AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT
ASANTE MAMPONG

RESPONSE OF MAIZE (*Zea mays* L.) TO DIFFERENT RATES OF NPK AND UREA BRIQUETTE FERTILISERS

ERIC DARKWAH AMPONSAH

MASTER OF PHILOSOPHY DEGREE IN CROP SCIENCE (AGRONOMY).

2025

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BY

ERIC DARKWAH AMPONSAH

(8201970014)

A Thesis submitted to the Department of Crop and Soil Sciences Education of the Faculty of Agriculture Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development in partial fulfilment of the requirements for award of a Master of Philosophy degree in Crop Science (Agronomy).

2025

DECLARATION

Candidate's declaration

I hereby declare that this thesis, with the exception of quotations and references contained in published works which have been duly acknowledged; is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Name: Eric Darkwah Amponsah

Signature: ……………………………. Date: ……………………………

Supervisors' Declaration

We hereby declare that the preparation and presentation of this thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

Prof. Kofi Agyarko (Principal Supervisor)

Signature: ……………………………. Date: ……………………………

Dr. Eliezer Bortei Borketey-La (Co-Supervisor)

Signature: ……………………………. Date: ……………………………

ACKNOWLEDGEMENT

I am highly indebted to the Almighty God for the strength, protection and wisdom accorded me to embark on this academic journey.

I also thank my supervisors; Prof. Kofi Agyarko and Dr. Eliezer Bortei Borketey-La for making time to supervise this thesis. Prof. Kofi Agyarko, your patience, dedication to duty and the quality assurance to this work cannot be over emphasised. God bless you abundantly for everything you have lost on this thesis. Also, lots of thanks goes to Professor Stephen Larbi Koranteng, HoD, Dept. of Crop and Soil Science AAMUSTED-M for his immense support.

To Prof. (Mrs.) Margaret Esi Essilfie, Dean, Faculty of Agriculture Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Asante Mampong campus, I am very grateful to you for your motherly advice and encouragement which fuelled my desire to complete this work. Out of your busy schedule you always kept reminding and encouraging me to finish hard even at the point when I almost gave up due to some challenges. Prof. thanks you so much.

To my wife (Vida Koranteng), and daughters: Claudia, Nina, Karen, Anna and Alicia. I thank you so much for your unwavering support.

DEDICATION

I dedicate this project to my mother, Elizabeth Yaa Kwakyewaa of blessed memory. Maame Kwakyewaa, you gave me education and everything from your sweat. Unfortunately, you did not enjoy from your toils as you left us some four years ago. May you continue to rest in the bosom of your maker. Rest in peace Maame Kwakyewaa. I also dedicate this thesis to Mr. Emmanuel Kwasi Asiedu, Senior Lecturer AAMUSTED, Mampong campus. You have been my source of inspiration.

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LIST OF ACRONYMS

DRMA:	Drought Resistant Maize for Africa
DRMV:	Drought Resistant maize varieties
GDP:	Gross Domestic Product
GSS:	Ghana Statistical Services
IFDC:	International Fertiliser Development Centre
TSP:	Triple Superphosphate
SAP:	Structural Adjustment Programme
SSA:	Sub-Saharan Africa
OENF:	Original Enhance Nitrogen Fertiliser

ABSTRACT

A multi-locational experiment was conducted at Amantin and Nsapor during the major rainy season from April to August 2022 to evaluate the effect of NPK fertilisers, in granule and briquette forms on the growth and yield of maize. A Randomised Complete Block Design with 7 treatments and replicated four times was used for the study. The treatments were; T1- (No fertilizer), T2 - Granule NPK & Urea (120-40-40) 200 kg/ha, T3 - Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha, T4 - Briquette NPK & Urea (114-44-44) 172.8 kg/ha, T5 - Briquette NPK & Urea (91-59-59) 230.4 kg/ha, T6 - Briquette NPK & Urea (76-29-29) 115.2 kg/ha and T7 - Briquette NPK & Urea (31-29-29) 115.2 kg/ha. The results showed that the treatments applied had no significant effect on the soil chemical properties (pH, available P, N, and exchangeable acidity and bases). The briquetted and granular NPK fertilisers had no significant effect on number of days to 50% emergence and 50% tasselling as well as days to 50% silking. Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha generally outperformed the Granule NPK & Urea (120-40-40) 200 kg/ha and control with regards to number of leaves, leaf chlorophyll content, and leaf area across both locations. Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha recorded significantly taller plants and internode length than Briquette NPK & Urea (114-44-44) 172.8 kg/ha. Briquette NPK & Urea (76-29-29) 115.2 kg/ha produced cobs with wider cob diameter than the control across both locations. Briquette NPK & Urea (114-44-44) 172.8 kg/ha and Briquette NPK & Urea (76-29-29) 115.2 kg/ha recorded significantly higher grain weight than the control in Amantin and Nsapor, respectively and hence recommended for maize production.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Maize *(Zea mays* L.) is an important cereal crop belonging to the *Poaceae* family, with high yielding capabilities. (Matsumoto and Yamano, 2011). Maize cultivation is mainly for the grain which is an important generative force for food for consumption. Additionally, it is cultivated for feeding livestock as fodder, particularly, in advanced countries. (Murdia *et al.*, 2016). Furthermore, in the world ranking, Maize (*Zea mays* L.) is third after wheat and rice justifying its importance as a global cereal crop (Farnia and Omidi, 2015). It is a quick growing crop and successfully grown as a biennial and as early and late crops as result of its higher adaptability and hence popularly known as "Queen of Cereals". Globally, the grains of maize also serve as a major source of feed for poultry and livestock. (Dei, 2017). Nutritionally, maize contains 72% starch, 10% protein, 4.8% oil, 8.5% fibre, 3.0% sugar and l.7% ash (Kaul and Olakh, 2019), while the endosperm consist of carbohydrates, the embryo is rich in minerals and fats with an estimated 80% of fat, and a substantial amount of minerals and protein in the kernel (Galani *et al.*, 2022).

In Ghana, maize promotes healthy nutrition which is crucial in many households (Adjei-Nsiah and Kermah, 2012). It constitutes a significant amount of cereal crop production with the proximate 50-60 % and so considered as a leading grain crop by the planted area. (Adjei-Nsiah and Kermah, 2012) As far as curbing hunger and promoting good nutrition are concerned, maize is one of the most important crops in the agricultural sector. The use of maize differs from place to place within the global space.

It can be eaten implicitly when processed with dairy products and meat in the advanced countries. (Gellings and Parmenter, 2016). In developing countries, the crop is widely used at first hand in many homes for consumption approximately for over 200 million people (Sultana *et al.,* 2019). The crop can be refined into fuel (ethanol) and processed into starch and cooking oil. A large quantity of maize products is for domestic and industrial use and this makes the crop suitable to curb hunger and malnutrition (Ofori *et al.,* 2015). Various projects and research activities geared towards boosting maize production and productivity have been introduced in the country. Notable among them include the Ghana Grains Development Project (GGDP) and the Sasakawa Global 2000 maize improvement programme (Akumbole *et al.,* 2019).

To ensure successful maize production and environmental sustainability in the agricultural enterprise, acceptable use of inputs is significant. One of the most important activities is fertiliser application. Maize consumes higher amount of nutrients, particularly, the essential elements (nitrogen, phosphorus, and potassium) and requires them in adequate quantities to attain full yield potential. (Mukherjee, 2013). The utilisation of these essential elements (nitrogen, phosphorus and potassium) reach their peak at the flowering stage. It is estimated that nutrient consumption of an individual maize plant could be pegged at 8.7g of nitrogen, 5.1g of phosphorus and 4.0g of potassium respectively (Ciampitti, 2012).

Every tonne of maize seeds harvested consume approximately 15.0 to 18.0 kg of nitrogen, 2.5 to 3.0 kg of phosphorus and 3.0 to 4.0 kg of potassium from the soil (Shehu *et al.,* 2019) Occasionally, most of the areas for the cultivation of maize are hit with water shortages leading to poor harvest of about 10- 25% (Fisher *et al.,* 2015). To ensure food stability and improve upon the precarious food situation, the Drought Resistant Maize for Africa (DRMA) programme has released 160 droughts resistant (DR) maize cultivars, between 2007 and 2013 (Makate *et al.*, 2017). The DR maize cultivars have been developed from widely acceptable methods without genetic manipulation. In addition to drought tolerance, the cultivars have other important characteristics, such as tolerance to diseases and highly rich in protein (Makate *et al.*, 2017). Essentially, some of the DR maize cultivars have higher nitrogen use efficiency. The transition from traditional to improved maize cultivars can be a catalyst for increasing farmers' use of other inputs, especially fertiliser (Smale *et al.*, 2013)

1.2 Problem Statement

One of the most important issues confronting the world today is food security. This has come due to rapid surge in the world's population growth as projected to increase to over 2.3 billion by 2050 (Hellin *et al.*, 2012). This population boom is estimated to predominately hit developing countries including those in Sub-Saharan African. Therefore, it has become crucial to produce more crops and fibre to feed the growing population. Higher productive crops and boosted crop production, and land expansion are expected to contribute significantly to crop production to about 80% in developing countries. (Martins *et al.*, 2013). All year-round planting and harvesting have negatively contributed to a decline in soil fertility and loss of soil plant nutrients (Aliyu *et al.*, 2021). Originally fertile cultivable lands that yielded 2 to 4 t/ha of grain produce, have been depleted into unproductive lands with crops now producing cereals below 1 t/ha due to several decades of over utilisation. (Zingore, 2016). Poor soil quality is noted as a major biophysical challenge negatively impacting tropical maize farming (Bationo *et al.*, 2018).

Ghana's Gross Domestic Product (GDP) has been on a decline in the agricultural sector, from 31.8% in 2009 to 19.9% in 2014 (Twerefour *et al.,* 2015). Similarly, growth rate in the agricultural sector has taken a downward trend from 7.2 in 2009 to 5.2. This was reported in the Ghana Statistical Service's revised version released of the 2014 GDP. This shows a worrying phenomenon since agriculture remains one of the most important sources of employment in Ghana. Therefore, it is expected to play a crucial role in reducing poverty and generate wealth (Abdul-Rahman *et al.,* 2019).

Soil fertility improvement and maintenance have become key to meeting the demand for food grain production for an ever-increasing population in developing countries. Good soil fertility management provides adequate nutrient to crops for yield maximisation (Johnston and Poulton, 2018). However, it is impossible to ensure sustainable crop yields without the application of fertilisers. Ghana's agricultural sector is predominantly farm-based economic activity which is primarily practised by smallholder farmers who use basic methods and tools for farming to produce for consumption and sell just little. Largely, subsistence cropping and rearing of domestic animal to produce Ghana's food and nutritional needs (MoFA, 2012; GSS, 2015).

Although fertiliser in Ghana is seeing an upward trend, cultivation of crops and yield are still on the low side (Abdul-Rahman *et al*. 2019). Application of inorganic fertiliser is crucial for the maintenance of physico-chemical properties and fertility of the soil. Goswami *et al.,* (2019) highlight that soil fertility decline, particularly deficiencies in primary macro nutrients nitrogen (N), (phosphorus (P), potassium (K) calcium (Ca), and sodium (Na), is a major biophysical constraint affecting arable crop production. Given the need for cultivating maize with enhanced growth yield and quality, this study investigates the growth and yield responses of drought-resistant maize to N.P.K fertiliser application.

1.3 Justification

Demographic changes imply that demand for food will keep climbing. The expectation is that utilisation of cereals as food and as feed for animals' consumption, will reach over 3 billion tonnes by 2050 (Islam and Karim, 2019). Currently, urea and ammonium sulphate [$(NH_4)_2SO4$] are major used commercial N fertilisers, but their use efficiencies are low in maize production, resulting in a low yield and environmental pollution. Mineralisation of the granule fertiliser is noted for being very fast as a result of a wider surface area (Anjum *et al.*, 2018). Briquette fertiliser is a compressed form of granular fertiliser into pill or tablet format weighing 2-4 grams, it is now being introduced by International Fertiliser Development Centre (IFDC) which is aimed at reducing the losses of applied fertiliser to crops through various means such as volatilisation, erosion and leaching (IFDC, 2017).

Agyin-Birikorang *et al.* (2018) reported that the use of NPK briquette increased maize yield by 16% as opposed to ammonium sulphate of 23% to 34% relative to urea under normal weather conditions. Maize plants cultivated in Ghana's Savannah Agro-Ecological Zones retrieved about 77 percent (77%) of the briquette fertiliser applied, improving maize output by 30% when compared to split application of granular fertiliser sources, according to Adu-Gyamfi *et al.* (2019) and Winings (2014). Burke and Black (2017) indicated that, a lot of crops do not have exact guidelines and timelines for application and this become a major challenge in the utilisation of mineral fertiliser. NPK briquette fertiliser product, allows for nutrient balanced site-specific fertilisation (IFDC, 2020). It is in the aforementioned views that field research was conducted to evaluate the performance of maize to different rates of NPK and Urea briquette fertilisers.

1.4 Objective of the Study

1.4.1 Main Objective

The main objective of the study was to evaluate the growth and yield responses of maize to NPK and Urea briquette fertilisers at different rates of application.

1.4.2 Specific Objectives

The specific objectives of this study were to;

1. Determine the effect of NPK and Urea briquette fertiliser on soil chemical and physical properties.
2. Assess the effect of NPK and Urea briquette on the phenology and vegetative growth of maize.
3. Evaluate the effect of NPK and Urea briquette fertiliser on the yield and yield components of maize.

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin and Botany of Maize

There have been several theories suggesting the ancestry of modem maize. It is generally known that maize was domesticated from its ancestor teosinte (*Zea mexicana*), even though there are various opinions available from different authors (Gaudin *et al.,* 2011). Scientists propose that maize evolved through a process of natural breeding, which might have started from the hybridisation of Gama grass to produce teosinte, and was later refined through the backcrossing of teosinte with primitive maize, ultimately giving rise to the diverse modern varieties of maize. (Gaudin *et al.,* 2011). It is possible to say that maize is the most cultivated among of all field crops. Its existence consistently for centuries could be attributive to man's care. It could not have survived as a natural plant in its present form. While maize is native to the Western Hemisphere, its specific original location has not been definitely identified (Nagoshi *et al.,* 2018).

Archaeological findings suggest that maize was seen in the Western Hemisphere at least 80,000 years ago, as indicated by ancient pollen grains found 200 feet beneath Mexico City (Oladejo and Adetunji, 2012). Another archaeological examination of the bat caves in New Mexico showed maize cobs that were 5,600 years old as determined by radiocarbons. Maize was tamed for agricultural use in the Tahuacano Valley of Mexico as believed by historians. The primitive wild maize strain is no longer in existence. (Oladejo and Adetunji, 2012). Maize plant typically reaches a height of 2.5 m but certain varieties can grow as tall as 12 m with the stems consisting of 20 internodes that are usually 18 centimetres long (Jaramillo *et al.,* 2013). A leaf emerges from each node, typically measuring 9 cm in width and 120 cm in length (Raza *et al.,* 2019). Maize can develop 8-20 leaves which are usually arranged spirally on the stem in two opposite rows. Its foliage is typical of the grasses, consisting of a sheath, ligules, auricles and a blade. The leaf blade is recognisable by its lengthy, slender and wavy appearance with a tapered tip and texture that ranges from smooth to hairy (Raza *et al.,* 2019). The plant root system is remarkably extensive, comprising fine roots that grow prolifically, with lengths reaching 1.5 m under optical situation. The female inflorescence (ear) is concealed within a protective covering of bracts and the silky fibres (Grieder and Hund, 2014). At the base of the ear, the silky strands of the flowers emerge first, followed by those at the top. These strands can receive pollen for approximately three weeks, although their receptivity begins to decline after ten days. (Grieder and Hund, 2014).

2.2 Climate and Soil Requirements of Maize

Maize grows well in warm temperatures. Areas with daily temperatures averaging less than 19 ^{o}C or where the mean of the summer months is less than 23 ^{o}C. According to Wang *et al.* (2014), maize performs better within a temperature range of 21-30 ^{o}C. Minimum temperature of 12 ^{o}C is needed for maize germination, but temperatures between 16 and 18 ^{o}C promote faster and more uniform germination (Domin *et al.*, 2019). At 20 ^{o}C, germination of maize should occur between five to six days. The critical temperature which negatively imparts yield is approximately 32 ^{o}C (Domin *et al.,* 2019). As long as the growth points underground, new foliage will continue to emerge, and frost damage will be minimal. Notably, maize produces around 10-16 kg of grains per millimetre of water consumed. To achieve a yield of 3152 kg/ha, annual rainfall of 350-450 mm is required (Ureta *et al.*, 2020). At maturity, each plant will have utilised approximately 250 litres of water, assuming no water stress.

Maize flourishes well under well drained sandy loam soils with pH of 5.7-7.5 and 500-800 mm of rainfall evenly distributed throughout the growing season for good yield (Abdul-Ganiyu *et al.,* 2015). Soils with productive depth, optimal morphological properties, good internal drainage with desirable moisture regime, enriched with adequate and balanced quantities of plant nutrients and chemical properties are favourable specifically for maize production (Kamran *et al.,* 2018) While maize could be planted on large scale in sandy soils (less than 10% clay) or clay-rich soils (more than 30% clay), the ideal soil texture for optimal maize production lies between 10% and 30% clay content, which provides a balanced air and hydrological conditions (Rizwan *et al.,* 2017). Maize can be cultivated on different soils, however, it does better on well-drained, well-aerated, deep warm loam and silty loam soils with enough organic matter and well supplied with available nutrients (Rizwan *et al.,* 2017).

Even though maize performs better in different soils, it does not yield well on poor sandy soils, except with heavy application of fertilisers. In clay-rich soils deep cultivation and ridging are crucial for improving drainage and aeration. While maize is suitable for off-season cultivation in swamps with proper drainage, environmental considerations often advised against planting in these areas. (Abdul-Ganiyu *et al.,* 2015). Maize is highly susceptible to waterlogging and can be severely damaged or killed if submerged under water two days. Ideally, maize performs better in well drained soils with a pH between 6.0 and 7.0, while it can tolerate a slightly broader pH range between 5.0 -7.0 (Ureta *et al.,* 2020). Extreme acidity or alkalinity can lead to nutritional deficiencies and mineral toxicities. In more acidic soils, liming is important to achieve optimum yields.

Additionally, maize is a heavy feeder and requires significant nitrogen inputs which can destroy soil nutrients, particularly, when high yield is achieved (Bukhsh *et al.,* 2012). To attain high maize yields, it is essential to strike a balance between optimal plant population, rich soil fertility, and sufficient soil moisture. Regular soil testing is highly recommended to determine soil characteristics, identify nutrient deficiencies, and receive expert guidance on optimising soil fertility and pH for maximum maize yields (Gransee and Führs, 2013). The major maize-producing areas in Ghana are often marked by soils with deficient nutrient levels, including low organic carbon (<1.5%), total nitrogen (<0.2 %), exchangeable potassium (<100 mg/kg), and available phosphorus (<10 pp), (Tetteh *et al.,* 2018). Additionally, many soils in Ghana are shallow and contain high levels of iron and manganese, further complicating maize production. These soil limitations, combined with inadequate soil fertility management, pose significant challenges to maize production nationwide (Tetteh *et al.,* 2018).

2.3 Growth Stages of Maize Plant

While natural factors significantly impact maize growth and yield, farmers can exert control through various management strategies, including choosing the right hybrid, preparing the soil, rotating crops, applying fertilisers, irrigation, and controlling pests (Umesha *et al.,* 2014). Knowledge of maize growth progression empowers producers to make informed, timely decisions about production practices, resulting in higher yields, improved efficiency, and increased profitability (Mohammed *et al.,* 2020). Under normal conditions, a maize plant typically produces 20-21 leaves, begins silking around 65 days after sprouting, and reaches maturity approximately 120 days after emergence. (Maresma *et al.,* 2019). While the general growth pattern remains consistent, the exact timing can differ significantly depending on factors such as hybrid variety, environmental conditions, planting date, and geographic location. For instance, an early maturing hybrid may produce fewer leaves or progress through the different growth stages at a faster rate. On the contrary, a late-maturity hybrid may develop more leaves and progress through each growth stage at a slower pace (Mohammed *et al.,* 2020). Maize plant development is categorised into two major stages: (a) the vegetative stage and (b) the reproductive stage. The vegetative stage starts from the seedling emergence up to tasselling. The reproductive stage commences at silking and pollination, up to grain-filling and maturity. Agronomists have further divided the vegetative stage by using the number of matured leaves (with expanded leaf collar) present on the maize plant (Siebers *et al.,* 2017).

The reproductive phase spans from kernel fertilisation to grain maturity. Fertiliser application, usually put into batches, should be completed within the first month to support the crop's physiological development. The time the plant develops into fifth leaf stage, its entire architecture, including leaves, ears, shoots, and tassel, is already formed in miniature. Despite its small size, the plant's yield potential is largely established, and the growing point remains protected beneath the soil surface, reducing vulnerability to external stresses. (Umesha *et al.,* 2014). The late vegetative stage is characterised by the complete emergence of the tassel, indicating that the maize plant has nearly attained its full growth potential. The 14-day window around silking is pivotal for yield determination, as any stress experienced by the plant during this period can compromise ear development and plant elongation, leading to reduced yields. Reaching silking with good fertility, sufficient water, and minimal damage is a critical milestone, indicating that growers are on track for a successful maize harvest, with the potential for high yields and excellent quality. (Maresma *et al.,* 2019).

2.4 Nutritive Value and Uses of Maize

As the third most important cereal crop worldwide, maize is a critical component of global food systems, supplying important nutrients for human and animal nutrition, and ranking behind only wheat and rice in importance (Murdia, 2016). Maize is a staple ingredient in various traditional dishes across Africa, with each country boasting its own unique recipes, such as Nigeria's Oji, Ghana's Kenkey, Cameroon's Koga, Mali's To, Ethiopia's Injera, and Kenya's Ugali. (Ely and Song, 2016). In many African cultures, maize is processed using traditional techniques, resulting in a variety of familiar foods. A common example is a warm maize paste or mush, often enjoyed with a traditional, low-strength beer (Murdia, 2016). The preparation and use of maize vary greatly depending on the region. In Africa, maize mush may be fried or baked, whereas in Central and Latin America, it is commonly consumed as maize bread or tortillas. Furthermore, maize is also utilised as livestock feed and as a primary product for industrial uses, particularly in developed countries (Chaudhary *et al.,* 2014).

In developing countries, majority of maize production is basically used for human consumption, however, its utilisation as animal feed is increasingly gaining momentum (Olaniyan, 2015). Beyond its food value, maize is also a crucial raw material for producing a range of products, such as starch, oil, protein, alcoholic beverages, sweeteners, and fuel. Notably, maize has the highest average yield per hectare compared to other cereal crops (Ladha *et al.,* 2016). Ghana's savanna agroecological zone has witnessed a notable shift in staple food preferences, with maize emerging as a major food source, gradually replacing sorghum and millet, which were previously the mainstay crops in the region (Tetteh *et al.,* 2018).

Domestic maize production in Ghana is currently meeting local demand for human consumption, but faces competition from the poultry industry and to a lesser extent, the livestock industry. Government estimates suggest that 85% of Ghana's maize crop is consumed by humans, with the remaining 15% used for animal feed, mainly in poultry production (Chaudhary *et al.,* 2014). Estimates indicate that, in 2000, Ghana's per capita maize consumption was approximately 42.5 kg (MoFA, 2010), with national consumption totalling around 943,000 metric tons in 2006 (SRID 2007) Separate data from Ghana's major feed mills shows that they utilise roughly 250,000 metric tons of maize annually for poultry feed production.

The maize plant is a valuable resource, with all its parts offering economic benefits. The grain, leaves, stalk, tassel, and cob can be transformed into a broad range of products, making maize a truly multipurpose crop (Chaudhary *et al.,* 2014). According to Ekpa *et al.* (2018), Maize offers a diverse range of uses due to its nutrient-rich composition. The grain provides starch, vitamins, proteins, and minerals, while the oil extracted from it is used for cooking and soap manufacturing. Furthermore, maize contains other valuable components, including sticky gum with dextrin for adhesive applications, and corn silk, which is a major source of maizeric acid, oils, and dietary fibre.

The cosmetic and pharmaceutical industries rely heavily on corn starch as a trusted diluent, leveraging its properties to achieve desired product textures and formulations (Huma *et al.,* 2019). Corn syrup extracted from maize is high in fructose, which makes it an effective sweetener, and its humectant properties help maintain moisture levels in certain food applications. Maize seeds are functional in making alcohol and stem fibres for manufacture of paper (Kumar and Jhariya, 2013). Maize is also a source of raw material for industries to produce products such as corn flakes, flour and maltodextrins (com oil) (Badora *et al.,* 2019) Maize seeds can be roasted and consumed as a coffee substitute. The plant is also a rich source of phytochemical secondary metabolites, including saponins, allantoin, sterols, stigmasterol, alkaloids, and polyphenols, which are present in its leaves, seeds, and silk, and offer various health-promoting properties (Kumar and Jhaliya, 2013). With its high antioxidant properties, this compound helps safeguard the body against the damaging effects of oxidative stressors, which are known to contribute to cellular damage and cancer. It also exhibits pain-relieving potential and analgesic activity, making it a valuable compound for overall health (Kumar and Jhaliya, 2013).

2.5 Maize Production in Ghana

Maize (*Zea mays*), is extensively cultivated throughout Ghana, covering a wide geographic range that includes the forest zone, transitional zone, southern regions, and the country's northernmost regions, comprising Upper West, Upper East, and Northern (Akumbole *et al.,* 2019). Maize has become an integral part of Ghana's agricultural landscape, owing to its prominence as the country's main staple crop and its substantial contribution to the national diet. As the leading cereal crop, maize is cultivated by a vast majority of rural households, underscoring its importance in Ghana's food system (Agyare *et al.,* 2014). Throughout Ghana, maize is a widely consumed food staple, second only to cassava in importance. The crop's extensive cultivation is driven by its significance as a main cereal grain, serving as a fundamental food source for a large portion of the Ghanaian population (Agyare *et al.,* 2014).

Maize also plays a significant role in Ghana's economy, serving as the country's second-largest commodity crop after cocoa. On the domestic front, maize is the leading cereal crop, and its production value is substantial, ranking 7th among all agricultural commodities and contributing 3.3% to the total agricultural production value between 2005 and 2010 (Ragasa and Kolavalli, 2014). Maize is also an important component of poultry feed and to a lesser extent the livestock feed sector as well as a substitute for the brewing industry.

In 2011, Brong Ahafo led the country in maize production, contributing (27%) of the national total, closely followed by Eastern Region at (20%) and then Central and Ashanti regions (12%) with Northern region producing the lowest (11%) (IFPRI, 2013) (Owusu *et al.*, 2013). Maize is the clear leader in Ghana's cereal production, occupying the largest share of planted area and generating 50-60% of the country's total cereal output, with paddy rice, sorghum, and millet trailing behind at (23%), (13%) and (9%), respectively (Iyanda *et al.,* 2014). Majority of maize cultivation in Ghana is undertaken by smallholder farmers, who typically cultivate under rain-fed conditions and have restricted adoption of improved agricultural practices, such as the use of enhanced seed varieties, fertilizers, and mechanization (Agyare *et al.*, 2014).

Average maize yield in Ghana is around 1.5 Mt/ha, but data from the Ministry of Food and Agriculture (MoFA) suggests that yields can reach up to 1.9 Mt/ha, highlighting the potential for further improvement to achieve optimal yields ranging from 2.5 to 4 Mt/ha (Darfour, 2016). Having said that, some farmers in Ghana have achieved remarkable maize yields of 5.0-5.5 Mt/ha by adopting modern farming practices, including the use of high-quality seeds, fertilisers, mechanized equipment, and irrigation systems (Agyare *et al.,* 2014).

2.6 Pests of Maize

In the tropics, pests attack is major constrains of maize production. They are responsible for considerable yield losses incurred in maize production. Different pests of maize exist; notable among them include weeds such as striga, rodent pests such as grasscutter, mice, squirrels, birds as well as insect pests. Insects pests and rodents such as mice are among the most devastating pests of maize (Diarra, 2016). Maize insect pests can be broadly categorised into on-farm pests, which damage the crop during growth, and storage pests, which infest grain after harvest. On-farm pests, particularly those that feed on leaves, can cause significant damage by either mining leaves or consuming large chunks, resulting in reduced photosynthetic capacity. (Tendeng *et al.,* 2019). In all the pests of maize, lepidopterous pests are considered to be the most destructive.

Stem and ear borers, armyworms, cut worms and grain moths are in this category (Tendeng *et al.,* 2019). Stem-borers are the most important pests of maize in the field and are scattered across the tropics. It is estimated that stem-borers are responsible for 15-78% and to a large extent 100% yield loss in maize (Kruger *et al.,* 2012).

Tendeng *et al.,* (2019), identified *Sesamia nonagrioides botanephago(Tams and Bowden), Eldana saccharina Wlk,* and *Busseola fusca fuller* as the most common stemborer species in Ghana, with high yield losses reported in the forest zone. *Sesemia* *calamistis* was also found to be a highly destructive field pest, affecting maize crops in all ecological zones surveyed in Ghana (Kruger *et al.*, 2012).

This pest has the potential to cause significant yield losses, typically ranging from 80% in normal conditions to a staggering 94.4% in more adverse situations (Diarra, 2016). *Sesamia species* are primarily responsible for the 'dead hearts' phenomenon in maize plants, regardless of age. The significant yield losses associated with this pest are due to its damaging effects on the stem and cob, as well as their tunnelling activities (Tendeng *et al.*, 2019). These pests consume plant tissue, severing vital xylem and phloem vessels, which disrupts the flow of essential nutrients and water, ultimately weakening the stems and making them prone to breakage even in gentle winds (Gesteiro *et al.*, 2021). By burrowing into the stems, the larvae can weaken the plant's structural integrity, interfering with the vascular system and potentially limiting or preventing the production of grains (Gesteiro *et al.*, 2021). The feeding activities of stem borer larvae at the pre-tasselling stage of maize growth can be devastating, as they destroy the meristem, resulting in the premature senescence of the middle whorl of leaves.

2.7 The Ghanaian Soil

Compared to other continents, Sub-Saharan Africa's (SSA) soils are generally of poor fertility, with many areas lacking the essential nutrients for optimal plant growth. (Stewart *et al.*, 2020). Characteristically, these soils have low nitrogen availability, micronutrient deficiencies (sulphur, magnesium, and zinc), and poor soil fertility due to heavy leaching, high acidity, and limited organic matter and cation exchange capacity (Pardo *et al.*, 2014). Soils subjected to continuous cropping often face not only chronic macronutrient deficiencies but also micronutrient limitations, particularly in zinc and boron, which can have detrimental effects on crop productivity. (Pardo *et al.,* 2014). SSA soils, including Ghana's, are physically degraded, with low organic matter levels and poor land cover, leading to poor soil structure, shallow roots, and increased erosion risk. Ghana's highly weathered soils are typically light-textured, with sandy loams and loams being the most common soil types (Gyekye *et al.,* 2020). In contrast to the surface layers, the lower soil horizons have denser textures, ranging from coarse sandy clay loams to clays. These heavier soils are typically found in valley bottoms, making them well-suited for rice cultivation (Pardo *et al.,* 2014).

In the B-horizons, subsurface layers that have undergone significant transformations or accumulation, coarse materials like gravel, stones, or hardened concretions are frequently abundant (Bryk, 2016). The coarse nature of the soils impairs their water-holding capacity, leading to frequent crop water stress during the growing season. Therefore, managing nutrient inputs and outputs is essential to maintain soil nutrient balances and ensure sustainable crop production (Sanyal *et al.,* 2014).

The soil nutrient balance is severely imbalanced, with nutrient removals vastly exceeding applications, causing soils to become increasingly impoverished. This trend is perpetuated by the persistent use of indigenous farming practices that prioritise short-term gains over long-term soil sustainability (Bryk, 2016). Tetteh et al. (2018) reported that nearly all crop balances in Ghana show a nutrient deficit, resulting from the disparity between nutrient application and removal. This nutrient gap compromises crop yields and contributes to the gradual decline of soil fertility (Pardo *et al.,* 2014).

2.8 Fertiliser Use in Sub-Saharan Africa

Sub-Saharan Africa (SSA) faces a pressing food security challenge, as population growth outstrips food production. The situation has decline since 1970, with a third of the population (33-35%) remaining malnourished, highlighting the need for a lasting agricultural solution (Coker *et al.,* 2015). The agricultural landscape in Sub-Saharan Africa is dominated by indigenous farming methods, characterised by low soil fertility and minimal use of external inputs, such as irrigation, fertilisers, and pesticides (Kuyah *et al.,* 2021).

The decline in investment in farm inputs, including fertilisers, seeds, and technology, is a major concern for African agriculture. To boost food production, soil fertility management must be prioritised. The strategic application of mineral fertilisers, coupled with advanced management techniques, is important for improving soil health and productivity (Kuyah *et al.,* 2021). The benefits of fertiliser application are widely acknowledged, as evidenced by the enhanced growth and productivity of plants grown in soils with recently applied fertilisers. (Roberts and Johnston, 2015).

The use of mineral fertilisers is essential for effective soil fertility management and will remain a cornerstone of agricultural development strategies in Sub-Saharan Africa, particularly those focused on increasing food production (Itelima *et al.,* 2018). According to Appiah (2020), fertilisers have played a crucial role in boosting crop yields in some developing countries, with 50-75% of yield improvements attributed to their use.

Soil nutrient depletion is a primary physical constraint hindering crop production growth in Africa, and it is a widespread issue plaguing the continent's agricultural sector (Gicheru, 2012). A staggering nutrient deficit has accumulated in SSA in the last 30 years with estimated average annual losses of 660 kg/ha of nitrogen, 75 kg/ha of phosphorus, and 450 kg/ha of potassium, impacting roughly 100 million hectares of cultivated land (Kuyah *et al.,* 2021). Coker et al. (2015) caution that inadequate fertiliser use will have severe repercussions, including soil nutrient depletion and the unsustainable use of marginal lands. The alarming scale of nutrient losses in SSA over the past 30 years underscores this warning, with average annual losses of 660 kg/ha of nitrogen, 75 kg/ha of phosphorus, and 450 kg/ha of potassium recorded across approximately 100 million hectares of cultivated land (Itelima *et al.*, 2018). To put this into perspective, the nutrient losses are equivalent to approximately 1.4 tonnes of urea ha-^{1,} 375 kg of Triple Superphosphate, (ISP) ha-^{1} or 0.9 tonnes of phosphate rock per (PR) of average composition ha^{-1}.

Nutrient depletion rates are site specific; they are dependent on the extent of land usage in previous years (Itelima *et al.,* 2018). Nutrient depletion at certain sites is almost negligible either due to low-intensive land usage or nutrient replacement through fertiliser application. Per annum, nutrient depletion on cultivated lands in Africa is estimated at 4.4 million tons nitrogen, 0.5 million tons Phosphorus and 3 million tons Potassium, which according to FAO (2013) is higher in magnitude than the annual fertilizer consumption.

2.9 Fertiliser Use in Ghana

Maize production is highly dependent on sufficient nutrient availability, particularly nitrogen, phosphorus, and potassium. These nutrients play a vital role in supporting robust vegetative growth and grain formation, with nitrogen and phosphorus being crucial for optimal maize development and high yields (Gomez, 2010). Fertiliser application is a vital farming practice that corrects soil deficiencies, ensuring optimal crop growth and productivity. Historically, fertiliser consumption saw a dramatic increase in the 1970s, rising tenfold, with a record high of approximately 31,000 tonnes of total nutrients in 2000 (Bartoli *et al.,* 2012) The FAO Fertiliser Program's efforts in Ghana were instrumental in promoting fertiliser use, and this likely had a positive impact on the country's fertilizer consumption rates.

The recommended fertiliser application rate per hector of cultivated land remained suboptimal, and the situation worsened after 2000 when the Structural Adjustment Programme (SAP) was introduced, resulting in the removal of key agricultural support mechanisms, including fertiliser subsidies, and a subsequent decline in fertiliser use. (Mbithe *et al.,* 2017). Fertiliser use experienced a temporary surge as the national economy recovered, but subsequently declined due to renewed economic instability and a weakening of the Cedi (Mbithe *et al.,* 2017).

Ghana's fertiliser usage rate of about 5 kg/ha is notably low, standing at roughly half the average rate for sub-Saharan Africa, which itself has the lowest fertiliser use among developing regions, averaging just 9 kg/ha (Sheahan, 2014). The adoption of mineral fertilisers in Ghana has been disappointingly slow, despite their recognised importance in national development plans. Ghana's average fertiliser application rate of less than 8 kg/ha is significantly lower than that of neighbouring countries, such as Malawi and Kenya, which have rates of 22 kg/ha and 32 kg/ha, respectively (Fuentes *et al.,* 2012).

The pattern of fertiliser application in Ghana reveals that major cash crops, such as cocoa and cotton, have the highest application rates. Maize has relatively moderate fertiliser use, while staple crops like millet, cassava, sorghum, and yam have very low or no fertiliser application (Sheahan, 2014). On average, fewer than 20% of households in Ghana use fertilisers, with usage rates differ substantially from region to region within the country (Quinones and Diao, 2011). The average fertiliser consumption stood at 11.88 kg/ha of arable land. This indicator tracks the quantity of fertiliser nutrients used per hectare of arable land, covering a broad array of products including N, P, and K fertilisers, aside ground rock phosphate (Fuentes *et al.,* 2012).

2.10 Fertilizer Formulations

Using appropriate land improvement technology seems to offer an opportunity to substantially increase crop production and income levels. Barrett and Bevis (2015), made references to poor soil nutrients in maize production as among the causes of low yield. In response, some fertiliser manufacturing institutions have unveiled various formulations of fertilisers. There exist a comprehensive range of fertiliser formulations that supply the most essential plant nutrients. A combination of Nitrogen (N), Phosphorus (P) and Potassium(K) designed to maximise crop performance, quality and formulations that meet precise crop requirement are needed (Timsina, 2018). N.P.K fertilisers are some of the most highly efficient sources of readily available nitrogen, phosphorus and potassium in the soil.

Each N.P.K formulation is tailored to supply precise quantity of N, P and K so that when accurately applied to a crop the fertilisers ensure accurate addition of these major nutrients (Timsina, 2018). Besides, some N.P.K fertilisers have been prepared such that in addition to supplying N, P and K, they can supply secondary macro nutrients and micro nutrients essential for specific crops (Njoroge *et al.*, 2018). These includes: essential nutrients from magnesium (Mg) and Sulphur (S) to manganese (Mn) and zinc (Zn), which ensures balanced nutrition throughout the growing season and results in improved yield and quality (Njoroge *et al.*, 2018). N.P.K fertilisers are mostly ammonium nitrate-based compound fertilisers.

Fertilisers typically contain a combination of ingredients, including ammonium, phosphate, and potassium salts, as well as inert fillers, secondary nutrients, and coating agents. For instance, NPK fertilisers with formulations like 15-15-15, 23-10-10, and 20-10-10 provide varying percentages of nitrogen (N), phosphorus P_2OS, and potassium K_2O to support plant growth (Sharma and Chetani, 2017). Furthermore, this fertiliser formulation not only contains 23% N, 10% P, and 5% K, but also actively supplies sulphur, magnesium oxide, and zinc to support plant growth (Nyalemegbe *et al.*, 2012).

2.11 Fertiliser Recommendations

Ghana's shifting soil conditions have rendered traditional fertiliser recommendations ineffective, underscoring the need for revised guidelines. Specifically, maize requires updated fertiliser recommendations to avoid over- or under-supply of essential nutrients, which can compromise crop growth and desired outcome (Bennett *et al.*, 2012). To achieve sustainable agriculture, the principle of balanced fertilisation necessitates the careful management of fertilisers to prevent harm and promote eco-friendly practices, ultimately supporting a viable and environmentally conscious agricultural sector for the future (Farnworth *et al.,* 2017). The adoption of high-yielding crop varieties will accelerate soil nutrient mining, highlighting the need for timely and adequate mineral fertiliser applications to prevent nutrient deficiencies and maintain soil productivity.

Vanlauwe *et al.,* (2015) identified a major constraint to fertiliser use: the uncertainty surrounding the most effective fertiliser type, rate, application and timing for various crops. Furthermore, the authors noted that the high cost of mineral fertilisers often prohibits their use, suggesting that testing lower, more cost-effective application rates could make them more viable for producers. According to Bationo *et al.,* (2018), Ghana's soils experienced significant nutrient depletion between 1993-1995, with an annual loss of 51-100 kg/ha of N, P_2OS, and K_2O. Meanwhile, the average annual nutrient requirement for optimal crop production exceeded 80 kg/ ha of N, P_2OS, and K_2O Bationo *et al.,* (2018).

2.12 Fertiliser Policy in Ghana

Following the Abuja declaration, the Government of Ghana introduced a fertiliser subsidy policy as part of its Food and Agriculture Sector Development Policy, aimed at promoting agricultural growth and development (Fosu, 2015). In an effort to improve food security, Ghana's fertiliser subsidy policy was established, supporting a countrywide initiative that started in 2008 and initially provided subsidies for four varieties of inorganic fertilisers (Fosu, 2015). The objective was to stimulate fertiliser use, thereby increasing crop yields across various categories, such as roots and tubers, grains, legumes, vegetables, and perennial crops, including cocoa, to improve overall agricultural productivity (Quansah, 2016).

The policy ensures nationwide price uniformity for subsidised fertilisers, with the overarching goal of reducing poverty, hunger malnutrition, and promoting overall well-being, in line with the objectives of the Millennium Development Goals (MDG1) (Apraku *et al.*, 2010). The fertiliser subsidy program covers four types of inorganic fertilisers: Urea, Ammonium Sulphate, NPK 15:15:15, and NPK 23:10:15. In 2008, the government subsidised approximately 600,000 50kg bags of fertiliser, costing around $14 million, while in 2007, an allocation of 37 million Ghana Cedis was made for the program (Quansah, 2016). Farmers acquired subsidised fertilisers by utilising coupons issued by the Ministry of Food and Agriculture (MoFA) and disseminated through local extension agents.

2.13 NPK Fertilizer Application and Maize Production

As a heavy feeder, maize responds well to timely and adequate NPK fertiliser application. Fertiliser recommendations are tailored to specific soil types based on routine analysis, and may vary. For maize production in Ghana, the recommended fertiliser application is 50 kg per acre of 15:15:15 NPK at planting or two weeks after, followed by topdressing with 50 kg per acre sulphate of ammonia or 25 kg per acre urea just before tasselling (Dhlamini *et al.*, 2020). Chemical fertilisers provide a rapid boost to crop yields because their nutrients are quickly accessible to plants, whereas organic fertilisers release nutrients more gradually, resulting in a slower but more sustained nutrient supply.

Ashgar *et al.,* (2010) emphasised the vital role of mineral fertilisers in increasing maize yields, with a significant contribution of 40-45%. NPK fertilisers, rich in essential nutrients, exert a strong influence on plant growth and development, fostering healthy cell growth, multiplication, and expansion, which in turn promotes vigorous plant growth and higher yields (Dhlamini *et al.,* 2020). The use of mineral fertilisers in Advanced agricultural methods have proved to beneficial, as they supply crops with readily available nutrients that correct deficiencies, promote resilience to stress, and support optimal soil fertility, ultimately leading to improved crop yields and quality (Soares *et al.,* 2019). NPK fertilisers play a vital role in supporting the nutritional needs of maize and other cereal crops. Their benefits are evident throughout the growth cycle, with significant effects on plant height, stem thickness, and biomass production. Nitrogen, a key component of NPK fertilisers, promotes robust vegetative growth, but can also delay maize maturity by prioritising leaf and stem development over reproductive growth (Ekwere *et al.,* 2013).

Ekwere *et al.,* (2013) demonstrated that increased fertiliser application rates led to improved maize yields, while Achieng et al. (2010) in Kenya found that applying NPK (17:17:17) fertiliser at specific rates (144, 60, and 120 kg/ha at planting), followed by 56 kg/ha of urea as a top-dressing, and supplemented with 20 kg/ha of Mg ($MgSO4.7H2O$) and 5 kg/ha of B ($Na2BO7.10H2O$) at planting, resulted in significantly higher maize yields. Obdiebube *et al.,* (2012) conducted a study to evaluate the impact of varying NPK (15:15:15) fertiliser rates on maize growth, applying rates of 0.10, 0.13, and 0.15 kg/ha, alongside control. The results indicated that maximum amount fertiliser usage of 0.15 kg/ha resulted in significant improvements in growth metrics, including plant height, leaf area, and grain yield, as opposed to lower application rates. A research conducted by Kolawole and Joyce (2009) also examined the influence of NPK 15:15:15 fertiliser on maize growth and yield. The results indicated that NPK fertiliser application had a significant positive impact on various growth metrics, including plant height, stem girth, leaf area, and dry matter accumulation, leading to improved maize productivity.

The recommended application rate for NPK 15:15:15 fertiliser in maize grain production was determined to be 400 kg/ha, which includes 60 kg N, 27.16 kg P, and 49.80 kg K. This rate achieved the highest levels of dry cob yield (12.44 t/ha), grain yield (7.95 t/ha), relative grain yield (2.26), and 100-seed weight (11.62 g), indicating its optimal level for successful maize grain production. Egbe *et al*., (2012) examined the effects of N application on development and yield of maize grown alone and in combination with Calliandra pruning, Gliricidia pruning or Senna pruning. The greatest grain yield was observed in Calliandra + fertiliser (4696 kg/ha) and least in control (3332 kg/ha). Wang *et al.*, (2020) investigated the effects of combining organic fertiliser with reduced NPK fertiliser rates and found that this method produced superior grain and biological yields in maize, surpassing the 50% NPK treatment and matching the 100% NPK fertiliser treatment. Consistent with these findings, Saidu and Babalade (2012) also indicated that applying poultry manure in combination with inorganic fertilisers resulted in the highest grain yield, while the sole application of inorganic fertiliser yielded the lowest results.

2.14 Briquette Fertiliser

NPK Briquette (NPKBriq) provides a unique nitrogen source, delivering N, P, and K, and sometimes S and Zn, to improve the efficient utilisation of these nutrients. The production of NPKBriq involves the physical transformation of commercially available prilled and granular N, P, and K fertilisers into larger, 1-4-gram super granules (IFDC, 2007). As a fully mineral-based fertiliser, it delivers N, P, and K nutrients in a balanced ratio that matches the unique requirements of the intended crop and soil type (Agyin-Birikorang *et al.*, 2018). This NPKBriq fertiliser product facilitates precise, site-specific fertilisation with a balanced nutrient profile, minimising nutrient losses, particularly N, and labour needs, as it requires only a single application, unlike the two to three split applications typically needed for prilled and granular fertilisers (Bandaogo *et al.*, 2014). NPKBriq has a lower surface area, resulting in slower dissolution and a more gradual release of nutrients over an extended period. This reduces nutrient losses, particularly N, and subsequently helps protect water and air quality, offering an environmental advantage over prilled and granular fertilisers (IFDC, 2015; Savant and Stangel, 1990).

2.15 Effect of Briquette Fertiliser on Crop Growth and Yield

Kokare *et al*., (2015) and Talpade *et al.,* (2011) reported that applying Urea-Godavari briquettes (3 per plant) at transplanting, 30 DAT, and 60 DAT yielded superior results in terms of chilli yield compared to other treatments. This application method also resulted in higher total N and P uptake, while applying Urea-Sulphur briquettes at the same intervals increased total K uptake. The use of all three briquette types further improved post-harvest soil nutrient status (N, P, and K) compared to recommended fertilizer doses based on soil tests as reported by Kadam *et al.* (2005) and Talpade *et al.,* (2011). Studies revealed that organically enhanced Nitrogen fertilisers (OENF) led to increased fibre concentrations in maize compared to NPKBriq at 85 kg N ha^{-1} in 2013. Furthermore, both OENF and NPKBriq had negligible effects on quality attributes when compared to ammonium sulphate and urea. In summary, NPKBriq's balanced nutrient profile produced comparable or better results in terms of maize grain quality compared to traditional nutrient management practices involving urea and ammonium sulphate, while OENF proved to be a suitable alternative N source for achieving similar or superior maize grain quality.

A single application of multi-nutrient fertiliser briquettes may be the optimal fertiliser management plan for maize production in northern Ghana (Adu-Gyemfi *et al.,* 2019). The use of multi-nutrient fertiliser briquettes in a single application can provide significant agronomic and environmental benefits, including increased maize yields through improved nutrient retention and utilisation, and reduced nutrient leaching into the environment (Xiaohui *et al.,* 2020). Generally, NPKBriq with a balanced nutrient profile demonstrates equivalent or greater impacts on maize grain quality than the commonly used nutrient management techniques involving urea and ammonium sulphate (Xiaohui *et al.,* 2020).

The use of urea briquettes and their deep placement led to improved nitrogen, phosphorus, and potassium use efficiency, likely due to the controlled release of nitrogen, which minimised losses and enhanced nutrient uptake and yield. These treatments significantly reduced nitrogen losses in irrigated rice (Rinky *et al.,* 2018). In contrast to other treatments, the leachates from urea plus organics briquettes exhibited much lower levels of nitrates and ammonia. The utilisation urea briquettes had enormous impact on the availability of N, P, and K in the soil at harvest time. The urea plus farm yard manure (FYM) briquette treatment was determined to be the most effective approach for irrigated rice cultivation, offering improved nitrogen usage efficiency over other nitrogen sources (Rinky *et al.,* 2018).

The results indicated that adding organics to urea briquettes and deep placement enhanced nitrogen, phosphorus, and potassium use efficiency, possibly due to the controlled release of nitrogen, which reduced losses and increased nutrient uptake, leading to higher yields. The treatments had a significant effect on nitrogen losses in irrigated rice, and the concentration of nitrates and ammonia in leachates from urea plus organic briquettes was significantly lower than in other treatments. The application of urea briquettes had a profound effect on the availability of NPK in the soil at harvest. Overall, the combination of urea plus farm yard manure (FYM) briquettes proved to be the most effective fertiliser approach for irrigated rice cultivation, exhibiting higher nitrogen use efficiency compared to the standard recommended fertilizer doses (Rinky Roy *et al.,* 2018).

Baral *et al.,* (2020) reported promising results on hybrid maize (Khumal Hybrid-2) in Western Nepal, focusing on N application methods. Their study found that deep placement of urea briquettes was a cost-effective approach, allowing for a 25% reduction in N application compared to conventional practices. Additionally, research by Kadam (2002) showed that briquette-form fertilisers significantly enhanced K uptake in tomato fruits compared to non-briquette forms.

2.16 Effect of Briquette Fertiliser on Soil Chemical Properties

Studies by Pillai (2004) and Bulbule *et al.,* (2008) reported an increase in available phosphorus when briquettes were applied to rice crops. Furthermore, Okare *et al.,* (2015) observed that the application of all three briquette types enhanced the post-harvest availability of N, P, and K in the soil, outperforming RDF and soil test-based

RDF. Leachate of N concentrations from the two briquette treatments were consistently similar to background levels throughout the sampling periods, with the FP resulting in the greatest leachate N concentrations, followed by its modifications.

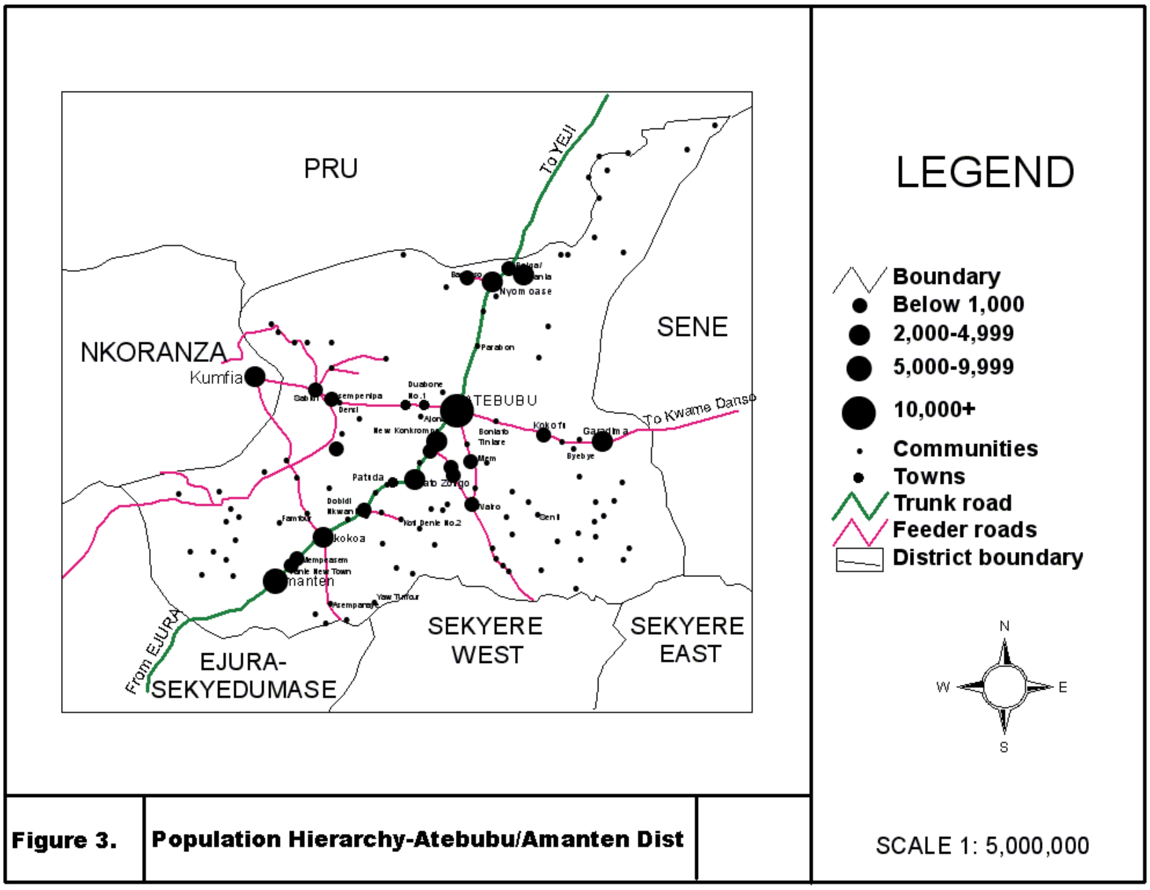
There was no notable difference established in the treatment of leachate P and K concentrations (Adu-Gyemfi *et al.,* 2019). Applying urea briquettes significantly affected the availability of N, P, and K in the soil atSS harvest. Overall, the urea plus FYM briquette application emerged as the most suitable fertiliser strategy for irrigated rice cultivation, offering higher nitrogen use efficiency than the recommended fertiliser dose (Rinky Roy *et al.,* 2018).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Experimental Site and Location

A multi-locational experiment was conducted at Amantin and Nsapor during the peak of the wet season beginning from April to August 2022. The Atebubu-Amantin Municipality is one of the 11 municipalities/districts in the Bono East Region of Ghana. The study location, Amantin, is located in the central woodland savannah agroecological zone, also known as the tree savannah. It is part of the transitional zone and was formerly forested. The current savannah conditions are known to have emanated from activities of human such as charcoal burning and annual bushfires (MoFA, 2023).

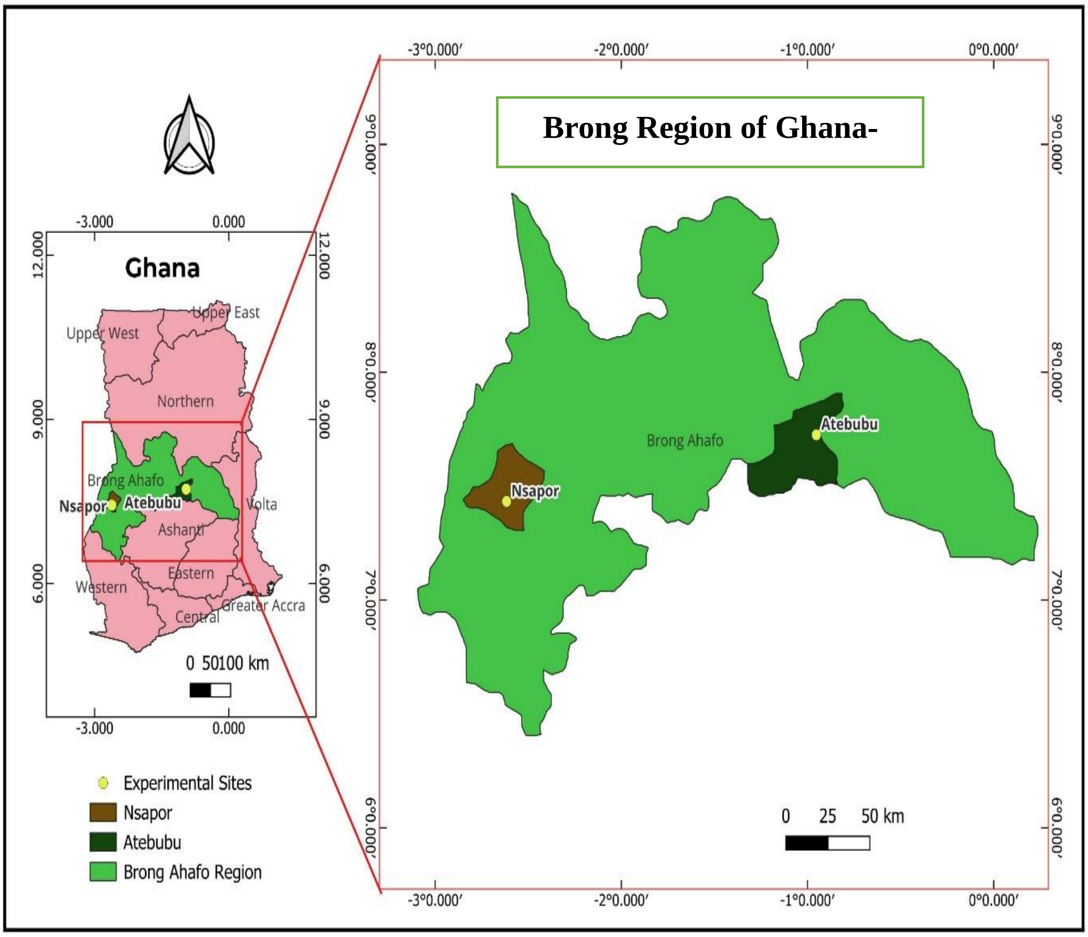
The municipality is surrounded by several districts, including the Pru Districts to the north, the Sene West District to the west, and the Nkoranza North District to the east, all of which are located within the Bono East Region. To the south, it shares borders with three districts in the Ashanti Region: Ejura-Sekyedumase, Sekyere East, and Sekyere West Districts. The municipal capital, Amantin, is situated approximately 155 kilometers from Kumasi and 108 kilometers from Techiman, the regional capital. The municipality spans a vast area of around 4,406 square kilometres. The Map of the Study area is shown in Figure 3.1



Source: Department of lands Commission, Amantin, 2018

Figure 3.1: Map showing the study area (Amantin)

Nsapor experimental site, Nsapor-Berekum, is a town in the Berekum Municipality, located in the Bono Region of Ghana. The town is situated on latitude 7.4333, and longitude -2.6166. It is approximately 17 kilometres north of Berekum, the municipal capital. Nsapor-Berekum is located in the Guinea savannah zone, characterised by a mix of trees and grasses. The town is surrounded by other towns and villages in the Berekum Municipality, including Ahenbronoso, Deduako, and Wiawso. Nsapor-Berekum is a relatively small town with a population of about 1,500 people. The main economic activities in the area are agriculture and petty trading. The town is surrounded by farmland where crops such as maize, yam, cassava, and groundnuts are cultivated. The Map of the Study area is shown in Figure 3.2.



***Source**: Department of lands Commission, Berekum West, 2020*

Figure 3.2: Map showing the study area (Nsapor)

3.2 Soil and Climatic Conditions

The soil types in Amantin range from fine silty loam to sandy loam, and are generally characterised by good drainage. The district experiences the tropical continental or interior savannah type of climate which is a modified form of the wet semi-equatorial type of climate. This is due to the location of the district in the transitional zone (between the two major climatic regions in Ghana). The total annual rainfall is between 1,400 mm to 1,800 mm and occurs in two seasons. The first rainy season begins in May or June whilst the second rainy season begins in September or October. The difference between the minor and the major seasons is hardly noticed owing to the transitional nature of the area (MoFA, 2023). Monthly temperatures of the location fluctuate, peaking at 30 °C in March and dropping to 24 °C in August. The average annual temperature falls within a narrow range of 26.5 °C to 27.2 °C. On rare occasions, temperatures have been known to soar to around 40 °C, as was recorded in 1999.

Between November and March/April, the district is affected by the Northeast Trade Winds (Harmattan). The local climate is characterised by instability, with rainfall patterns fluctuating greatly between years. For instance, some years like 1983 and 1994 saw delayed or low rainfall, while others experienced excessive rainfall, storms, and destructive downpours that impacted crops and infrastructure (MoFA, 2023). The climate of Nsapor-Berekum is a tropical savannah climate, with distinct wet and dry seasons. The rainy season lasts from May to October, with the heaviest rainfall starting from June to September. During this period, the area receives an average of 1,200 to 1,500 mm of rainfall.

The dry season spans from November to April, and during this period, there is little to no rainfall (MoFA, 2023). Temperatures in Nsapor-Berekum are generally high throughout the year, with mean temperatures found between 25°C to 30°C. The hottest months are February to April when temperatures can reach up to 38°C. The harmattan, a dry and dusty trade wind from the Sahara, occurs from December to February and can cause a drop in temperatures and low humidity levels (MoFA, 2023). The climate of

Nsapor-Berekum is suitable for a broad range of crops, with the rainy season providing ample water for crop growth, while the dry season allows for the harvesting and processing of crops. However, climate change and variability pose a significant challenge to agricultural production in the area, with the increasing frequency of droughts and floods affecting crop yields and livelihoods of local communities (MoFA, 2023).

3.3 Vegetation

Although Amantin falls within the interior wooded savannah or tree savannah, its transitional nature means it lacks typical savannah features. The savannah is densely wooded, but the trees are generally smaller than those in moist deciduous forests. Researchers believe that the area was once forested, but human activities have resulted in the current savannah conditions prevailing in the transitional zone. (MoFA, 2023). Nsapor-Berekum lies in the Guinea savannah zone, a region typified by a mixture of wooded areas and grasslands.

The vegetation in the area is relatively dense, with tall grasses and scattered trees that provide shade and shelter for people and animals. The most common tree species in the area include shea, dawadawa (*Parkia biglobosa),* and baobab (*Adansonia digitata*). In addition to trees, the vegetation in Nsapor-Berekum includes a variety of grasses, herbs, and shrubs. The most common grass species in the area include Guinea grass (*Panicum maximum*) and spear grass (*Imperata cylindrica*), which are important for grazing and forage for livestock. Other important plants in the area include okra (*Abelmoschus esculentus*), cassava (*Manihot esculenta*), and yam (*Dioscorea spp*.), which are stapled crops in local cuisine (MoFA, 2023).

3.4 Agriculture

It is observed that, as high as 70.2 % of households in the Atebubu-Amantin district are engaged in agriculture. In the rural localities, eight out of ten households (89.4 %) are agricultural households while in the urban localities, 90.6 % of households are into agriculture. The vast majority of households in the district (95.5%) engage in arable farming. Poultry, specifically chickens, are the predominant livestock reared in the district. Agriculture is a major economic activity in Nsapor-Berekum and the surrounding areas, with the majority of the population engaged in farming.

The fertile soil and favourable climatic setting in the area support a broad range of crops, including maize, yam, cassava, millet, sorghum, cowpea, groundnuts, and vegetables. Yam and maize are the most widely cultivated crops in the area, with yam being an important cash crop that is sold in local markets and transported to other regions of Ghana. Other crops such as cowpea and groundnuts are also important for their nutritional value and income-generating potential. Livestock production is also an important component of agriculture in Nsapor-Berekum, with cattle, sheep, and goats being raised for meat and milk production. Poultry farming, particularly the production of local chickens, is also common in the area. Farming in Nsapor-Berekum is largely done using traditional methods, although there is increasing adoption of modern technologies and practices, including the use of improved seed varieties, fertilizer, and irrigation.

3.5 Geology

The underlying geology of Amantin consists of rocks from the Voltaian formation, which spans approximately two-fifths of Ghana's surface area. These sedimentary rocks, including sandstones, shales, mudstones, and limestones, exhibit horizontal layering. However, the Voltaian formation poses a challenge for underground water exploration and exploitation. Nsapor lands on the other hand are generally sandy and loamy, with low nutrient content.

3.6 Relief and Drainage

The municipality's terrain is characterised by a relatively flat landscape with gentle rolls and undulations, featuring elevations between 60-300 meters above sea level. Notably, the area lacks significant highlands or hills. The Pru River, a tributary of the Volta Lake, is the primary drainage system, flowing through the northern part of the district. Other key watercourses include the Nyomo and Bresuo Rivers. The slow flow of these rivers facilitates the deposition of fertile alluvial soils, offering considerable potential for enhanced food production in the district (MoFA, 2023). The Nsapor zone is characterised by low-lying hills and valleys with broad valleys. The area is generally flat with an elevation ranging from 200 to 300 meters above sea level. The landscape is dominated by a mixture of grasslands and scattered trees, with occasional patches of forest in the valleys (Fowe *et al.,* 2015). The area is drained by several small streams that flow into the larger tributaries of the Black Volta River. The streams are intermittent, and their flow is highly seasonal, with most of the runoff occurring during the rainy season from May to October. The Black Volta River is an major source of water for irrigation, and fishing in the area (Fowe *et al.,* 2015).

3.7 Experimental Design and Treatments

3.7.1 Experimental Design

A Randomised Complete Block Design (RCBD) with seven treatments and replicated four times was used for the study.

3.7.2 Treatments

The treatment combination is presented in Table 3.1.

Table 3.1: Treatment combinations

Treatment Code	**Treatment combinations**
Treatment Code	
T1	Control
T2	Granule NPK & Urea (120-40-40) 200 kg/ha
T3	Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha
T4	Briquette NPK & Urea (114-44-44) 172.8 kg/ha
T5	Briquette NPK & Urea (91-59-59) 230.4 kg/ha
T6	Briquette NPK & Urea (76-29-29) 115.2 kg/ha
T7	Briquette NPK & Urea (31-29-29) 115.2 kg/ha

3.8 Land preparation

The total field area measured 41 m x 26 m (1066 m^2). The land preparation involved clearing weeds and removing stumps, followed promptly by ploughing, liming, and pegging, and plot preparation for sowing maize seeds at the two sites, Amantin and Nsapor. The experimental field was demarcated into four blocks, each subdivided into seven plots, with 2 m and 0.5 m spacing between blocks and plots, respectively. In total, 28 plots were utilised for the study. Each experimental plot measured 5 m x 5 m (25 m²).

3.9 Soil Sampling and Analysis before Planting and after Harvesting of Maize

An undisturbed soil samples were taken with core samplers of 5.0 cm internal diameter, by 5.0 cm (height) from each plot at both experimental sites; Amantin and Nsapor. These samples were utilised to determine bulk density, total porosity, and particle density. Additionally, disturbed soil samples were collected randomly from a depth of 0 – 20 cm on each plot to assess particle size and chemical properties. After harvesting representative soil samples were taken for routine analysis. Final soil infiltration was determined on each experimental plot and the values recorded in mm/hr. Soil samples were collected from each plot using the core sampler, as previously described, and utilised to determine bulk density, porosity, and particle density. Again, soil samples were taken from each experimental plot, air dried and taken to the laboratory of the university of Energy and Natural Resources for the determination of chemical properties as described earlier.

3.10 Planting Material and Planting

Sanzal sima maize variety was obtained from the International Fertiliser Development Centre (IFDC). IFDC is a science-based public international organisation based in the USA working to alleviate global hunger by introducing improved agricultural practices and fertiliser technologies to farmers and linking farmers to markets. The *Sanzal sima* maize variety is white in colour. The *Sanzal sima* maize variety was selected owing to tolerance to maize diseases and early maturing characteristics (maturing within 110 days) post-planting, and its adaptation to local growing conditions. Three seeds were sown per hole on 13th April 2022 and 27th April 2022 at Amantin and Nsapor, respectively. The planting distance was 75 cm x 40 cm. The number of rows was 6 and the number of hills per row was 12. Thinning out to two (2) seedlings per hole and vacant stands were supplied in with new seeds at one week after sowing.

3.11 Agronomic Practices

Different rates of inorganic fertilisers were applied 3 weeks after planting through deep placement. Two NPK and Urea briquette fertilizers were deep placed 5 to 10cm deep by the side of each of the maize plant. The NPK granules were top dressed 3 weeks after planting. The fertiliser granules were spread around the base of the maize plant. Weeds were managed for both experiments at 3-4 WAP maize using hoe and cutlass before the close of the canopy to reduce the competition with crops. After the 3-4 weeks period, weed control was done by hand pulling. The incidence of pests and diseases were periodically monitored during routine visits to the experimental sites; Amantin and Nsapor to check for pests like the fall armyworm (*Spodoptera exempta*). Pests were controlled by spraying with Cydim super (Cypermethrin+Dimethoate) with the recommended rate of 40ml per 15-litre Knapsack sprayer tank. This was done four 4 WAP for both cropping seasons.

3.12 Data Collected

3.12.1 Phenological Data

3.12.1.1 Days to 50% emergence

A plot attained 50% emergence when half of the number of seeds sown within the four middle rows had emerged and the days for each plot to attain this was recorded.

3.12.1.2 Days to 50% tasselling and silking

This achieved when half of the number of seeds sown within the four middle rows had tasseled and silked and the days for each plot to attain this was recorded.

3.12.2 Vegetative Growth Data

The vegetative or growth parameters were taken on five plants from each treatment which was randomly sampled from the four middle rows. Data on vegetative parameters were taken at 2 weeks intervals beginning from 35 days after planting (DAP), that is 5 weeks after planting.

3.12.2.1 Plant height

The heights of the tagged plants (5 plants) in each plot were measured and recorded from 5 weeks after planting and every two weeks thereafter. Their means were computed before their analysis and recorded in cm.

3.12.2.2 Number of leaves per plant

The number of leaves were counted and recorded at 5 weeks after planting (WAP) and every two weeks interval.

3.12.2.3 Leaf chlorophyll content

Leaf chlorophyll concentration was quantified using a SPAD chlorophyll meter (Konica Minolta SPAD-502 plus), which measures a relative index of leaf chlorophyll concentration. The device was initially calibrated and then clamped to three positions on the leaves: the lower section, the middle portion, and towards the leaf tip. The 5th and 6th leaves at the same stalk of the maize plant were selected for chlorophyll content and averages were computed.

3.12.2.4 Stem diameter

Using a Vernier calliper, the girth of each stem was measured at the second internode from the soil surface and recorded in centimetres (cm) estimated at both locations.

3.12.2.5 Internode length

The length of the internode is the distance between two successive nodes. Measurements were made with a ruler. The lower side of the ruler (zero mark) is placed on the soil, as close as possible to the plant base to measure the distance between two nodes. The length of the internodes was measured in centimetres (cm) with the help of a ruler estimated at both locations.

3.12.2.6 Leaf area

Leaf length was measured from the junction of the leaf blade and leaf sheaths, and leaf width was measured at the widest part of the leaf estimated at both locations. They were measured on two leaves sampled from tagged plants from the bottom, middle and upper sections of the canopy. The leaf area was calculated according to the following equation: Leaf area = LL x LW x K. Where LL= leaf length, LW= leaf width, and K is a constant = 0.75 according to Stewart and Dwyer (1999). The length of each fully opened leaf lamina was measured from leaf base to tip and breadth was taken at the widest point of the leaf lamina. The product of leaf length and breadth was multiplied by a factor of 0.75 (Saxena and Singh, 1965), to determine the leaf area.

3.12.3 Yield and yield components of Maize Measured

Parameters measured included number of cobs per plot, biomass weight at harvest, cob weight, grain weight, 100-seed weight, cob diameter and cob length,

3.12.3.1 Number of cobs harvested

The total number of cobs from the four middle rows of each treatment was counted on the day of harvest and mean recorded as the number of cobs per plot at both locations.

3.12.3.2 Biomass weight at harvest

The maize crops were cut at the time of harvest from the ground level weighed oven dried at 105^0C for 72 hours and reweighed to obtain the biomass weight at Amantin and Nsapor. The mean was recorded in kg/ha

3.12.3.3 Cob weight per plot

The cobs of each treatment plot were weighed using an electronic weighing scale and the mean was recorded in kg/ha.

3.12.3.4 Cob diameter

Five cobs were randomly selected from the four middle rows of each treatment plot to determine the cob diameter. The diameter was measured with a digital vernier calliper and the values recorded in centimetres at Amantin and Nsapor.

3.12.3.5 Cob length

Five cobs were randomly selected from the four middle rows of each treatment plot to determine the cob length. The length was measured using meter rule and the values recorded in centimetres at Amantin and Nsapor.

3.12.3.6 100-seed weight

After shelling, 100-seeds were randomly selected from the four middle rows of each treatment plot, weighed with an electronic weighing scale and the mean recorded in grams (g) at Amantin and Nsapor.

3.12.3.7 Grain weight per plot

After shelling, grains from the four middle rows of each treatment plot were sun-dried to constant moisture. The dried grains were then weighed with an electronic weighing scale and their grain weight per plot ($9m^2$) was subsequently recorded in kg/ha at Amantin and Nsapor.

3.13 Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) using Statistix Version 9.0 Software package and the treatment means were separated and compared using Tukey’s Honestly Significant Difference (HSD) at 95 % confidence level (Littell *et al.,* 1996).

CHAPTER FOUR: RESULTS

4.1 Soil Chemical Properties

The initial soil chemical properties (0-20 cm depth) at the experimental sites were analysed and recorded on Table 4.1. The pH of the soil at Amantin was 6.5 which is slightly acidic, while at Nsapor, it was 5.5, indicating acidic soil condition. Both sites showed low levels of available P, ranging from 0-10 ppm. Exchangeable potassium quantities were determined to be 50 ppm at Amantin but 40 ppm at Nsapor. Total nitrogen content was determined to be 0.07% at Amantin and 0.06% at Nsapor. The N level was low at both locations. Organic matter constituted 1.8% and 1.6% of the soil composition at Amantin and Nsapor, respectively, with a carbon-to-nitrogen (C/N) ratio of 15 at both locations.

4.2 Soil Physical Properties

The initial soil physical properties as determined before planting is presented on Table 4.1. The values recorded for porosity was 45.3% at Amantin whilst Nsapor recorded 46.3%. The soil bulk density recoded at the two locations revealed 1.34g/cm^3 and 1.31g/cm^3 at Amantin and Nsapor respectively. The infiltration rate was much higher at Nsapor than Amantin with 40.7 mm/h at Nsapor but 15.5 mm/h at Amantin (Table 4.1). The soil textural class was determined to be Clay loam at Amantin whilst at Nsapor it was sandy loam (Table 4.1).

Table 4.1: Background soil chemical and physical properties at Amantin and Nsapor

Parameter	**Unit**	**Location**	
		Amantin	**Nsapor**
pH	1:2.5H_2O	6.5	5.5
Organic C	%	0.87	0.87
Total N	%	0.07	0.06
OM	%	1.8	1.6
Ca^{2+}	Ppm	800	349
Mg^{2+}	Ppm	123	68
Ex. K^+	Ppm	50	<40
Boron	Ppm	<0.5	<0.5
Available P	Ppm	0-10	0-10
Manganese	Ppm	130	118
Zinc	Ppm	<1	1.1
CEC	Meq/100g	6.3	3.9
Iron	Ppm	140	106
Copper	%	2	1.8
C/N ratio	N/A	15	15
Bulk density	g/cm^3	1.34	1.31
Porosity	%	45.3	46.4
Particle density	g/cm^3	2.62	2.65
Infiltration	mm/h	15.5	40.7
Sand	%	27.3	48.8
Silt	%	34.4	43.6
Clay	%	38.3	7.6
Texture classification		Clayey loam	Sandy loam

4.3 Climatic Conditions of Amantin and Nsapor

The climatic data of the two experimental sites is presented in Table4. 2. The highest rainfall of 980 mm was recorded at Nsapor whilst Amantin recorded 909 mm.

The maximum temperature of 34.5^0C as against 34.2^0C in the month of April was recorded at Amantin and Nsapor respectively.

Table 4.2: Climatic Data for 2022 Major Rainy Season for Amantin and Nsapor

Months	**Rainfall (mm)**		**Temp (Max)°C**		**Temp (Min)°C**		**Humidity (%) 15.00hr**		**Wind speed (m/s)**	
	Aman	**Nsa**	**Aman**	**Nsa**	**Aman**	**Nsa**	**Aman**	**Nsa**	**Aman**	**Nsa**
April	170	230	34.2	34.5	22.7	22.3	23.8	23.5	4.6	4.3
May	273	277	32.0	32.3	21.9	21.7	22.8	22.3	4.5	4.2
June	210	218	30.1	31.9	21.3	21.6	21.7	22.7	4.1	4.4
July	114	116	31.5	30.5	28.9	22.4	21.1	22.5	4.7	4.1
August	142	139	33.5	30.8	29.5	24.8	21.5	22.9	3.6	4.5
Total	**909**	**980**								

***Source**: Ghana Meteorological Services*

Ama=Amantin; Nsa=Nsapor

4.4 Soil Chemical Properties after Harvest of Maize

The initial soil chemical properties provided valuable insights into the nutrient status and characteristics of the soil at the two locations, Amantin and Nsapor. The pH values were slightly acidic, with Amantin having a higher initial pH of 6.3 compared to Nsapor's pH of 5.5. The available phosphorus (P) levels were within the range of 0-10 ppm, and the exchangeable potassium (K) levels varied between 40-50 ppm at Amantin and below 40 ppm at Nsapor. Calcium, iron, magnesium, boron, copper, and zinc levels were generally low, highlighting potential deficiencies in these micronutrients. After harvest, the amended plots showed an increase in some nutrient levels and a decrease in some while some remained the same as compared with the control treatment (Table 4.3). Available P levels remained within the initial range of 0-10 ppm across all treatments and locations, indicating that the fertiliser treatments did not greatly impact the phosphorus availability. Exchangeable K levels varied but did not show consistent patterns across treatments. However, it is noteworthy that granule NPK and briquette NPKS treatments generally resulted in slightly higher exchangeable K levels compared to the control.

Calcium, iron, and magnesium levels did not show substantial changes after the application of fertiliser treatments. Boron, copper, and zinc levels remained low, suggesting a potential need for additional micronutrient supplementation.

The cation exchange capacity (CEC) values exhibited relative consistency across treatments and locations, although minor increases were noted in the fertilised treatments compared to the control. No significant differences were observed among treatments for total nitrogen and organic matter content.

The results in total nitrogen showed no significant difference among treatments and between locations. However, Granule NPK & Urea (120-40-40) 200 kg/ha recorded the highest value (0.08%) of total nitrogen whilst Granule NPK and Urea 150 kg/ha recorded the least value (0.06) in Amantin (Table 4.3).

Table 4.3a: Soil chemical properties after harvest at Amantin and Nsapor

	pH 1:2.5 H_2O	Organic C (%)	Total N (%)	OM (%)	Exchangeable Bases(ppm)			Boron (ppm) Ratio	Available P(ppm)	Mn (ppm)	Zn (ppm)	CEC (ppm)	Fe (Meq/100 g)	Cu (ppm)	C/N (ppm)
					Ca	Mg	K								
Amantin															
Control	6.3	0.87	0.07	1.8	800	130	50.0	0.5	10	110	1.0	6.3	140	2.0	15
Granule NPK & Urea (120-40-40) 200kg/ha	6.4	0.82	0.07	1.8	800	130	50.0	0.52.0	11	120	1.0	6.3	140	2.0	15
Briquette NPK & Urea (121-58.7-59) 230.4kg/ha	6.5	0.87	0.08	1.8	800	130	50.0	2.0	15	125	2.0	6.3	140	2.0	15
Briquette NPK& Urea (114-44-44) 172.8kg/ha	6.5	0.87	0.07	1.7	788	130	50.0	2.0	15	110	2.0	6.3	140	2.0	15
Briquette NPK& Urea (91-59-59) 230.4kg/ha	6.5	0.88	0.07	1.8	798	130	50.0	2.0	15	120	1.0	6.3	140	2.0	15
Briquette NPK& Urea (76-29-29) 115.2kg/ha	6.5	0.87	0.06	1.6	801	130	50.0	2.0	15	120	1.0	6.3	140	2.0	15
Briquette NPK& Urea (31-29-29) 115.2kg/ha	6.5	0.85	0.07	1.7	800	130	50.0	2.0	15	130	1.0	6.3	140	2.0	15
Fpr	**4.30**	**0.15**	**1.45**	**3.92**	**2.33**	**1.82**	**0.86**	**0.01**	**1.77**	**0.51**	**0.34**	**0.11**	**0.02**	**0.01**	**0.05**
HSD (5%)	**0.50**	**0.33**	**0.26**	**0.70**	**14.09**	**0.08**	**0.76**	**1.53**	**0.08**	**17.01**	**1.46**	**0.47**	**0.18**	**1.53**	**0.22**
Nsapor															
Control	5.5	0.87	0.06	1.5	349	68	40.0	0.5	10	118	1.1	3.9	106	1.8	15

Table 4.3b: Soil chemical properties after harvest at Amantin and Nsapor

Granule NPK & Urea (120-40-40) 200kg/ha	5.5	0.82	0.08	1.4	400	69	41.5	0.5	11	118	1.0	3.3	110	1.8	15
Briquette NPK & Urea (121-58.7-59)230.4kg/ha	5.5	0.88	0.07	1.5	288	71	40.0	0.5	10	117	2.1	4.1	109	1.8	17
Briquette NPK& Urea (114-44-44) 172.8kg/ha	5.5	0.81	0.05	1.3	338	65	39.5	0.5	11	118	2.0	3.4	106	1.8	17
Briquette NPK& Urea (91-59-59) 230.4kg/ha	5.5	0.88	0.06	1.4	339	66	40.0	0.5	10	117	1.0	4.2	108	1.8	17
Briquette NPK& Urea (76-29-29) 115.2kg/ha	5.5	0.87	0.07	1.6	321	65	48.0	0.5	10	117	1.0	3.2	104	1.8	14
Briquette NPK& Urea (31-29-29)115.2kg/ha	5.5	0.81	0.07	1.5	330	69	41.0	0.5	10	118	1.0	3.3	105	1.8	16
Fpr	**3.12**	**0.75**	**1.63**	**0.87**	3.22	4.11	3.24	2.73	0.99	0.63	0.06	0.97	0.41	0.53	0.43
HSD (5%)	**0.48**	**0.12**	**0.07**	**0.42**	64.13	6.34	15.01	0.73	2.24	2.10	0.06	2.46	6.12	1.01	1.07
Loc. Int Amant.*Nsap.															
Fpr	**1.00**	**3.82**	**3.06**	**0.31**	2.19	0.56	1.03	1.04	2.33	0.76	1.46	0.01	0.03	0.22	0.03
HSD (5%)	**0.06**	**0.23**	**0.19**	**0.20**	12.10	14.0	2.71	0.52	0.17	0.41	0.26	0.02	3.02	0.06	0.06
CV (%)	**0.42**	**2.05**	**7.72**	**7.14**	1.88	3.99	4.70	6.23	3.23	4.13	2.78	6.27	1.16	1.11	5.16

4.5 Phenology

4.5.1 Days to 50% emergence

Table 4.4. showed no significant (P≥0.05) difference among treatments at both locations with regards to days to 50% emergence. No significant difference was recorded between locations as well as treatment x location interactions (Table 4.4).

Table 4.4: Effects of NPK granules and Briquettes fertilizer on the 50% Emergence at Amantin and Nsapor

Treatment	Days to 50% Emergence	
	Amantin	Nsapor
Control	4.30	4.20
Granule NPK & Urea (120-40-40) 200 kg/ha	4.50	4.50
Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha	4.50	4.50
Briquette NPK& Urea (114-44-44) 172.8 kg/ha	4.30	4.20
Briquette NPK& Urea (91-59-59) 230.4 kg/ha	4.00	4.00
Briquette NPK& Urea (76-29-29) 115.2 kg/ha	4.30	4.20
Briquette NPK& Urea (31-29-29) 115.2 kg/ha	4.30	4.20
Mean	4.30	4.26
HSD ($P \leq 0.05$)	1.04NS	0.66NS
CV (%)	10.39	10.39
Location	0.25 NS	
Treatment x Location	0.65 NS	

4.5.2 Days to 50% tasseling

From Table 4.5 the different rates of fertilizer had no significant effect on days to 50% tasseling at Amantin and Nsapor (Table 4.5). Locations as well as treatment x location interactions had no significant effect on number of days to 50% tasseling.

4.5.3 Days to 50% silking

Table 4.5 revealed no significant (P≥0.05) difference in days to 50% silking among treatment at both locations. Location as well as treatment x location interactions had no significant effect on number of days to 50% silking.

Table 4.5: Effects of NPK granules and Briquettes fertilizer on 50% tasseling and silking at Amantin and Nsapor

Treatment	Days to 50% tasseling		Days to 50% silking	
	Amantin	Nsapor	Amantin	Nsapor
Control	59.00	59.00	63.30	63.25
Granule NPK & Urea (120-40-40) 200 kg/ha	58.80	58.75	63.80	63.75
Briquette NPK & Urea (121-58.59) 230.4 kg/ha	58.50	58.50	63.30	63.25
Briquette NPK & Urea (114-44-44) 172.8 kg/ha	58.30	58.25	63.50	63.50
Briquette NPK & Urea (91-59-59) 230.4 kg/ha	58.80	58.75	63.50	63.50
Briquette NPK & Urea (76-29-29) 115.2 kg/ha	58.30	58.25	63.50	63.50
Briquette NPK & Urea (31-29-29) 115.2 kg/ha	59.00	59.00	63.80	63.75
Mean	58.67	58.64	63.53	63.5
HSD ($P \leq 0.05$)	1.52NS	0.96NS	1.87NS	1.19NS
CV (%)	1.11	1.12	1.26	1.25
Location	0.73 NS		0.72 NS	
Treatment x Location	1.93 NS		1.89 NS	

4.6 Vegetative Growth

4.6.1 Number of leaves per plant

The number of leaves per plant measured at 5 and 7 WAP showed significant (p≤0.05) differences among treatments across both locations (Table 4.6). At 5WAP the Granule

NPK and Urea (120-40-40) 200 kg/ha recorded the greatest (8.1) number of leaves per plant and differed significantly from Briquette NPK & Urea (114-44-44) 172.8 kg/ha with the least mean (7.30) at Amantin (Table 4.6). At Nsapor, the Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha recorded significantly greater number of leaves per plant the control which recorded the least mean number at 5 WAP. At 7 WAP in both locations plants that received Granule NPK & Urea (120-40-40) 200 kg/ha recorded the highest number of leaves per plant and was significantly different from plants grown on the unamended plots. At 5 WAP, number of leaves per plant recorded in Nsapor was significantly higher that of Amantin vice versa at 7 WAP. Treatment x location interactions had significant effect on number of leaves per plant at 5 and 7 WAP.

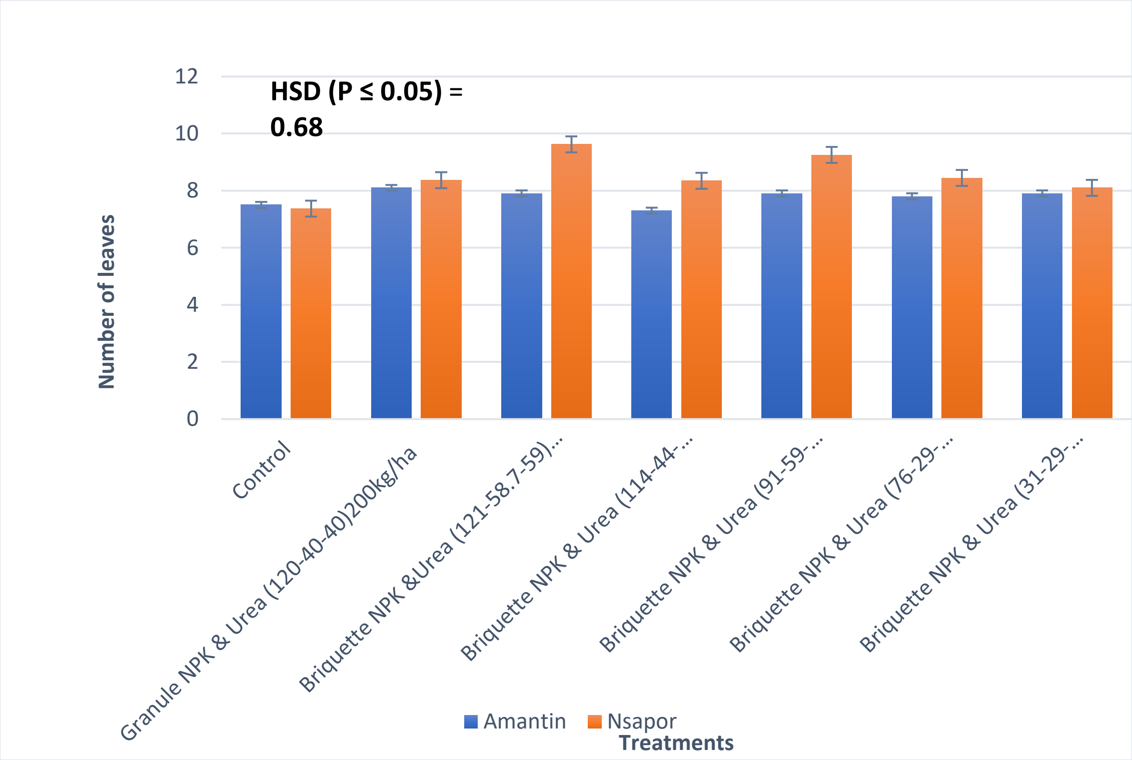


Figure 4.1 Effects of NPK granules and briquettes fertilizer on the number of leaves per plant at Amantin

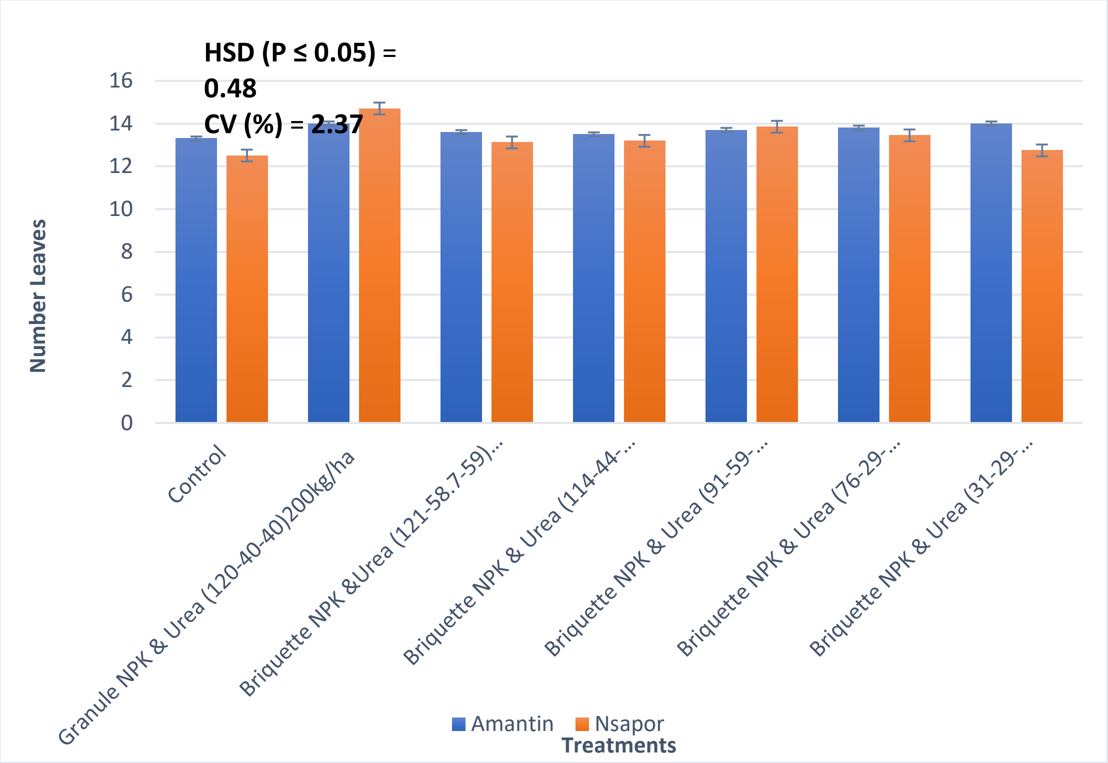


Figure 4.2 Effects of NPK granules and briquettes fertiliser on the number of leaves per plant at Nsapor

4.6.2 Plant height

Table 4.7 shows the results of maize plant height as influenced by NPK granules and Briquettes fertiliser at Amantin and Nsapor. There were significant differences between the different fertiliser rates at 5 and 7 WAP across both locations. At 5 WAP, in Amantin and Nsapor plants that received Briquette NPK & Urea (121-58.7-59) 230.4kg/ha recorded significantly taller plants than plants that received Briquette NPK & Urea (114-44-44) 172.8kg/ha and Control plot, respectively. At 7 WAP, in Amantin and Nsapor Briquette NPK & Urea (91-59-59) 230.4kg/ha produced plants that were significantly taller than plants grown on the unamended plots across both locations. At 5 and 7 WAP significantly taller plants was observed in Nsapor than Amantin. Treatment x location interactions had significant effect on plant height at 5 and 7 WAP.

Table 4.7: Effects of NPK granules and Briquettes fertiliser on maize Plant Height at Amantin and Nsapor

Treatment	Plant height (cm) 5 WAP		Plant height (cm) 7 WAP	
	Amantin	Nsapor	Amantin	Nsapor
Control	46.50ab	54.70b	133.60c	170.08b
Granule NPK & Urea (120-40-40) 200 kg/ha	54.90ab	65.65ab	173.10a	189.85ab
Briquette NPK & Urea (121-58.7-59) 230.4kg/ha	58.70a	73.60a	172.90a	193.50a
Briquette NPK & Urea (114-44-44) 172.8kg/ha	44.00b	65.87ab	146.60b	187.25ab
Briquette NPK & Urea (91-59-59) 230.4kg/ha	53.50ab	71.15a	174.20a	195.35a
Briquette NPK & Urea (76-29-29) 115.2kg/ha	51.30ab	63.95ab	164.50a	186.25ab
Briquette NPK & Urea (31-29-29) 115.2kg/ha	52.40ab	56.40b	167.60a	174.45ab
Mean	51.61	64.47	161.79	185.25
HSD ($P \leq 0.05$)	13.09	13.71	12.78	23.29
CV (%)	17.08	18.65	5.32	11.64
Location	5.26**		6.91**	
Treatment x Location	15.67**		28.49**	

4.6.3 Leaf area

There were significant differences between treatments at 5 and 7 WAP across both locations (Table 4.8). At 5 WAP, Briquette NPK and Urea Briquette NPK & Urea (121-58.7-59) 230.4kg/ha recorded the widest leaf area (366.5 cm^2) followed by Briquette NPK& Urea (91-59-59)230.4kg/ha (354 cm^2) which differed significantly from the control with least value (267 cm^2) at Amantin. At 7 WAP, Briquette NPK & Urea (121-58.7-59) 230.4kg/ha recorded significantly wider leaf area (570 cm^2) than the control which recorded the least (255.47 cm^2)

At 5 WAP in Nsapor, there was no significant difference between the granular and briquette amended plots in leaf area. However, all the amended plots differed significantly from the control which produced the least leaf area. Similarly, at 7 WAP, there was no significant difference between the granular and briquette amended plots in leaf area. However, all the amended plots differed significantly from the control which produced the least leaf area. Briquette NPK& Urea (76-29-29) 115.2kg/ha recorded the widest leaf area (706.60 cm^2) whereas the control recorded the least. At 5 WAP significantly wider leaf area was observed in Nsapor than Amantin vice versa at 7 WAP. Treatment x location interactions had significant effect on leaf area at 5 and 7 WAP.

Table 4.8: Effects of NPK granules and Briquettes Fertiliser on Maize Leaf Area at Amantin and Nsapor

Treatment	Leaf area (cm^2)		Leaf area (cm^2)	
	5 WAP		7 WAP	
	Amantin	Nsapor	Amantin	Nsapor
Control	267c	255.47b	357e	480.13b
Granule NPK & Urea (120-40-40)200kg/ha	330abc	340.57a	492bc	679.10a
Briquette NPK & Urea (121-58.759)230.4kg/ha	366.5a	336.93a	570a	667.28a
Briquette NPK & Urea (114-44-44)172.8kg/ha	300abc	337.55a	408de	624.60a
Briquette NPK & Urea (91-59-59)230.4kg/ha	354ab	366.58a	510b	654.35a
Briquette NPK & Urea (76-29-29)115.2kg/ha	317abc	366.68a	455cd	706.60a
Briquette NPK & Urea (31-29-29)115.2kg/ha	285bc	345.70a	402de	660.47a
Mean	347.07	338.61	456.29	638.93
HSD ($P \leq 0.05$)	70.98	34.25	54.95	43.34
CV (%)	15.07	13.9	8.13	8.26
Location	24.07**		30.8**	
Treatment x Location	46.98**		59.92**	

4.6.4 Leaf chlorophyll content

There were no significant differences between treatments in leaf chlorophyll content at 5 WAP at both locations. However, significant differences were observed between the treatments where, Granule NPK & Urea (120-40-40) 200kg/ha recorded the highest leaf chlorophyll content at Amantin, in the 7 WAP. There were no significant differences among treatments at 7 WAP at Nsapor. Significant differences were observed between the locations and treatment x location interactions at both 5 and 7 WAP.

Table 4.9: Effects of NPK granules and Briquettes fertiliser on leaf chlorophyll content at Amantin and Nsapor

Treatment	Leaf chlorophyll content (SPAD) 5 WAP		Leaf chlorophyll content (SPAD) 7 WAP	
	Amantin	Nsapor	Amantin	Nsapor
Control	41.40	44.05	46.10bc	48.25
Granule NPK & Urea (120-40-40)200kg/ha	41.90	44.97	52.10a	50.57
Briquette NPK &Urea (121-58.7-59) 230.4kg/ha	45.00	48.02	50.20ab	51.72
Briquette NPK & Urea (114-44-44) 172.8kg/ha	41.00	43.65	50.70ab	49.37
Briquette NPK & Urea (91-59-59)230.4kg/ha	42.70	45.50	49.30abc	46.27
Briquette NPK & Urea (76-29-29)115.2kg/ha	43.10	44.87	51.90ab	51.07
Briquette NPK & Urea (31-29-29)115.2kg/ha	41.20	42.42	44.20c	45.72
Mean	42.32	44.79	49.21	48.99
HSD ($P \leq 0.05$)	6.79NS	7.48NS	5.84	7.74NS
CV (%)	10.81	10.34	7.98	8.91
Location	2.64**		2.53**	
Treatment x Location	6.69**		5.71**	

4.6.5 Stem diameter

At Amantin, the widest stem diameter (1.8 cm) was recorded by Briquette NPK& Urea (91-59-59) 230.4kg/ha at 5 WAP which was significantly different from all the other treatments (Table 4.10). At 7 WAP at Amantin, Briquette NPK& Urea (91-59-59) 230.4kg/ha and Granule NPK & Urea (120-40-40) 200kg/ha both recorded the widest stem diameter of 2.0 cm and was significantly different from Briquette NPK & Urea (114-44-44) 172.8kg/ha and Briquette NPK & Urea (76-29-29) 115.2kg/ha. At Nsapor, plants that received Briquette NPK & Urea (121-58.759) 230.4kg/ha had the widest stem diameter and was significantly different from the control at 5 WAP. At 7 WAP, Briquette NPK & Urea (114-44-44) 172.8kg/ha recorded the widest stem diameter which not significantly different from other amended plots except the control (Table 4.10). Significant differences were observed between the locations and treatment x location interactions at both 5 and 7 WAP.

Table 4.10: Effects of NPK granules and Briquettes fertiliser on maize Stem diameter at Amantin and Nsapor

Treatment	Stem diameter (cm) 5 WAP		Stem diameter (cm) 7 WAP	
	Amantin	Nsapor	Amantin	Nsapor
Control	1.50d	1.30b	1.70c	1.82b
Granule NPK & Urea (120-40-40)200kg/ha	1.70ab	1.47ab	2.00a	1.90ab
Briquette NPK & Urea (121-58.759) 230.4kg/ha	1.60bc	1.65a	1.90ab	1.95ab
Briquette NPK & Urea (114-44-44) 172.8kg/ha	1.60c	1.52ab	1.80b	2.07a
Briquette NPK & Urea (91-59-59) 230.4kg/ha	1.80a	1.57a	2.00a	1.92ab
Briquette NPK & Urea (76-29-29) 115.2kg/ha	1.60bc	1.47ab	1.80b	1.95ab
Briquette NPK & Urea (31-29-29) 115.2kg/ha	1.70bc	1.62a	1.90ab	2.05a
Mean	1.64	1.51	1.87	1.95
HSD (P ≤ 0.05)	0.12	0.23	0.14	0.18
CV (%)	4.84	4.33	5.14	6.32
Location	0.05**		0.06**	
Treatment x Location	0.17**		0.15**	

4.6.6 Internode length

The results revealed that Briquette NPK & Urea (91-59-59) 230.4kg/ha recorded significantly longer internode length than the control and Granule NPK & Urea (120-40-40) 200kg/ha at 5 WAP in Amantin (Table 4.11). Briquette NPK & Urea (121-58.7-59) 230.4kg/ha recorded significantly longer internode length than the control, Briquette NPK& Urea (114-44-44)172.8kg/ha and Briquette NPK & Urea (31-29-29) 115.2kg/ha at Nsapor in 5WAP. There was no significant difference between the granular and Briquette treated plots in internode length at 7 WAP in Amantin. However, all the amended plots differed significantly from the unamended plot (Table 4.11). Briquette NPK & Urea (121-58.759) 230.4kg/ha recorded significantly longer internode length than the control, Briquette NPK& Urea (76-29-29) 115.2kg/ha and Briquette NPK& Urea (114-44-44) 172.8kg/ha at 7 WAP in Nsapor. There were significant differences between the locations as well treatment x location interactions in internode length at 5 and 7 WAP.

Table 4.11: Effects of NPK granules and Briquettes fertiliser on Internode length at Amantin and Nsapor

Treatment	Internode length (cm) 5 WAP		Internode length (cm) 7 WAP	
	Amantin	Nsapor	Amantin	Nsapor
Control	7.90b	7.77c	11.10b	12.87d
Granule NPK & Urea (120-40-40)200kg/ha	7.90b	8.77abc	14.30a	15.87ab
Briquette NPK & Urea (121-58.759) 230.4kg/ha	8.90ab	10.05a	14.20a	16.12a
Briquette NPK & Urea (114-44-44) 172.8kg/ha	9.40a	8.30bc	13.70a	13.82cd
Briquette NPK & Urea (91-59-59) 230.4kg/ha	9.50a	9.50ab	14.10a	14.75abc
Briquette NPK & Urea (76-29-29) 115.2kg/ha	9.20a	9.02abc	14.10a	14.07bcd
Briquette NPK & Urea (31-29-29) 115.2kg/ha	8.40ab	8.47bc	14.00a	14.32abc
Mean	8.72	8.84	13.64	14.55
HSD ($P \leq 0.05$)	1.26	1.40	1.75	1.82
CV (%)	9.67	9.45	8.62	10.61
Location	0.48**		0.64**	
Treatment x Location	1.28**		1.71**	

4.7 Yield and Yield Components of Maize

4.7.1 Number of cobs harvested

The results revealed significant differences among treatments in the number of cobs harvested per hectare. The average of 56,111 number of cobs per hectare was harvested in Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha while the least 39,222 number of cobs per hectare was recorded under the control plot (Table 4.12). Briquette NPK & Urea (114-44-44) 172.8 kg/ha recorded the significantly greater number of cobs per hectare than Briquette NPK & Urea (76-29-29) 115.2 kg/ha at Nsapor. There were significant differences between locations as well treatment x location interactions in number of cobs harvested.

4.7.2 Biomass weight at harvest

Significant differences were observed in the biomass weight at harvest among treatments at Amantin and Nsapor. The greater biomass weight 7972.3 kg/ha was recorded under Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha at Amantin which was significantly different from control and Granule NPK & Urea (120-40-40) 200 kg/ha (Table 12). Briquette NPK & Urea (76-29-29) 115.2 kg/ha recorded the greatest biomass weight and was significantly different from the control at Nsapor. There were significant differences between the locations as well treatment x location interactions in biomass weight at harvest.

Table 4.12: Effects of NPK granules and Briquettes fertiliser on the Number of cobs harvested and Biomass weight at Amantin and Nsapor

Treatment	Number of cobs harvested/ha		Biomass weight at harvest (kg/ha)	
	Amantin	Nsapor	Amantin	Nsapor
Control	39,222b	48,333ab	4638.80c	3855.30b
Granule NPK & Urea (120-40-40)200kg/ha	45,000ab	49,722ab	6666.50b	4638.50a
Briquette NPK & Urea (121-58.759) 230.4kg/ha	56,111a	55,833ab	7972.30a	4405.50ab
Briquette NPK & Urea (114-44-44) 172.8kg/ha	35,000b	58,611a	7416.50ab	4816.30a
Briquette NPK & Urea (91-59-59) 230.4kg/ha	42,000b	49.722ab	7222.30ab	4657.50a
Briquette NPK & Urea (76-29-29) 115.2kg/ha	40,556b	47,777b	7138.80ab	4864.50a
Briquette NPK & Urea (31-29-29) 115.2kg/ha	47,556ab	50,556ab	6916.80ab	4381.50ab
Mean	43635.00	44411.70	6853.14	451.01
HSD (P ≤ 0.05)	11,578.2	10.774.5	1140.7	732.74
CV (%)	22.10	21.32	11.20	10.92
Location	6,055.5**		349.66**	
Treatment x Location	9,389.84**		925.11**	

4.7.3 Cob weight per plot

There were significant differences among treatments with regards to cob weight per plot (kg/ha) at Amantin and Nsapor (Table 4.13). At Amantin, plants grown on Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha and Briquette NPK & Urea (91-59-59) 230.4 kg/ha recorded the greatest cob weight per plot which was not significantly different from each other but differed significantly from the control and Briquette NPK

& Urea (31-29-29) 115.2 kg/ha. At Nsapor, plants grown on Briquette NPK & Urea (76-29-29) 115.2 kg/ha recorded the greatest cob weight per plot and was significantly different from the control. There were significant differences between the locations as well treatment x location interactions in cob weight per plot.

4.7.4 Grain weight per plot

Table 4.13 revealed that the application of different granule and briquette fertilisers had significant ($P \leq 0.05$) differences in the grain weight per plot at Amantin and Nsapor. At Amantin, Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha recorded the greatest (3752.8 kg/ha) grain weight per plot which was significantly higher than the rest of the treatments except Briquette NPK & Urea (91-59-59) 230.4 kg/ha.

At Nsapor, Briquette NPK & Urea (76-29-29) 115.2 kg/ha recorded the greatest (4864.5 kg/ha) grain weight per plot which was not significantly different from the other granular and Briquette amended plots but differed significantly from plants grown on the unamended plots. There were significant differences between the locations as well treatment x location interactions in grain weight per plot.

Table 4.13: Effects of NPK granules and Briquettes fertiliser on the cob weight per plot and grain weight per plot (9m2) at Amantin and Nsapor

Treatment	Cob weight per plot (kg/ha)		Grain weight per plot (kg/ha)	
	Amantin	Nsapor	Amantin	Nsapor
Control	2253.00c	6077.30b	1989.00e	3855.30b
Granule NPK & Urea (120-40-40)200kg/ha	4438.80ab	6860.50a	3252.80bc	4638.50a
Briquette NPK & Urea (121-58.759) 230.4kg/ha	5591.50a	6627.70ab	3752.80a	4405.50ab
Briquette NPK & Urea (114-44-44) 172.8kg/ha	5291.80ab	7038.20a	3233.30bc	4816.30a
Briquette NPK & Urea (91-59-59) 230.4kg/ha	5425.00a	6879.00a	3580.70ab	4657.50a
Briquette NPK & Urea (76-29-29) 115.2kg/ha	4130.50abc	7087.00a	3047.00c	4864.50a
Briquette NPK & Urea (31-29-29) 115.2kg/ha	3400.00bc	6603.50ab	2500.00d	4381.50ab
Mean	4361.51	6739.03	3050.80	4517.01
HSD ($P \leq 0.05$)	1907.1	732.72	491.22	732.74
CV (%)	29.59	7.32	10.84	10.92
Location	509.32**		228.19**	
Treatment x Location	1347.5**		603.74**	

4.7.5 100-seed weight

Table 4.14 shows results of 100-seed weight as affected by granular and Briquette NPK fertilizer. There were significant differences between the treatments in 100-seed weight across both locations. At Amantin and Nsapor, Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha recorded the greatest 100-seed weight of 36.8 g and 36 g, respectively and was significantly different from the control. 100- seed weight recorded in Amantin was significantly higher than that of Nsapor. Treatment x location interaction had no significant effect on 100-seed weight.

Table 4.14: Effects of NPK granules and Briquettes fertiliser on the 100-seed weight at Amantin and Nsapor

Treatment	100-seed weight (g)	
	Amantin	Nsapor
Control	32.8d	32.25d
Granule NPK & Urea (120-40-40)200kg/ha	35.3b	35.50ab
Briquette NPK & Urea (121-58.7-59)230.4kg/ha	36.8a	36.00a
Briquette NPK& Urea (114-44-44)172.8kg/ha	36.3a	35.50ab
Briquette NPK& Urea (91-59-59)230.4kg/ha	34.5bc	33.00c
Briquette NPK& Urea (76-29-29)115.2kg/ha	34.5bc	32.75d
Briquette NPK& Urea (31-29-29)115.2kg/ha	34.0c	33.50c
Mean	34.89	34.07
HSD ($P \leq 0.05$)	0.99	0.72
CV (%)	1.93	2.56
Location	1.26**	
Treatment x Location	1.34NS	

4.7.6 Cob length

Significant differences were observed among the treatments in cob length at Amantin and Nsapor. Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha recorded the longest cob length of 15.9 cm and differed significantly from the control at Amantin. Granule NPK & Urea (120-40-40) 200kg/ha recorded the longest cob length value of 16.35 cm and differed from the control at Nsapor (Table 4.15). Location and treatment x location interactions were significant.

4.7.7 Cob diameter

Table 4.15 shows results of cob diameter as affected by granular and Briquette NPK fertilizer. There were significant differences between the treatments in cob diameter across both locations. Plants that received Briquette NPK & Urea (76-29-29) 115.2 kg/ha had the widest cob diameter (4.5 cm and 4.52 cm) which was significantly different from the control at both locations. Plants grown on the unamended plot recorded the least value cob diameter of 3.7 cm and 3.67 cm at both locations. Location had no significant effect on cob diameter whereas treatment x location interaction was significant.

Table 4.15: Effects of NPK granules and Briquettes fertiliser on the Cob length and Cob diameter at Amantin and Nsapor

Treatment	Cob length (cm)		Cob diameter (cm)	
	Amantin	Nsapor	Amantin	Nsapor
Control	13.30b	13.25c	3.70c	3.67c
Granule NPK & Urea (120-40-40)200kg/ha	14.20b	16.35a	4.00bc	4.0bc
Briquette NPK &Urea (121-58.759) 230.4kg/ha	15.90a	14.57bc	4.10b	4.07bc
Briquette NPK & Urea (114-44-44) 172.8kg/ha	14.60ab	13.95bc	4.00bc	4.07bc
Briquette NPK & Urea (91-59-59)230.4kg/ha	13.80b	15.27ab	4.10b	4.07bc
Briquette NPK & Urea (76-29-29)115.2kg/ha	14.40ab	14.55bc	4.50a	4.52a
Briquette NPK & Urea (31-29-29)115.2kg/ha	14.70ab	15.07ab	4.30ab	4.25ab
Mean	14.41	14.72	4.10	4.09
HSD ($P \leq 0.05$)	1.59	1.53	0.39	0.40
CV (%)	7.42	8.65	6.39	7.34
Location	0.60**		0.13NS	
Treatment x Location	0.78**		0.36**	

CHAPTER FIVE: DISCUSSION

5.1 Effects of Fertiliser Treatments on Soil Chemical Properties

After the harvest, the fertilizer treatments did not significantly alter the pH values compared with the control treatment at both locations. This trend may be due to the short-term nature of the study. This finding aligns with previous studies by Ayoola, (2006) and Taiwo (2021), who indicated that mineral fertiliser treatment did not have significant difference on soil pH after planting for two years in cassava-based cropping system. No significant differences were observed in residual soil NPK concentrations among treatments at either location (Table 3). This implies that the majority of granular NPK applied at high rates, not utilised by plants, failed to accumulate in the soil, likely due to losses via leaching and/or surface runoff. Conversely, the briquettes probably didn't dissolve in time for plant uptake.

The Nsapor experimental site's sandy-loam soil with low organic matter content rendered it prone to NPK leaching, potentially accounting for substantial NPK losses, as evidenced by locational differences in NPK content (Table 4.3). Given the crop in question, maize, these initial soil chemical properties can substantially impact growth and yield. Specifically, low available phosphorus and zinc levels, coupled with acidic soil conditions, can constrain maize growth and productivity. However, the high levels of calcium at Amantin soil may favour maize growth and yield, while the high CEC also at Amantin can help retain nutrients in the soil. The C/N ratio in Nsapor soil may indicate slower organic matter decomposition, potentially leading to a build-up of organic matter in the soil, which could positively impact maize growth and productivity in the long term. This is in agreement Liu *et al*. (2010) who reported that the application of mineral fertilisers has no significant effect on soil C/N ratio.

The available phosphorus (P) content in the soil after harvest remained relatively low across all treatments, with concentrations ranging from 0-11 ppm. This suggests that the application of different fertiliser formulations did not substantially increase the availability of phosphorus in the soil. It may be necessary to consider additional strategies, such as phosphorus-specific fertilisers or soil amendments, to address potential phosphorus deficiencies and enhance crop productivity. The exchangeable potassium (K) levels in the soil were indicating that the applied K^+ was either utilised by the crops or lost through leaching and or runoff as affirmed by Kareem *et al*., 2020).

Calcium (Ca) levels in the soil ranged from 331 to 801 ppm across the treatments (Table 3). There was however, no significant difference among treatments both at both locations. The observed consistency in calcium concentrations indicates that the different fertiliser treatments did not have a significant impact on calcium content in the soil (Tetteh *et al.*, 2016). Similarly, the iron (Fe) and magnesium (Mg) levels in the soil were within an acceptable range for plant growth as stated by Sutar *et al.* (2017), with values ranging from 104 to 140 ppm and 6110 to 6118 ppm, respectively (Table 3). These concentrations suggest that the soil provided sufficient iron and magnesium to meet the nutrient requirements of the maize crop. The concentrations of boron (B), copper (Cu), and zinc (Zn) in the soil as recorded in both locations and among all treatments did not show any significant differences. This agreed with the result of Sutar *et al.* (2017) who indicated that micro-nutrients supplement applied in maize nutrition could, either be utilized by the maize plant or it could be lost through leaching, run off or through volatilisation.

The total nitrogen (N) content in the soil varied among treatments, ranging from 0.05% to 0.08 % (Table 4.3). These levels suggest that the different fertiliser treatments had a variable impact on the soil's nitrogen content.

The carbon-to-nitrogen (C/N) ratio, which indicates the decomposition of organic matter and nutrient availability, ranged from 14 to 16 across the treatments. These values suggest a relatively balanced C/N ratio in the soil, providing favourable conditions for nutrient mineralisation and plant uptake. According to Sutar *et al.* (2017) C/N ratios of < 25 ensures mineralisation, between 25-35, there is no gain, whilst > 35 will result in immobilisation. In conclusion, the analysis of the soil data after harvest from the seven treatments provides insights into the soil nutrient status and potential limitations for maize production. The findings suggest the need for additional strategies to address deficiencies in phosphorus, potassium, and micronutrients.

5.2 Effects of Fertiliser Treatments on Phenological Development

The phenological data presented in the study provides valuable insights into the growth and development stages of maize plants in response to different fertiliser treatments. At both Amantin and Nsapor, the data indicates that there were no significant differences in the phenological stages among the different fertiliser treatments at both locations. This suggests that the fertiliser treatments did not have a significant impact on the timing of key phenological events such as emergence, tasseling and silking. This result is in line with the findings by Xiaohui *et al.* (2020) who inferred that the phenological developments of maize plants were primarily influenced by other factors such as genetics and environmental conditions, rather than the specific fertiliser treatments applied. The greatest number of maize plant germination and establishment in both

Amantin and Nsapor is due to the healthy seeds used as planting materials and favourable environmental condition.

5.3 Effects of Fertiliser Treatments on Vegetative Growth of Maize

The analysis of vegetative growth parameters including plant height, number of leaves per plant, leaf chlorophyll content, and leaf area showed variations between treatments and locations, suggesting the influence of different fertiliser treatments on maize growth and development.

5.3.1 Number of leaves per plant

Significant ($P<0.05$) differences were recorded in respect to the number of leaves per plant at Nsapor but not Amantin (Table 4.6). Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha performed significantly different from some of the briquette fertilisers and the control at Nsapor at 5WAP and 7WAP. These findings agreed with the results by Kareem *et al*. (2020), who reported that increasing the level of NPK fertiliser showed significant differences in leaf production. Again, they added that high yielding maize required large quantities of soil nutrient which enable all the upper leaves and most of the lower leaves to remain green until the crop is nearly mature.

5.3.2 Plant height

The various fertilizer combinations revealed significant differences with regards to plant height (Table 4.7). At 5WAP, no significant differences were recorded in plant height among the treatments possibly because the briquette fertilisers might have not released most of its nutrients. All treatments with fertiliser amendments outperformed the control at Amantin and Nsapor at 7WAP. These could be due to nutrient availability to the plants to absorb at the early stages of growth. This result conformed to the finding by Shoji *et al.* (2001) who indicated a higher plant height within two weeks with mineral fertiliser as a result of increasing level of fertiliser application.

5.3.3 Leaf area

The results as presented in Table 4.8 revealed that at 5WAP, the least value (267 cm^2) was recorded under the control but was not significantly different from Granule NPK & Urea (120-40-40) 200kg/ha, Briquette NPK& Urea (114-44-44) 172.8 kg/ha, Briquette NPK& Urea (76-29-29) 115.2 kg/ha and Briquette NPK & Urea (31-29-29) 115.2 kg/ha at Amantin (Table 4.8). But at Nsapor at 5WAP all treatments performed significantly higher than the control. Results in the 7WAP revealed that Briquette NPK & Urea 230.4 kg/ha recorded the highest (570 cm^2) and the least was recorded under the control which showed significant differences among treatments. Location and treatment interactions also showed significant differences. These results agree with Berdjour *et al*. (2020), who recorded higher leaf area (429 cm^2) of maize with 120:60:60 NPK kg/ha fertiliser in Guinea Savannah which was attributed to the solubility, absorption and translocation of the absorbable nutrients by the plant for leaf synthesis as a result of timely release of nutrient.

5.3.4 Leaf chlorophyll content

Chlorophyll content in leaf under Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha between treatments at both Amantin and Nsapor were not significantly different ($P > 0.05$) among treatments at 5WAP even though it recorded the highest values (Table 4.9). At 7WAP, there were significant differences among treatments at Amantin. Granule NPK & Urea (120-40-40) 200 kg/ha recorded the higher value which was significantly different from control and Briquette NPK & Urea (31-29-29) 115.2 kg/ha. The differences in chlorophyll content could be attributed to the rate of application. The result agreed with the findings by Wamalwa *et al.* (2019) who reported an increase in leaf chlorophyll content due to increase in NPK application rate of 100 kg/acre. There were location differences but no differences were observed among treatment. This result could be attributed to the soil nutrient dynamics at the two locations.

5.3.5 Stem diameter

The highest significant stem diameter (1.8 cm) was recorded by Briquette NPK & Urea (91-59-59) 230.4 kg/ha at 5WAP at Amantin (Table 4.10). At Nsapor there was no significant difference was recorded among other treatments except the control. Treatments containing fertilizer amendments recorded significantly higher values than the control at 7WAP at Amantin. This suggested that the rates of fertiliser applied influenced stem diameter of the maize plant. This result aligned with Kareem *et al.* (2020) who reported a significant increase in stem diameter when NPK rates were applied to two maize varieties.

5.3.6 Internode length

All Briquette NPK and Urea fertilizers recorded a significant value of internode length at Amantin at 5WAP and 7 WAP than the control (Table 4.11). This finding could be attributed to the availability of nutrients as released by the fertilisers which was utilised by the crop to develop its internode. This result compared with the result from Sukhijinder and Misal (2020) who reported 100% recommended dose NPK having significant difference value in internode length when compared with 50% NPK + 25% farm yard manure + 25% vermicompost. At Nsapor, other treatments containing fertiliser amendment had significant higher values in internode length as compared with the control at 5WAP (Table 4.11). There were location interaction differences among the treatments, which could be attributed to the soil nutrient dynamics at the two locations.

5.4 The Impact of Fertiliser Treatment on Yield and yield components

5.4.1 Number of cobs harvested

Significant differences were observed in the number of cobs harvested at both locations, Amantin and Nsapor (Table 4.12). This result did not conform to findings by Oladejo and Adetunji (2012) who reported no significant differences in number of cobs harvested and attributed it to factors which could be purely genetic and not the influence of fertiliser applied. The result showing significant differences in this study could be as a result of rodent and bird attack on some experimental plots that have resulted into reduced number of cobs harvested.

5.4.2 Biomass weight at harvest

Significant differences were observed in respect to biomass weight at harvest at Amantin. The treatments Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha recorded the highest biomass (7972.3 kg/ha) whilst the control recorded the least among all treatments. The observation at Nsapor recorded significant difference among the treatment with Briquette NPK & Urea (91-59-59) 200 kg/ha recording the highest. This observation could be due to the rate and the nature of fertiliser amendment applied (Table 4.12). This observation affirms Anjum *et al.* (2018), assertion that, different rates of nitrogen application had influence on yield and yield components of maize varieties.

5.4.3 Cob weight per plot

Significant differences were observed among some treatment in cob weight in kg/ha (Table 4.13). Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha recorded a higher value which was only significant when compared with Briquette NPK & Urea (31-29-29) 115.2 kg/ha and control but not with other treatments. Location differences were observed. This finding agreed with Morris *et al.* (2007), who found out that one-time application of NPK fertiliser increased maize yields.

5.4.4 Grain weight per plot

Table 4.13 revealed that the application of different granule and briquette fertilisers have significant differences (P>0.05) in the grain weight per plot between treatments at Amantin. The highest grain weight was recorded by Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha which was significantly different from other treatments. At Nsapor, there were significant differences among treatment where other treatments did quite better than the control. These findings agreed with the result by Adu-Gyamfi *at al.* (2019) who reported that one-time application of multi-nutrient fertiliser briquettes increased maize grain yields.

5.3.5 100-seed weight

There were significant differences (P>0.5) among treatments as observed at Amantin where treatment with fertilizer application weighed far more than the control (Table 4.14). The same trend was recorded at Nsapor. However, there was no significant difference between Briquette NPK & Urea (76-29-29) 115.2 kg/ha and the control at Nsapor. The highest 100 seed weight was recorded by Briquette NPK & Urea (121-58.7-59) 230.4 kg/ha, followed by Briquette NPK& Urea (114-44-44) 172.8 kg/ha.

Significant difference was observed between locations, which could be attributed to the differences in the soil textural class found at the two locations. These results agreed with the findings by Dhakal *et al.* (2020) who recorded higher 100 seed weight in maize when briquette urea was deep placed and increased agronomic and economic efficiency of maize.

5.4.6 Cob diameter

The results revealed marginal significant differences in the cob diameter recorded in this study at both Amantin and Nsapor. Briquette NPK & Urea (76-29-29) 115.2 kg/ha recorded the highest value of 4.5 cm and 4.52 cm in both locations which was significant among other treatments except with Briquette NPK & Urea (31-29-29)115.2 kg/ha at Amantin and Nsapor respectively. This result conformed with the findings by Kombat (2015), who found significant difference in cob diameter of maize when NPK fertiliser was applied.

5.4.7 Cob length

The cob length measured for the tagged plant in this study revealed significant differences among some treatments (Table 4.15). Briquette NPK & Urea (121-58.7-59)230.4kg/ha performed significantly better than only Granule NPK & Urea (120-40-40) 200kg/ha, Briquette NPK & Urea (91-59-59) 230.4 kg/ha and control. This result did agree with the findings by Kombat (2015) who found significant differences in cob length by the application of 375 – 400 kg/ha of NPK fertiliser.

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

- Although, there was no significant difference between the treatments, Briquette NPK& Urea (91-59-59)230.4kg/ha and Granule NPK & Urea (120-40-40)200kg/ha recorded the highest organic C, total N, Ca, and K across both locations as compared to the control.
- The Briquette NPK & Urea (121-58.7-59)230.4kg/ha and Briquette NPK& Urea (91-59-59) 230.4kg/ha significantly enhanced the plant height, leaf chlorophyll content, and leaf area in both locations.
- Briquette NPK & Urea (121-58.7-59)230.4kg/ha and Briquette NPK& Urea (76-29-29)115.2kg/ha recorded the highest grain weight per plot at Amantin and Nsapor, respectively.

6.2 Recommendations

- Farmers should apply Briquette NPK& Urea (91-59-59)230.4kg/ha and Granule NPK & Urea (120-40-40)200kg/ha to enhanced the organic C, total N, Ca, and K content in the soil.
- Farmers should apply Briquette NPK & Urea (121-58.7-59)230.4kg/ha and Briquette NPK& Urea (91-59-59) 230.4kg/ha to enhance the vegetative growth of maize.
- Farmers should apply Briquette NPK & Urea (121-58.7-59)230.4kg/ha and Briquette NPK& Urea (76-29-29)115.2kg/ha for higher grain weight per plot.
- Further experiments should be conducted at different locations with the same treatments for comparisons and recommendations.

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APPENDIX

Guide to interpreting of soil analytical data

Nutrient	**Rank/Grade**
Phosphorus (ppm), (Bray 1)	
<10	Low
10-20	Moderate
>20	High
Potassium K (ppm)	
<50	Low
50-100	Moderate
>100	High
Calcium, Ca (ppm)/Meq=0.25 Ca	
<5.0	Low
5.0	Moderate
5.0-10.0	High
>10	Alkaline
ECEC (cmol(+)/kg	
<10	Low
10-20	Moderate
>20	High
Soil pH (Distilled water Method)	
<5.0	Highly acidic
5.1-5.5	Very acidic
5.6-6.0	Moderately acidic
6.0-6.5	Low acidity
6.5-7.0	Neutral
7.0-7.5	Slightly alkaline
7.6-8.5	Moderately alkaline
>8.5	Alkaline
Organic Matter (%)	
<1.5	Low

1.6-3.0	Moderate
>3.0	High
Nitrogen (%)	
<0.1	Low
0.1-0.2	Moderate
>0.2	High
Exchangeable Potassium (cmol (+) /kg)	
<0.2	Low
0.2-0.4	Moderate
>0.4	High
Source: (SRI, 2022)	