2), 373-393.

Essilfie, M. E., Appiah, E., Asiedu, E. K., & Owusu, S. E. (2023). Growth and Yield Response of Maize ( Zea mays L .) to Integrated Nutrient Management of Biochar , Organic and Inorganic Fertilizers. *Asian Journal of Advances in Agricultural Research*, *23*(4), 69–91. https://doi.org/10.9734/AJAAR/2023/v23i4481

FAO-RAF. (2000). Integrated soil management for sustainable agriculture and food security. In Case Studies from Four Countries in West Africa. Accra, Ghana: FAO Regional Office.

Farhad, W., Cheema, M. A., Hammad, H. M., Saleem, M. F., Fahad, S., Abbas, F., ... & Bakhat, H. F. (2018). Influence of composted poultry manure and irrigation regimes on some morpho-physiology parameters of maize under semiarid environments. *Environmental Science and Pollution Research*, *25*, 19918-19931.

Fathi, A., & Afra, J. M. (2023). Plant Growth and Development in Relation to Phosphorus: A review. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Agriculture*, *80*(1), 1-7.

Food and Agricultural organization of the United Nations (FAO) (2005). Fertilizer Use by Crop in Ghana. Land and Plant Nutrition Management Service and Water Development. Land and Water Development Division, first version, published by FAO, Rome, 2005.

Food and Agricultural Organization of the United Nations (FAO) (2020). GIEWS – Global Information and Early Warning System. Country briefs, 15-April-2020. Available online at:8http://www.fao.org/giews/countrybrief/country.jsp?code=GHA. Last accesses [29/06/2020].

Fuglie, K., and N. Rada. 2013. Resources, Policies, and Agricultural Productivity in SubSaharan Africa. USDA-ERS Economic Research Report No. 145.

Gao, C., El-Sawah, A. M., Ali, D. F. I., Alhaj Hamoud, Y., Shaghaleh, H., & Sheteiwy, M. S. (2020). The integration of bio and organic fertilizers improve plant 13 growth, grain yield, quality and metabolism of hybrid maize (Zea mays L.). *Agronomy*, *10*(3), 319.

Geng, Y., Cao, G., Wang, L., & Wang, S. (2019). Effects of equal chemical fertilizer substitutions with organic manure on yield, dry matter, and nitrogen uptake of spring maize and soil nitrogen distribution. *PloS one*, *14*(7), e0219512.

GoG. (2010). Plants and Fertiliser Act, *2010 (Act 803).* Accra: Ministry of Food and Agriculture, Government of Ghana (GoG).

GSS. (2014). District Analytical Report: Mampong Municipal. Ghana Statistical Service. Accra, Ghana. Available at http://www2.statsghana.gov.gh/docfiles/2010_District_Report/Ashanti/MAMPONG%20MUNICIPAL.pdf

GSS. (2014). District Analytical Report: West Gonja District. Ghana Statistical Service. Accra, Ghana. Available at http://www2.statsghana.gov.gh/docfiles/2010_District_Report/Northern/West_Gonja.pdf

Gurmessa, B. (2021). Soil acidity challenges and the significance of liming and organic amendments in tropical agricultural lands with reference to Ethiopia. *Environment, Development and Sustainability*, *23*(1), 77-99.

Hama, B. M., & Mohammed, A. A. (2019). Physiological performance of maize (Zea mays L.) under stress conditions of water deficit and high temperature. *Applied Ecology & Environmental Research*, *17*(1).

Hasnain, M., Chen, J., Ahmed, N., Memon, S., Wang, L., Wang, Y., & Wang, P. (2020). The effects of fertilizer type and application time on soil properties, plant traits, yield and quality of tomato. *Sustainability*, *12*(21), 9065.

Holford, I. C. R. (1997). Soil Phosphorus: its measurement, and its uptake by plants. *Aust. J Soil Res. 35*, 227 – 239.

Hossain, F., Muthusamy, V., Bhat, J. S., Jha, S. K., Zunjare, R., Das, A., ... & Kumar, R. (2016). Maize. *Broadening the genetic base of grain cereals*, 67-88.

Hue N. V. (1995). Sewage Sludge. In: J. E. Rechcigl (ed) Soil amendment and environmental quality. Lewis Publ., Boca Raton. FL. P. 193 – 239.

Islam, M. T., Islam, A. S., & Sharaf Uddin, M. (2019). Physiological growth indices of maize (Zea mays L.) Genotypes in Sylhet. *BioRxiv*, *518993*.

Jaswal, A., Prasad, M. D., Singh, A., & Singh, M. (2021). Fertilizers and their roles in plant growth. *Advanced research and review in Agronomy*, 71-88.

Jjagwe, J., Keneth, C., Karungi, J, Komakech, A. J. and Lederer, J. (2020). Comparative Performance of Organic Fertilizers in Maize (*Zea mays* L.) Growth, Yield and Economic Results. *Agronomy*, 2020, 10, 69; doi: 10.3390/agronomy10010069

Kakar, K., Xuan, T. D., Noori, Z., Aryan, S., & Gulab, G. (2020). Effects of organic and inorganic fertilizer application on growth, yield, and grain quality of rice. *Agriculture*, *10*(11), 544.

Kakar, K.; Nitta, Y.; Asagi, N.; Komatsuzaki, M.; Shiotau, F.; Kokubo, T.; Xuan, T.D. (2019). Morphological analysis on comparison of organic and chemical fertilizers on grain quality of rice at different planting densities. *Plant Prod. Sci*., 22, 510–518.

Kanton, R. A. L., Prasad, P. V. V., Mohammed, A. M., Bidzakin, J. K., Ansoba, E. Y., Asungre, P. A., ... and Sugri, I. (2016). Organic and inorganic fertilizer 10 effects on the growth and yield of maize in a dry agro-ecology in northern Ghana. *Journal of Crop Improvement*, *30*(1), 1-16. DOI: 10.1080/15427528.2015.1085939

Karamina, H., & Fikrinda, W. (2020). Soil amendment impact to soil organic matter and physical properties on the three soil types after second corn cultivation. *AIMS Agriculture and food*, *5*(1), 150-169.

Knoema (2020). Ghana – Maize production quantity. World Data Atlas, 2020. Available online at:https://knoema.com/atlas/Ghana/topics/Agriculture/CropsProduction-Quantity-tonnes/Maize-production. Last accesses [29/06/2020].

Kumar, R., Kumar, R., & Prakash, O. (2019). Chapter-5 the impact of chemical fertilizers on our environment and ecosystem. *Chief Ed*, *35*, 69.

Kyere, K. W. A. B. E. N. A. (2021). *Assessment of heavy metals in selected dumpsite soils and plants in Kumasi and Asante Mampong, Ghana* (Doctoral dissertation, University of Education, Winneba).

Mahmood, F., Khan, I., Ashraf, U., Shahzad, T., Hussain, S., Shahid, M., & Ullah, S. (2017). Effects of organic and inorganic manures on maize and their residual impact on soil physico-chemical properties. *Journal of soil science and plant nutrition*, 17(1), 22-32.

Maqbool, M. A., Beshir Issa, A., & Khokhar, E. S. (2021). Quality protein maize (QPM): Importance, genetics, timeline of different events, breeding strategies and varietal adoption. *Plant Breeding*, *140*(3), 375-399.

Marfo-Ahenkora, E. (2020). *Strategies for Sustainable Productivity of Maize (Zea Mays L.)-Based Farming Systems of Smallholder Farmers in Ghana* (Doctoral dissertation, University of Cape Coast).

Mbarushimana, J. D. D. (2019). *Effect of Inorganic Fertilizers and Planting Density on Growth and Yield of Selected Maize Varieties in Eastern Rwanda* (Doctoral dissertation, University of Nairobi). 15

MiDA (Millennium Development Authority) (2010). Investment opportunity in Ghana: maize, rice, and soybean. Accra, Ghana. A publication of Millennium development Authority (MiDA) in conjunction with the United States Millennium Challenge Corporation, Accra, Ghana.

MoFA (2012). Ghana maize strategy document and investment opportunities for the private sector. Research and Information Directorate (SRID), Accra, Ghana.

MoFA (2016). Agriculture in Ghana – Facts and Figures (2015). *Statistics, Research and Information Directorate (SRID)*

MoFA (2020). West Gonja; topography and drainage. Retrieved at https://mofa.gov.gh/site/directorates/district-directorates/northernregion/250-west-gonja

Moss, A. F., Khoddami, A., Chrystal, P. V., Sorbara, J. O. B., Cowieson, A. J., Selle, P. H., & Liu, S. Y. (2020). Starch digestibility and energy utilisation of maizeand wheat-based diets is superior to sorghum-based diets in broiler chickens offered diets supplemented with phytase and xylanase. *Animal Feed Science and Technology*, *264*, 114475.

Niamat, B., Naveed, M., Ahmad, Z., Yaseen, M., Ditta, A., Mustafa, A., ... & Xu, M. (2019). Calcium-enriched animal manure alleviates the adverse effects of salt stress on growth, physiology and nutrients homeostasis of Zea mays L. *Plants*, *8*(11), 480.

Nunes, A. L., Lorenset, J., Gubiani, J. E., & Santos, F. M. (2018). A multy-year study reveals the importance of residual herbicides on weed control in glyphosate-resistant soybean. *Planta Daninha*, *36*.

Ogundijo, D. S., Adetunji, M. T., Azeez, J. O., Arowolo, T. A., Olla, N. O., Adekunle, A. F., & Borek, S. (2015). Influence of organic and inorganic fertilizers on soil chemical properties and nutrient changes in an Alfisol of South Western Nigeria. *Int J Plant Soil Sci*, *7*(6), 329-337.

Ogunwole, J. O., Iwuafor, E. N., Eche, N. M., & Diels, 1. (2010). Effect of organic and inorganic soil amendments on soil physical and chemical properties in a West Africa Savanna agroecosystem. *Tropical and Subtropical Agroecosystems*, *12*(2), 247-255.

Pauw, K. (2022). A review of Ghana’s planting for food and jobs program: Implementation, impacts, benefits, and costs. *Food Security*, *14*(5), 1321-1335.

Poole, N., Donovan, J., & Erenstein, O. (2021). Agri-nutrition research: Revisiting the contribution of maize and wheat to human nutrition and health. *Food Policy*, *100*, 101976.

Rahman, N. A., Larbi, A., Opoku, A., Tetteh, F. M., & Hoeschle-Zeledon, I. (2019). Crop–livestock interaction effect on soil quality and maize yield in Northern Ghana. *Agronomy Journal*, *111*(2), 907-916.17

Raimi, A., Adeleke, R., & Roopnarain, A. (2017). Soil fertility challenges and Biofertiliser as a viable alternative for increasing smallholder farmer crop productivity in sub-Saharan Africa. *Cogent Food & Agriculture*, *3*(1), 1400933.

Rautiainen, S., Manson, J. E., Lichtenstein, A. H., & Sesso, H. D. (2016). Dietary supplements and disease prevention—a global overview. *Nature Reviews Endocrinology*, *12*(7), 407-420.19

Rayne, N., & Aula, L. (2020). Livestock manure and the impacts on soil health: A review. *Soil Systems*, *4*(4), 64.

Raza, S. T., Wu, J., Rene, E. R., Ali, Z., & Chen, Z. (2022). Reuse of agricultural wastes, manure, and biochar as an organic amendment: A review on its implications 14 for vermicomposting technology. *Journal of Cleaner Production*, *360*, 132200.

Ren, K., Xu, M., Li, R., Zheng, L., Liu, S., Reis, S., ... & Gu, B. (2022). Optimizing nitrogen fertilizer use for more grain and less pollution. *Journal of Cleaner Production*, *360*, 132180.

Sangwan, S., Kumar, S., & Goyal, S. (2014). Maize utilisation in food bioprocessing: An overview. *Maize: nutrition dynamics and novel uses*, 119-134.

Shamuyarira, K. W., Shimelis, H., Mathew, I., Zengeni, R., & Chaplot, V. (2022). A meta-analysis of combining ability effects in wheat for agronomic traits and drought adaptation: Implications for optimizing biomass allocation. Crop Science, 62(1), 139-156.

Singh, T. B., Ali, A., Prasad, M., Yadav, A., Shrivastav, P., Goyal, D., & Dantu, P. K. (2020). Role of organic fertilizers in improving soil fertility. *Contaminants in agriculture: sources, impacts and management*, 61-77.

Singh, V. K., Malhi, G. S., Kaur, M., Singh, G., & Jatav, H. S. (2022). Use of organic soil amendments for improving soil ecosystem health and crop productivity. *Ecosystem Services*.

Stockdale, E. A., Griffiths, B. S., Hargreaves, P. R., Bhogal, A., Crotty, F. V., & Watson, C. A. (2019). Conceptual framework underpinning management of soil health—supporting site-specific delivery of sustainable agro- ecosystems. *Food and energy security*, *8*(2), e00158.

Tetteh, F. M., & Nurudeen, A. R. (2015). Modeling site-specific fertilizer recommendations for maize production in the Sudan savannah agroecology of Ghana. *African Journal of Agricultural Research*, *10*(11), 1136- 1141.

Wongkiew, S., Polprasert, C., Koottatep, T., Limpiyakorn, T., Surendra, K. C., & Khanal, S. K. (2022). Chicken manure-based bioponics: Effects of acetic acid supplementation on nitrogen and phosphorus recoveries and microbial communities. *Waste Management*, *137*, 264-274.

Wongnaa, C. A., & Mbarushimana -Vitor, D. (2019). Scale efficiency of maize farmers in four agro ecological zones of Ghana: A parametric approach. *Journal of the Saudi Society of Agricultural Sciences*, *18*(3), 275-287.

Yahaya, S. M., Mahmud, A. A., Abdullahi, M., & Haruna, A. (2023). Recent advances in the chemistry of nitrogen, phosphorus and potassium as fertilizers in soil: a review. *Pedosphere*, *33*(3), 385-406.

Yang, N., Wang, Y., Liu, X., Jin, M., Vallebueno-Estrada, M., Calfee, E., & Ross-Ibarra, J. (2023). Two teosintes made modern maize. *Science, 382*(6674), eadg8940.

Zhong, S., Liu, H., Li, Y., & Lin, Z. (2021). Opposite response of maize ZmCCT to photoperiod due to transposon jumping. *Theoretical and Applied Genetics*, *134*(9), 2841-2855.