AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS
TRAINING AND ENTREPRENEURIAL DEVELOPMENT

Growth and Yield Performance of Maize (*Zea mays* L.) as Influenced by NPK Briquettes Fertilizers blended with RP, S, and Zn

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MASTER OF PHILOSOPHY CROP SCIENCE
(AGRONOMY)

2024

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A THESIS IN THE DEPARTMENT OF CROP AND SOIL SCIENCES
EDUCATION, FACULTY OF AGRICULTURE EDUCATION, SUBMITTED TO
THE SCHOOL OF
GRADUATE STUDIES, IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF
MASTER OF PHILOSOPHY CROP SCIENCE
(AGRONOMY)
IN THE AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING
AND ENTREPRENEURIAL DEVELOPMENT

NOVEMBER, 2024

DECLARATION

I, Daniel Asamoah, declare that this thesis except for quotations and references contained in published works which have all been identified and acknowledged is entirely my original work and it has not been submitted either in part or whole for another degree elsewhere.

Signature:………………………………….

Date:…………………………………………

SUPERVISORS' DECLARATION

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

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ACKNOWLEDGEMENT

May the almighty God be the Glory, honour and praise. I am heartily thankful to my supervisor. Prof. Kofi Agyarko whose knowledge, support and patience enabled me to develop an understanding of the subject matter. His guidance helped me in the research and writing of this thesis. I would also like to thank Rev. Kwame Nkrumah Hope for his insightful comments and encouragement as second supervisor. I thank my uncle Nana Osei Kusi Appiah, Qffinso my fellow study mates and Francis Boakye Asmah.

I grateful to my research work sponsor Fertilizer Research and Responsible Implementation (FERARI) in collaboration with International Fertilizer Development Centre (IFDC), who gave me this opportunity under the FERARI project, funds and inputs for the trials provided through IFDC.

DEDICATION

This work is dedicated to my dear wife Mrs. Juliana Asamoah and my children Jaida Bemah Asamoah, and Nana Abi Kusi Asamoah

ABSTRACT

Two field experiments were conducted at different locations at the Multipurpose Nursery at the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUTED) Mampong Ashanti and Ejura Agricultural College Crop Farm from April 2021 to August 2021. The objective of the study was to determine the effect of growth and yield of maize as influenced by NPK briquettes formulations. The Randomized Complete Block Design (RCBD) was used with eight treatments and four replications. There were eight (8) treatments made up of different rates of inorganic fertilizers formulated into briquette namely: T1- NPK 23-10-5 (NPK 276-40-40 kg/ha) (control), T2- NPK 23-10-5+ (RP) (NPK 276-40-20 (40) kg/ha), T3- NPK 23-10+5 + (RP + P) + K+S (NPK 276-40-20 (40+40) +40+6.2 kg/ha), T-4 NPK 23-10-5 (RP + P) + K + S+ Zn (NPK 276-40-20 (40+40) +40 +6.2+2.5 kg/ha) T-5 NPK 23-10-5 (RP + P) (NPK 276-40-20 (40+4 kg/ha), T6- NPK 23-10-5 (RP +P) + S (NPK 276-40-20 (40+40) +6.2 kg/ha), T7- NPK 23-10-5+P+S+K (NPK 276-40-20 (40+40+6.2 kg/ha) and NPK 23-10-5+P+S (NPK 276-40-20 (40+6.2 kg/ha). The results showed that NPK 23-10-5+ (RP) (NPK 276-40-20 (40) kg/ha and NPK 23-10-5 (RP + P) + K + S+ Zn (NPK 276-40-20 (40+40) +40 +6.2+2.5 kg/ha) tasselled and silked earlier than other treatments and was significantly different from NPK 23-10-5+P+S+K (NPK 276-40-20 (40+40+6.2 kg/ha) and other treatment. There were significantly taller plants at 7 and 9 WAP, greater number of leaves per plant at 13 WAP, wider stem diameter at 13 WAP with plants grown on NPK 23-10-5+P+S+K (NPK 276-40-20 (40+40+6.2 kg/ha) in Mampong across the growing period than other treatments. Similarly, NPK 23-10-5+P+S+K (NPK 276-40-20 (40+40+6.2 kg/ha) application produced significantly higher number of cobs per plot, dehusked cob weight per plot, number of plants harvested and cob diameter than NPK 23-10-5 (NPK 276-40-20 kg/ha) which had the least mean values for the Ejura field. The NPK 23-10-5+P+S+K (NPK 276-40-20 (40+40+6.2 kg/ha) had significantly greater number of lodged plant and cob length at Ejura compared to NPK 23-10-5+P+S+K (NPK 276-40-20 (40+40+6.2 kg/ha with the least mean value. Total grain weight per plot, total stover weight plot at harvest, 100 seed weight, undehusk cobs per plot and grain yield per hectare, chlorophyll content on sixth leaf at 13 DAP for maize planted on NPK 23-10-5+P+S+K (NPK 276-40-20 (40+40+6.2 kg/ha were significantly higher in Ejura than those planted at Mampong. It is recommended that farmers are encouraged to apply NPK 23-10-5 (RP + P) + K + S+ Zn (NPK 276-40-20 (40+40) +40 +6.2+2.5 kg/ha) and NPK 23-10-5+P+S+K (NPK 276-40-20 (40+40+6.2 kg/ha) to their maize for higher growth and yield with sustained soil fertility.

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CHAPTER ONE: INTRODUCTION

1.1 Background of the study

NPK briquette possesses less surface area and thus dissolve slower, releasing nutrients at a more moderate pace for a long time, which eventually reduce nutrient losses, particularly N, and consequently protect water and air quality compared with the granular fertilizers (Bogusz *et al*., 2021). The increased N-use efficiency with the fertilizer briquette implies lower N losses to water bodies and volatilization (Gaihre *et al.,* 2015). Maize (*Zea mays* L.) is the oldest and most widely cultivated and consumed cereal crop in the world (Amali & Namo, 2015). The cultivation of maize is a major farming activity in Ghana and the forest-transition zone is a popular maize growing area in the country (Mamudu *et al.,* 2017). In Ghana, maize grain is utilized in the preparation of various foods such as *tuo zaafi (TZ), kenkey, banku, akple* and *corn wine* and also as feed for livestock.

The maize husk is used as wrappers in the preparation of kenkey while the leaves, stocks and the cobs are also utilized for some domestic purposes such as source of fuel wood and bedding material for livestock (Mamudu *et al.,* 2017). The maize crop requires adequate soil fertility for optimum growth and high grain yield (Amali & Namo, 2015). Optimum growth, development, establishment and yield of the crop is associated with better crop fitness, competition ability with weeds, and higher tolerance to various biotic stresses such as weeds, pests, diseases or abiotic stresses such as low or high temperatures, salinity and drought (Abdelaal *et al.* 2022). Plant and soil nutrients provide good conditions for the developmental needs of crops including maize. Nitrogen base fertilizers such as NPK or its combination are vital in the growth and production of the crop.

1.2 Problem statement

The land size of countries and communities is usually fixed and limited, making it a scarce resource especially in the phase of increasing industrialization. The issue of declining soil fertility in sub-Saharan Africa is also a major constraint to agricultural development (Delaune, 2018). Plant-soil nutrient depletion and declining soil fertility which are major contributory factors to crop failure are common in Africa (Chianu *et al.,* 2012). The productivity and fertility of agricultural land can be replenished when exhausted. Continuous cropping and other cropping systems without nutrient replenishment via crop residues, manure, mineral fertilizer or regeneration during fallow periods has led to nutrient mining and degradation of soil resources (Tittonell & Giller, 2013). Despite the improvements made over the years in the agricultural sector, a combination of constraints such as declining soil fertility, population growth, low uptake of external inputs, and climate disruption has resulted in a dramatic fall in per capita food production (Brankov *et al.,* 2020).

Low soil fertility is identified as a major factor causing crop failure and decreased crop productivity in many tropical cropping systems where fertilizer usage is low and agricultural residues are not returned to the soil to replace lost and depleted nutrients caused by leaching, erosion or uptake by crops (Agyeman *et al.,* 2013). Studies conducted by Agyeman *et al.* (2013) on the performance of maize in response to application of NPK and Nitrogen fertilizers was studied on soils in the forest and forest-savannah transition zones recorded significant grain yield. It is therefore, on this basis that the current research seeks to study the growth and yield response of maize to different NPK fertilizer formulation in the transition zone of Ghana.

1.3 Justification

To eradicate the problem of low yield in maize, nutrient management is an option as it utilizes available inorganic nutrients to build ecologically sound and economically viable farming system (Gruhn *et al.,* 2000). Inorganic fertilizer delivers readily available nutrients for plant growth and subsequent yield. Their use has always been effective in the tropics, due to enhancement of soil nutrients, balanced, high organic matter status and triggers other factors that allows the uptake of the nutrients. Workings by Gruhn *et al.* (2000) confirmed that the application of NPK gave higher yields than the organic fertilizer alone for maize production. Zelalem *et al.* (2014) found that the application of inorganic fertilizers assimilated with 75/60 kg of N and P ha^1 was lucrative in boosting maize yield. Similarly, Wakene *et al.* (2014) found highest grain and biological yields in maize due to the application of inorganic fertilizers (NPK). The above literature point to the fact that application of inorganic fertilizer is a guarantee for crop productivity in many soils since they are effective to improve soil fertility that may boost plant growth, development and yield. Soils in the forest-savanna transition zone of Ghana are reported to be more appropriate for maize production than those in the Guinea –savanna zone (Nketia *et al.*, 2018).

Adu-Gyamfi *et al.* (2019) reported that through the use of fertilizer briquettes, maize plants grown in Savanna agro-ecological zones of Ghana, recovered N 77 % for the applied fertilizer to increase maize yield by N 30 %, relative to split application of granular fertilizer sources. What is absent in the literature of inorganic fertilizer on maize growth and yield is the inadequate information on the effect of essential macro and micro nutrients formulated into fertilizer briquettes on the growth and yield of maize. This has created a knowledge gap on the appropriate levels and efficiency of a fertilizer briquette which is made up of single and / or combination of major and minor nutrients on growth and yield of maize, especially in the tropics and for that matter in the transitional agro - ecological zone of Ghana. This study will therefore contribute to fill the knowledge gap and provide suggested type of fertilizer briquette that provides better growth and yield of maize to farmers for adoption. The study will also provide data and information to potential researchers who may find it worthy to their work. The study will further provide recommendations for future research in the area of inorganic fertilizer combinations and in other geographical locations, or agro-ecologies in Ghana.

1.4 Objectives of the study

1.4.1 Main objective

The main objective of this study was to determine the effect of NPK briquettes fertilizers blended with RP, S, and Zn on maize growth and yield.

1.4.2 Specific objectives

The specific objectives of this study were:

1. To determine the effect of different enhanced fertilizer briquettes on growth performance of maize.
2. To determine the effect of different enhanced fertilizer briquettes on grain yield of maize.
3. To determine the effect of macro (N,P,K RP,S) and micro (Zn) nutrients blend as fertilizer briquettes on soil physiochemical properties.

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin and distribution of maize

There is some controversy on the origin of maize, though it is generally accepted that its centre of origin is located in Mesoamerica, primarily Mexico and the Caribbean from where it spread rapidly. Maize (*Zea mays* L.) is the third most important crop after wheat and rice, widely cultivated in tropics, sub-tropics and temperate regions to almost all the conditions of irrigated to semiarid of the world. In some countries, 'corn' means the 'local staple', while in other countries, it is used for any 'cereal'. The ear of maize is unique among cereals, and morphologically similar wild pro-genitor of maize could not be found. Therefore, its evolution has been a great scientific challenge and of great interest for both biologists and archaeologists. Many hypotheses have been proposed by different scientists to explain the origin of maize. Among them, (1) tripartite hypothesis, (2) catastrophic sexual transmutation theory, (3) Tripsacum - *Zea diploperennis* hypothesis, and, (4) teosinte hypothesis were debated and discussed in detail by different scientists (Matsuoka *et al.* 2012).

2.1.1 Wild Relatives of maize

The wild relatives of crop plants constitute an increasingly important genetic resource for improving agricultural production and maintaining sustainable agro ecosystems (FAO, 2018). A crop wild relative (CWR) can be defined as 'a wild plant taxon that has an indirect use derived from its relatively close genetic relationship to a crop' (Maxted *et al*., 2016). The grass genus *Zea* comprises of seven genera with varying chromosome number and are classified into two groups, viz. old-world group and new world group. *Coix, Chionachne, Sclerachne, Trilobachne* and *Polytoca* belong to the old-world group and these originated from Southeast Asia. New world group consists of *Zea* and Tripsacum and are native to Mexico and Central America. *Z. mays ssp. mays* is the only species of *Zea* with economic importance, and the other species of *Zea* are generally referred to as teosintes (Farnham, 2013).

2.1.2 Teosintes

Teosintes are wild grasses which mainly originated in Mexico and Central America and represent potential genetic resources for maize improvement. All species of teosinte can be crossed with maize (Wang *et al*., 2022). The group of four species including *Z. diploperennis*, *Z. nicaraguensis*, *Z. luxurians* and *Z. perennis*, and three subspecies of *Z. mays including Z. mays* spp. *huehuetenangensis*, *Z. mays* spp. *mexicana and Z. mays* spp. *parviglumis*, are collectively called teosintes (Fukunaga *et al*., 2015). Among these, *Z. mays* spp. *mexicana* is annual type teosinte that spread across the central high-lands of Mexico (Raemaekers, 2018).

2.1.3 Tripsacum

Tripsacum commonly called as ‘gamma grass’ belongs to the secondary gene pool of maize as defined by Harlan *et al.* (2017). This genus consists of about 16 perennial and warm species which originated in Mexico and Guatemala but are also distributed in the USA and South America while some of these are also detected in Asian regions (Chaudhary *et al.,* 2014). It possesses wide variation in chromosome number (2n = 36, 64, 72, 90, 108) among different species. After teosinte, *Tripsacum* is used widely as a source of valuable traits in maize due to its wider adaptation and resistance to heat, drought and waterlogging stresses.

2.1.4 Asiatic Genera

Asiatic genera, namely, *Coix, Sclerachne, Polytoca, Chionachne* and *Trilobachne,* collectively called as 'Oriental *Maydeae'*, are prevalent across the Southern parts of Asia including India, Myanmar, China and Malaysia (Chaganti, 2015). Based on botanical features, the Asiatic genera are classified into two major groups: first, Coix wherein the caryopsis is enclosed in modified spathe, and second, Trilobachne, Chionachne, Polytoca and Sclerachne with caryopsis enclosed in indurated lower glume. The members of the second group differ from each other with respect to nature of lower glume of fruit, kind of grain base, visibility of hilum and rachis over the length and bearing of inflorescence on plant (Sachan and Sarkar, 2015).

2.2 Economic and nutritional importance of maize

Reports indicate that 90% of the world's calorific requirement is provided by only 30 crops, with wheat, rice, and maize alone providing about half the calories consumed globally (MoFA, 2005). The per capital consumption of maize in Ghana in 2,000 was estimated at 42.5 kg (MoFA, 2000) and an estimated national consumption of 943,000 metric tonnes in 2006 (MoFA, 2000). One million metric tonne of maize is reported to be marketed annually in Ghana. A very large quantity of maize grains produced remains within households of producers as a primary staple food (Gage *et al.,* 2012). The maize grain is consumed in different forms in various traditions and cultures and large proportion of the maize is used in the poultry industry as feed. Only about 20% to 25% of the total maize marketed is used for industrial purposes (Amanor-Boadu, 2012). In sub-Saharan Africa, maize is a staple food for an estimated 50% of the population and provides 50% of the basic calories. It is an important source of carbohydrate, protein, iron, vitamin B, and minerals. Africans consume maize as a starchy base in a wide variety of porridges, pastes, grits, and beer. Green maize (fresh on the cob) is eaten parched, baked, roasted or boiled and plays an important role in filling the hunger gap after the dry season. Maize grains have great nutritional value as they contain 72% starch, 10% protein, 4.8% oil, 8.5% fibre, 3.0% sugar and 1.7% ash (Chaudhary *et al.,* 2014). *Zea mays* is the most important cereal fodder and grain crop under both irrigated and rainfed agricultural systems in the semi-arid and arid tropical areas (Hussan *et al.,* 2003). Domestic maize production seems to be meeting the local demand for human consumption. The maize supply in Ghana has been increasing steadily over the past few years with an average supply at 1.4 million tonnes over the period 2015-2017.

However, human consumption is competing with the poultry industry and to a lesser extent the livestock industry. While there is no reliable data for maize used in animal feed, the Government of Ghana estimates that 85% of all maize grown in Ghana is destined for human consumption and the remaining 15% is used for feeding mainly poultry. Data obtained from major feed mills in Ghana indicates that about 250,000 tonnes of maize is used for poultry feed annually. This is in line with the data on consumption of white maize in 2016 where the poultry industry absorbed 170,000 tonnes of domestic production. A deficit of around 110,000 tonnes in 2016 was observed which most probably was compensated mainly with informal imports of maize given the negligible volumes of formal imports in 2016. The same deficit of around 115,000 tonnes was registered in the year 2010. In the North, millet and sorghum are the main cereals produced and consumed, but in times of scarcity, maize, which is usually a surplus crop, is used as a substitute for these grains.

2.3 Constraints to maize production

2.3.1 Striga infestation

Striga is a neglected parasitic weed pest but important determinant of yield in maize farms. Striga species largely depend on a host plant to obtain their nutrients and water for survival. Several studies highlighted the negative effect of Striga in the Guinea savanna ecological zone, specifically in Niger and Ghana (Albert *et al.* 2011). Striga is a significant negative predictor of maize yield across all models, but the analysis shows that the negative effect of Striga on maize yield can be reduced by weeding, herbicide (Denwar & Haruna, 2006) and fertilizer applications. Other practices recommended for effective control of Striga include the adoption of Striga tolerant or resistant varieties, fertilizer timing (Di Tomaso, 2015), and intercropping and rotation with soybeans (Groote, 2010).

2.3.2 Impact of soil properties on yield of maize

The role of nonmarket factors, such as soil fertility, has not been extensively addressed in earlier studies on fertilizer programs, but a better understanding of this dimension may lead to innovations that fit the needs of small-scale farmers (Braimoh & Vlek, 2006). Physical properties, such as soil structure, are as important as chemical properties in determining soil fertility. Labile soil structure had a significant negative effect on yield in a study and this could be attributed to the dominance of silt-sized particles which led to a high vulnerability to mechanical stress. Poor structured soils are vulnerable for structure deterioration upon mechanical stress, such as raindrop splash and tillage. The consequences can be serious for crop growth: Soil pores block, surface sealing by crusts and hard setting occurs when soils become dry (Nelson & Oades, 2018). Lower infiltration rates, higher surface runoff, and soil erosion as well as lower root penetration, reduced seedling emergence, and aeration are the consequences (Häring & Stahr, 2017). Soil organic matter has an overall positive effect on chemical and structural soil properties; an effective measure to improve soil structure is to increase soil organic carbon by increasing organic inputs (e.g., manure and compost) and reducing losses from erosion and decomposition (Akoto-Danso *et al.*, 2018). Further, mulching is recommended to reduce vulnerability of surface crusting by raindrop splash and erosion. However, only a small body of literature included soil variables when determining fertilizer application profitability, with very interesting findings. Kenyan farmers, for example, profit from fertilizer application if their fields have at least 3% of soil carbon (Marenya & Barrett, 2009). Depending on the location, other soil properties can be crucial, as in Zambia under acidic soil conditions, phosphoric fertilizers were found to be unprofitable (Burke *et al.* 2017). To address low productivity, substantial investment is required in technical know-how (Groote. 2010).

2.3.3 The potential of fertilizers in maize production

Several reports focused on policies and the role of the private sector in sub-Saharan Africa to explain low fertilizer use. The results have shown that even with increasing private sector participation, fertilizer use at plot level remains too low to ensure food supply, taking into account continuous losses in soil fertility (Crawford *et al.* 2006). Enabling farmers to achieve higher yields through profitable fertilizer application is expected to increase the demand for inputs. However, current input and output prices do not suggest that a sustainable demand for fertilizer will emerge. Still, promoting higher fertilizer application using subsidies has remained a particularly popular policy instrument to increase yield. Several studies have shown that fertilizer use was associated with higher maize yields (Cairns *et al.*, 2013). This was expected because maize has high nitrogen (N) requirements, and nitrogen deficiency is a major cause of low yield. However, Ragasa and Chapoto (2017) reported that farmers in northern Ghana are farther away from applying the optimal fertilizer rate as compared to farmers in the south. Simulation studies found that the availability of fertilizer in small packages of 5 kg or less will increase both adoption and use intensity (Freeman & Omiti, 2003). In Ghana, smaller packages are available at a 20–80% higher price per kilogram compared to the full bag. Resource-poor farmers, who are not able to purchase an entire bag, are most disadvantaged by this pricing policy. The main purpose of the fertilizer subsidy policy (FSP) is to support smallholder farmers (Cooper *et al.,* 2016).

In a study, Lilli *et al.* (2019) suggested that the program is, by and large, not reaching the target group. Fertilizer and yield output prices differ substantially across the country due to differences in access to infrastructure and markets, which have a substantial impact on transport costs and price information. Therefore, in remote areas, farmers have low bargaining power and are dependent on farm gate sales. At subsidized prices and assuming perfect implementation of the FSP, the rough estimation of fertilizer profitability, VCR, is on average only 0.8. The calculated value of the VCR with fertilizer prices without subsidy is 0.7. The standard interpretation is that VCR values greater than 1 indicate that farmers increase their income by using fertilizer. However, this interpretation does not take the risks associated with fertilizer use into account. Some authors suggest a threshold of a VCR of 2 or more to accommodate price and climatic fluctuations, which could then lead to a sustainable demand for fertilizer by smallholders (Crawford & Kelly, 2002). The results on VCR clearly show that at the current fertilizer and maize prices, a sustained demand for fertilizer will not emerge. The VCR values calculated in this study differ greatly from the rate of (at least) 2.6 found by

Ragasa and Chapoto (2017). The study by Ragasa and Chapoto (2017) was based on aggregated data from the entire country, whereas this study focuses on northern Ghana, which is suffering from harsh climatic conditions and poor infrastructure. Second, data for their study were collected from the end of 2012 and the beginning of 2013. Since then, the high depreciation rate has increased the fertilizer price by 57% from 39 Ghana Cedi in 2012 to 89 Cedi in 2015 (Resnick & Mather, 2016).

2.3.4 Fertilizer subsidy cards increase fertilizer utilization

Different FSP implementation strategies have been adopted in Ghana, for example, vouchers and direct subsidy have both been used. The current subsidy card is seen as a new "smart" instrument to address shortcomings of the earlier methods. The efforts of the program are reflected in the results of the Tobit model: Ownership of the subsidy card (which applied to 16% of the surveyed farmers) was associated with a higher fertilizer application rate. Nevertheless, the program also has its challenges. During the focus group discussions, farmers reported problems in gaining access to the card. As a result, two farmers share one card, which increases the percentage of farmers who have access to subsidized fertilizer to 19%, but reduces the amount of fertilizer per card user.

Farmers in communities located closer to larger towns are registered through their mobile phones as an alternative to the physical subsidy card. However, very few farmers own a phone and they were generally dissatisfied with this option. Despite the program's aim to target smallholder farmers, the share of farmers who own a card (or, alternatively, are registered through the mobile phone's SMS system) is alarmingly low. Houssou *et al.* (2017) also reported that in 2011, 78% of the subsidy benefits went to unintended beneficiaries and only 17% of the recipients were poor. In the present study, the distance between the homestead and the field is associated with lower fertilizer application rates, which is likely related to labor and transport costs. This finding is in line with other studies, which found that transaction costs rise with distance to input markets and are a major limiting factor to fertilizer application and application rates (Martey *et al.,* 2013).

2.3.5 Governance challenges limit the effectiveness of the FSP

The focus group discussions provided additional information on the challenges farmers have faced when accessing the FSP and clarified the reasons behind the participants' choices. The challenges are manifold, but lack of information turned out to be a major problem: It was unclear to most farmers (a) whether the FSP will be implemented in the given year; (b) when it will be implemented; (c) who is eligible for the fertilizer subsidy card; (d) what were the modalities to receive a card and whether it is free of charge; and (e) what amount of subsidies each farmer is entitled to every year.

The focus group discussions indicate that poor targeting of the program and related problems of elite capture and rent-seeking are under-mining the purpose of the program. Extension agents were in charge of giving out the fertilizer subsidy card. One of the problems found in the literature is that they have no verifiable standard method to identify the actual target group of smallholders (Houssou*, et al.,* 2017). This problem is consistent with the results of the Tobit model in the present study: a household's wealth variables (donkey carts and the use of other inputs) were significantly associated with access to a subsidy card. Additionally, card holders still faced the problem that subsidized fertilizer was not always available when needed and, in the quantity, foreseen by the FSP. This finding echo other studies, which also identified distribution problems and availability at the retailers as major constraints preventing farmers from applying the recommended fertilizer rates (Freeman & Omiti, 2003). The literature also supports the perception of the focus group discussion participants that elite capture is a major challenge of the program. In the Northern Region, Imoru (2015) found that network connections and influence were important factors influencing the participation in the FSP. Similarly, Jatoe (2016) states that large-scale farmers had not only better access to the subsidies, they were also able to acquire amounts far beyond the amount foreseen in the subsidy program. In spite of these governance challenges, FSPs remain an attractive policy to attract media and voters' attention, especially during election times (Jayne & Rashid, 2013).

2.4 Nutrient absorption by maize and its fertilizer requirements

Total nitrogen was an essential factor of maize in all growth stages. Increased nitrogen fertilizer leads to more dry matter production and grain yield. Also, increasing nitrogen accelerates green growth, increases the above-ground mass of the plant, and increases the evaporation of plants and causes the roots to expand and bulk up (Ali *et al.,* 2016). Numerous reports recorded the positive effect of nitrogen on grain growth per grain, grain weight, and grain yield of maize, with a tendency to use higher amounts of nitrogen fertilizer Bojtor *et al.* (2021) observed that essential nutrients include nitrogen, phosphorus, potassium, sulphur (in first cluster) and calcium and magnesium (in second cluster) in the different leaf stages. The growth stages of maize were also found to have different nutrient demands. Phosphorus and nitrogen should be provided to the plant immediately after germination to start growing stems, leaves, and shoots. Insufficient nitrogen supply after one or two weeks of planting to the sixth week reduces the plant's potential yield (Girma *et al.,* 2017). Current results indicate that sulphur, potassium, molybdenum, and nitrogen had maximum effect on NPK treatments, and molybdenum, potassium, and iron had maximum effect on growth stage on leaves. The highest uptake of phosphorus occurs in the sowing stage, but phosphorus uptake in the whole plant decreases in the ripening stage (Piperno & Flannery, 2016). Iron is a useful element in photosynthesis and has a special role in plant nutrition. However, the high percentage of bicarbonate and carbonate in the soil causes iron deficiency in plants (Sipos, 2019). Some research studies indicate the effect of iron and manganese fertilizers on quantitative and qualitative traits and the positive role of these elements in increasing maize protein. Also, the lack of these elements has a negative effect on the percentage of protein and other quality characteristics of corn (Brodowska, 2021).

The first cluster includes nitrogen and sulphur and the second includes calcium and zinc in the NPK treatments on stalk. Nitrogen and potassium had their maximum effect on the stalk during the vegetative growth period. Manganese and copper were important and favourable for the different growth stages and treatments on the stalk. Adding iron and manganese fertilizer is recommended if the amount of these elements is less than optimal, causing discoloration other than chlorophyll in leaves and the reduction of growth regulator factors in the plant. This study indicated that increasing nitrogen negatively correlates with zinc and cooper; that is, increasing amount of nitrogen causes decreasing zinc and copper. Also, an increasing amount of potassium caused decreasing iron and manganese concentration. Phosphorous correlated negatively with nickel and copper. The iron and manganese fertilizer use increases photosynthesis and transfers photosynthetic materials to different parts of the plant, thereby growing the stem. Improving nutritional conditions and the positive role of iron can be useful in photosynthesis and optical photosystems’ performance in increasing growth indices such as stem diameter (IFDC, 2007). Nitrogen and calcium had a maximum impact for grain stage and nitrogen and phosphorus had a favorable effect during the cob-corn stage. The nitrogen effect on the quantitative and qualitative properties of maize showed that nitrogen increases the production of dry matter, grain yield, and its components (Montemurro and De Giorgio, 2015). If there is adequate nitrogen in the soil, crops will have vegetative growth, larger leaf area, and significant yield (Bozovic *et al.,* 2020).

2.4.1 Availability of fertilizer

Despite differences of opinion on other issues, many analysts of fertilizer use and policy in Africa and the rest of the developing world contend that basic problems of availability (i.e. getting the right fertilizer to the right place at the right time) are at least as important as price-response interactions in determining fertilizer use (Pinstrup-Andersen, 2013). Often referred to as non-price factors, these problems can be accommodated within a pricing framework by noting that, in effect, they raise the shadow price of fertilizers to farmers. Although the features of the African fertilizer economy that lead to high prices are often intertwined with those that constrain availability, policy makers have often focused solely on the one effect (high prices) rather than on availability, and ignored the underlying causes completely. Ghana currently has no fertilizer manufacturing plants (Rajicic *et al.,* 2020).

Fertilizer is imported to the country through the port at Tema. The port has limited capacity and can accommodate 10 m draft vessels of up to 20,000 tons. The port is publicly owned and managed by the Ghana Ports and Harbour Authority. Fertilizer importers complain that the port is operating inefficiently with delays leading to high rent charges. The fertilizer is imported as bulk and bagging is done by only one British company, Nectar and the daily offload rate is 2,000 tons. Fertilizer importation and distribution before 1990 was carried out by the Ministry of Food and Agriculture (MoFA). The fertilizer market was liberalized in 1990 and the importation and distribution since then is being carried out by the private sector. Except WIENCO, all the companies in the fertilizer import trade are multinational companies (Mousavi and Nagy, 2021). Their involvement in the fertilizer supply chain is at various levels. YARA is a major supplier to most of the importers either through direct import order or through stock inventory credit. Finance is considered a major problem to all members of the fertilizer supply chain in Ghana. The importers rely on three forms of finance, namely auto-financing, supplier financing and formal loan from the banking system to import and distribute fertilizer. With the formal banking system, Letters of Credit (LC) and import bill are required to process the loans. The farm gate price is determined by the import costs and the margins (5-10 %) taken by the distribution sector. The costs include product costs, port charges, bonded warehousing, loading, unloading and bagging, transportation, interest on loans, and other fees (Illes *et al.,* 2020).

2.5 Fertilizer use in Africa

Low fertilizer use is one of the factors explaining lagging agricultural productivity growth in Africa. In 2002, the average intensity of fertilizer use in Sub-Saharan Africa was only 8 kilograms per hectare, much lower than in other developing regions. Even when countries and crops in similar agro-ecological zones are compared, the rate of fertilizer use is much lower in Africa than in other developing regions, and crop yields are correspondingly lower (Mousavi *et al.,* 2019). African soils present inherent difficulties for agriculture, and land-use practices during the past several decades have exacerbated those difficulties through nutrient mining by crops, leaching, and inadequate erosion control. Africa’s land degradation problems can be attributed to many causes, but analysts generally agree that a fundamental contributing factor has been the failure by most farmers to intensify agricultural production in a manner that maintains soil fertility. The inherent lack of fertility, along with widespread soil nutrient mining, has led to expansion of the agricultural frontier in Africa and the opening up of less favorable soils for cultivation. This is a scenario for disaster over the long run, given the difficulty of restoring tropical soils to productive capacity. In many tropical soils, the restoration of organic matter a key component in soil fertility is a very long-term proposal, and in lateritic soils such as those found throughout large parts of Africa, restoration may even be impossible. So, without nutrient replenishment, many African farmers risk taking their soil resource base beyond a point of no return. Evidence reviewed in this report suggests that the low use of fertilizer in Africa can be explained by demand-side as well as supply-side factors. Demand for fertilizer is often weak in Africa because incentives to use fertilizer are undermined by the low level and high variability of crop yields on the one hand and the high level of fertilizer prices relative to crop prices on the other.

The demand-depressing effects of unfavourable price incentives are aggravated by many other factors, including the general lack of market information about the availability and cost of fertilizer, the inability of many farmers to raise the resources needed to purchase fertilizer, and the lack of knowledge on the part of many farmers about how to use fertilizer efficiently. These constraints on the demand side are narrowed on the supply side by factors that reduce the timely availability of affordable fertilizer in the market. In many African countries, private investment in fertilizer distribution is discouraged by an unfavorable business climate characterized by excessive regulations, an abundance of taxes and fees, and high levels of rent seeking. As a result, fertilizer marketing is left mainly in the hands of inefficient public agencies. More fundamentally and regardless of whether it is being done by public agencies or private firms fertilizer distribution is unprofitable in many parts of Africa because of the weak and dispersed nature of demand, the small market size, high transportation costs stemming from inadequate road and rail infrastructure, and the limited availability and high cost of financing.

2.6 Challenges in fertilization

2.6.1 Leaching Losses

Nitrate (NO^-_3) fertilizers are susceptible to leaching losses (Almasri and Kaluarachchi, 2004). The extent of leaching is more in sandy soil compared to clayey soils. The situation is further aggravated when soil is bare than cropped soil. The main problems related to NO^-_3 leaching are eutrophication of surface waters, increased production of nitrous oxide from receiving water bodies, and a higher concentration of NO^-_3 in drinking water (WHO recommends <50 mg NO^-_3 per litre of drinking water). According to Lehmann and Schroth (2003), nitrate leaching is lower in subsoil due to the increase in net positive charge, and the nitrate held in subsoil can be taken up by deep-rooted crops.

It is important to distinguish between nitrate movement within the soil profile (i.e., topsoil to subsoil), and leaching beyond the root zone, into the groundwater. Losses from ammoniacal fertilizers are higher during the summer season because of rapid oxidization by nitrifying organisms. The activity of the nitrifying organism can be reduced to minimize leaching losses. Various chemical compounds inhibit microbial nitrification of N fertilizers and reduce the leaching loss. Phosphorus losses by subsurface leaching are negligible compared to losses by erosion and surface runoff. Subsurface leaching increases when P is in soluble organic form, as manure; the soil's capacity to bind inorganic P is saturated; preferential flow of water through channels and cracks in the soil prevents soluble P from getting in contact with the soil's adsorption sites. Furthermore, drained soils have a higher rate of subsurface leaching compared to undrained soils. Compared to inorganic P, dissolved organic P is more mobile in soil (Havlin *et al.,* 1999). Potassium can be lost in drainage water in sandy and acid soils and in high rainfall areas. Losses can be minimized by modifying the time of application with crop growth stage to maximum plant uptake period and also applying the fertilizer in split doses.

In Clayey soils, there are no leaching losses. Moreover, recently developed slow-release K fertilizers are not subject to leaching losses, for example, potash frits, potassium metaphosphate, and fused potassium phosphate. Sulfate, added to soil as a secondary nutrient along with N and K fertilizers, is susceptible to leaching from the topsoil and accumulating in the subsoil. In the subsoil SO_4^{2-} is only available later in the season to deep-rooted crops. Leaching can also result in SO_4^{2-} losses to groundwater. Sulphate is also readily leached from surface soils; maximum losses are in soils dominated by monovalent cations such as K and Na and minimal in soils with high amounts of Al (Havlin *et al.,* 1999).

2.6.2 Gaseous Losses

Gaseous losses of N from soils may be through (1) ammonia volatilization under high pH conditions in alkaline soils and (2) loss as N_2, N_2O, and NO due to denitrification. These losses are influenced by soil pH, fresh organic matter, moisture, temperature, and soil microbial diversity. Ammonia volatilization at high pH can be minimized by proper placement of urea. Cantarella *et al.* (2005) reported volatilization losses ranging 37–64 % of urea applied to maize crop at various locations. It is recommended to apply ammoniacal fertilizers at least 10–15 cm below the soil surface. Alternatively, urea should be used instead of nitrate fertilizer wherever there are high chances of losses of N by denitrification processes.

2.6.3 Immobilization

Immobilization is a major cause of reduced FUE as nutrients released from fertilizer become unavailable for growing crops over a certain period of time via chemical, physicochemical, and microbiological immobilization (FAO, 2020). Ammonium and K ions are immobilized by strong adsorption by 2:1 type clay minerals such as vermiculite (Barshad and Kishk, 2017). High soil pH further enhances this type of fixation. Practical soil fixation can be reduced by timely and proper placement of fertilizer. Fertilizer should be carefully selected so that it will have minimum interaction with the soil. Furthermore, the time and mode of application should be selected to ensure minimum immobilization of nutrients, such as preferable use of nitrate fertilizer may improve availability.

At low pH, the efficiency of water-soluble P is very low. In acidic soils, P is known to react with Fe/Al oxides to form insoluble complexes (Vance *et al.,* 2013). However, rock phosphate has shown increased solubility and availability under acidic conditions. In calcareous soils, applied P is invariably converted into tri-calcium phosphate, an insoluble P compound (Rahmatullah *et al.,* 2014). Under such conditions water soluble P are relatively more efficient than water insoluble P such as rock phosphate. Microbiological fixation of fertilizer N may be of concern when undecomposed organic matter of wider C/N ratio is present in the soil. However, this is a temporary type of immobilization. Application of a starter dose of N fertilizer to organic matter or by allowing enough time for complete decomposition of undecomposed organic matter may improve the N availability for the crop. Sulfate can bind to clays, and it is less mobile than nitrate but has higher mobility than phosphate.

2.6.4 Soil Compaction and Fertilizer Use Efficiency

Soil compaction is a common observation under mechanized farming and is one of the major problems facing modern agriculture. Soil compaction increases soil strength and decreases soil physical fertility through decreasing storage and supply of water and nutrients, which leads to additional fertilizer requirement and increasing production cost (Kummu *et al.,* 2012). Numerous physical changes in soils due to compaction result in a poor response for N and P fertilizers. Soil compaction results in the soil particles coming closer resultantly decreasing soil bulk density and soil porosity. Because the points of contact between soil particles are increased, compaction also results in an increase of soil strength. In fine-textured soil, compaction reduces the available water capacity of soil, resulting in decreasing nutrient availability (Shah *et al.,* 2017).

2.6.5 Soil Temperature

Soil temperature is one of the important environmental factors affecting plant growth and fertilizer response of crops (Zheng *et al.,* 2022). Temperature affects most physical processes occurring in the soil and the rate of chemical reactions increases with rise in temperature that controls nutrient availability. Soil temperature affects fertilizer efficiency by changing solubility of fertilizers, cation exchange, and ability of the plants to absorb and use nutrients (Hussain *et al.,* 2017). Volatilization losses of N are related to high soil and atmospheric temperature. Soils in warm regions generally fix higher amounts of P compared to temperate regions. Soil temperature can be managed to an extent by common management practices including tillage, mulching, and irrigation. Moreover, root growth is severely affected by either too cold or hot soil temperature ultimately affecting nutrient uptake (Marschner, 1995).

2.6.6 Soil Moisture

Soil moisture regulates nutrient movement within soil and their uptake by plants. Drought conditions can limit nutrient uptake because of decreased nutrient movement as well as decreased root growth (Marschner, 1995). Excessive moisture leads to leaching loss of added fertilizers whereas lack of moisture results in poor availability of the added fertilizer and high osmotic pressure of the soil solution due to concentration effect fertilizers (Taylor *et al.,* 2013). Thus, efficient water management is complementary to efficient fertilizer management. Maximum efficiency of fertilizers can be obtained only in the presence of adequate soil moisture and vice versa. Sardans & Peñuelas (2021) demonstrated that increasing soil moisture from 10 to 28 % increased K transport by up to 175 %.

2.6.7 Soil pH

Soil pH is one of the major edaphic factors that regulate nutrient availability (Marschner, 1995). Most plant nutrients are available at soil pH 6 to 7.5. If soil pH is lower or higher than the range, nutrient availability reduces sharply and even 1 unit pH increase or decrease can decrease/increase 100 times nutrient availability. At low pH, most micronutrients except molybdenum are available and even can be present in toxic concentrations because of their increased solubility (Tan, 2011). In contrast, their availability reduces at alkaline pH particularly of Zn, Fe, Cu, and Mn. Plant nutrient availability depends on the prevalent soil pH. In highly acidic or alkali soils, efficiency of P fertilizers is low. In such situations, efficiency of fertilizers can be increased by correcting the soil condition, using suitable amendments. Physiologically alkaline fertilizers such as calcium carbonate and the like should receive priority on acid soils and physiologically acid fertilizers, or alternatively use of acidic fertilizers such as ammonium sulphate on alkaline soils. At pH higher than 7, Ca and Mg ions, as well as the presence of carbonates of these metals result in precipitation of P fertilizers, decreasing their availability (Shen *et al.,* 2011).

2.6.8 Soil Organic Matter

The organic matter in soil not only supplies different nutrient elements, but also improves physical conditions of soils, stimulates microbial activity, protects the soil from erosion, retards the fixation of nutrients, increases mobility of nutrients in soils, increases the buffering capacity, and helps in many other ways (Tan, 2011). Potential benefits of organic matter in soil in turn increase the efficiency of applied inorganic fertilizers. However, a high amount of organic matter may not prevent P losses as a result of leaching. This may be due to the absence of Al and Fe compounds, which are mainly responsible for P retention under low pH conditions (Vance *et al*., 2013).

2.6.9 Plant Characteristics

Crop species vary in their ability to absorb nutrients form soil. Furthermore, there is significant variation within cultivars of the same crop species (Aziz *et al.,* 2014). Numerous researchers have observed varietal variations for K uptake in ryegrass, maize, soybean, and barley (Dunlop *et al.,* 2019). Because the roots are the principal organs through which plants take up nutrients, the rooting pattern and habit have an important bearing on nutrient removal. Crops with shallow extensive fibrous roots are able to uptake a greater amount of fertilizer applied per unit area (Lynch, 2015). The fertilizer needs of deep-rooted crops are generally lower than shallow-rooted crops. Wang *et al.* (2016) identified five plant root factors that significantly influence nutrient uptake from soil. These include ion flux, root radius, rate of water uptake, root length, and rate of root growth.

2.6.10 Fertilizer Characteristics

Nutrient mobility, type of fertilizer, and the time and method of application significantly influence the FUE (Sadras and Lemaire, 2014). Nitrogenous fertilizers are highly mobile and subjected to both downward and lateral mobility. In contrast, P is highly immobile (Smeck, 2018). Potassium is also mobile but compared to N its mobility is lower (Nastri *et al.,* 2000). To get maximum efficiency N and K fertilizer should be applied in frequent split doses and P as basal dressing or near the root zone (Awan *et al.,* 2017). The type of fertilizer also determines the efficiency (Zaman *et al.,* 2005). Ammonium and urea fertilizers are more efficient than nitrate fertilizers for paddy soils (Datta, 2016). Water-soluble P materials are more efficient for short duration crops and in soils that are neutral to alkaline in reaction. There is also a certain amount of interaction noticed among crops and fertilizers. For example, paddy performs better when ammonium sulphate is applied as N carrier and for tobacco when potassium sulphate is applied as K carrier (Vann *et al.,* 2013).

2.7 The use of fertilizer briquette

NPK Briquette of large-sized super granules is an alternate N source, supplying N along with P and K with a goal of increasing the N, P, and K use efficiencies. NPK Briquette is manufactured via the physical manipulation of the current commercially available prilled and granular N, P, and K fertilizers (Bandaogo *et al.,* 2014). It is entirely mineral and supplies N, P, and K nutrients in a ratio that fits the targeted crop and soil (Agyin-Birikorang *et al.,* 2018). This kind of NPK Briquette fertilizer product, therefore, allows for nutrient-balanced site-specific fertilization in order to reduce nutrient, particularly N, losses and save labor because of its single application relative to the two to three split applications of commonly used prilled and granular fertilizers.

NPK Briquette possesses less surface area and thus dissolves slower, releasing nutrients at a more moderate pace over a longer time, which eventually reduces nutrient losses, particularly N, and consequently protects water and air quality compared with the granular fertilizers. Agyin-Birikorang *et al.* (2018) reported that NPK Briquette increased maize yield by 16 % compared with ammonium sulfate (+P and K) and by 23% to 34% relative to urea (+P and K) under normal weather conditions; NPK Briquette also resulted in higher N, P, and K use efficiencies. Rice yields were increased by 25% to 50% with the application of the fertilizer briquette compared with commercial granular fertilizer in Vietnam and Cambodia (IFDC, 2007). In Bangladesh, the rice yield was enhanced by 25–35 %, while expenditure on commercial fertilizer was decreased by 24–32 % when the fertilizer briquette was used (Anik *et al.,* 2022; Gaihre *et al.,* 2017). The increased N-use efficiency with the fertilizer briquette implies lower N losses to water bodies and the atmosphere through leaching and volatilization (Gaihre *et al.,* 2015). Kapoor *et al.* (2018) reported that significantly higher grain and straw yield of rice was observed with deep placement of NPK briquettes compared to the broadcast application of NPK. Work on cabbage by Firake *et al.* (2014) suggested that the placement of NPK briquettes at 10 cm depth in the soil maintained a high level of NH^{-}_{4} during the active absorption period by the cabbage crop. Kapoor *et al.* (2018) and Rea *et* *al.* (2019) also observed significantly higher N, P, and K uptakes with deep placement of NPK briquettes compared to a broadcast application.

2.8 Effect of macro nutrients on growth and yield of maize

Zhang *et al.* (2020) observed that N is not generally translocated to grain from other plant parts until the "blister" or "milk" stage of grain development. Kosgey *et al.* (2013) reported that the N accumulation in leaf was higher during early stages but declined later at kernel filling stage. These researchers also observed that the stalk N accumulation was higher at early kernel filling but declined thereafter. Swank *et al.* (2012) posited that stalk was the key source of N for early kernel filling in irrigated crops.

The results presented here revealed that at silking both P and K accumulation were of the order stem > leaf > tassel (Xu *et al.,* 2022). At physiological maturity, the trend for P accumulation was grain > leaf > stem > other part of stalk, and that for the K accumulation was stem > grain > leaf > other part of stalk. The effects of year and cultivar factors on grain and stover yields of tested maize hybrids were found to be non-significant; however, NPK levels had significant effects on them. The grain yields produced at 75 % Recommended Nutrient Package (RDF) were statistically similar to the yield achieved at higher rates. Both grain and straw yields were found to be increased with increasing N levels up to 125 % RDF, and thereafter declined. However, increase in N level from 75 to 150 % RDF did not bring about significant variation in grain and straw yields of maize hybrids. Close inspection of the data however reveals that greater dry matter accumulation was achieved at 125% RDF. This result suggests that plants tried to maintain a synchrony between the vegetative and the reproductive stage up to 75 % RDF, but failed to maintain the same at 100 and 125 % RDF (Raemaekers, 2018). In case of tested maize hybrids with stay green nature, the formation of new reproductive structures is coupled to the development of vegetative structures, and vegetative growth can therefore not become zero. This coupling causes strong allometry between vegetative and reproductive weight, especially at higher fertilizer doses (100 and 125 % RDF). Omission of nutrients reduced grain yields. The grain yield reduction was in the order −N plot > −K plot > −P plot. It clearly depicts the fact that N is the most limiting nutrient for maize followed by K and P in the study location (Ragasa *et al.,* 2017). Greater importance of N fertilization to maize productivity has also been revealed by Liu *et al.* (2011). In the study of Ray *et al.* (2020), grain yield had positive relations with dry matter, N, P, and K accumulation at silking, post-silking, and physiological maturity stages; however, grain yield had the lowest association with post-silking K accumulation. Further inspection of the data revealed that K accumulation at physiological maturity was less than that of silking stage which clearly signifies post-silking K loss.

Moreover, grain K concentration at physiological maturity was largely contributed by K remobilization from leaf and stalk portion. Hence, post-silking K accumulation failed to exert significant impact on grain yield. Positive effects of dry matter Ul-Allah *et al.,* (2020) accumulation on grain yield of maize have been well documented by previous researchers across different geographical locations. Besides clarifying the dynamics of the macronutrients within the plant parts at various levels of NPK application, this study also highlights the complimentary role of each nutrient in its translocation and remobilization as well as yield building in maize. The necessity of supplying adequate amounts of the major nutrients to stabilize maize yield in the alluvial soils of humid tropics is further underlined (Ray *et al.,* 2020).

2.9 Effect of micro nutrients on growth and yield of maize

Generally, micronutrient-deficient soils do not support optimum crop yields because plant growth becomes retarded by the deficiency, leading to low yields (Chatzistathis, 2014). The increase in P may have been due to the interaction of P with Fe, Mn, or Zn (Bukhsh, *et al.,* 2012). Thus, no re-greening in upper untreated new growth leaves was expected nor observed, confirming previously described deficiency correction theory (Bryson *et al.,* 2014). However, plant and soil Fe concentrations alone were not predictive indicators of grain yield response to foliar Fe. This is consistent with the findings from a hydroponics study evaluating foliar Fe (Stewart *et al.,* 2019).

Hossain *et al.* (2018) observed that 100-seed weight of maize responded positively to Zn application to soil. The mutual use of Zn, Fe and Mn significantly enhanced seeds/cob weight (Hussain *et al.,* 2011). Application of $ZnSO_4$, $MnSO_4$ and Cu increased 100 seed weight. Hossain *et al*. (2018) reported significant straw yield response to Zn application. Significant influence of B and Zn on the dry matter production was also reported by Jahiruddin *et al.* (2011). Seedling emergence and establishment are the key processes in the survival and growth of plants. Seedling establishment was improved for seeds primed with micro-nutrients as compared to seeds primed with water. Seedlings primed with micro-nutrient solutions resulted in higher, longer, thicker and heavier seedlings.

Zeng *et al.* (2012) supports these findings with similar conclusions that Nutrient Seed Priming (NSP) improved seedling height, length, thickness and weight of maize and soybean respectively. The accessibility of micronutrients in the seeds are vital for protein synthesis and enzymes responsible for seedlings to effectively utilize the other nutrients in the soil. This consequently improved seed germination and seedling establishment. Moreover, micronutrients such as Mo and B are required for effective use of NPK nutrients by variety of crops (Singh *et al.,* 2014). In addition, these improvements in growth and developments for seedlings primed with solutions could be due to the earlier uptake of solutions which activated the germination process. Seeds which, are soaked in water for a particular duration and dried before seminal root protrusion can develop and grow faster (Rajendra and Prasad, 2023).

Seeds primed with micronutrients emerged earlier than the control, which could have increased their establishment resulting in superior use of nutrients as evidenced by better seedling weight, shoot length and root length. In addition, the increase in the root length of seeds primed with micronutrients could be due to activation of cell respiration and cycling during priming. Activation of cell respiration and cycling, repair of macromolecules, assimilated materials translocation and weakening of seed coat structure results in faster root emergence (Kan *et al.,* 2019). Nutrient seed priming especially at low concentration increased the content of chlorophyll compared with the higher concentration and the control. This could have enhanced the photosynthesis of the seedling and hence better growth. In study of Nciizah *et al.* (2020), the best treatment was B 0.01%. This treatment resulted in the earliest seedling emergence, highest seedling weight, root length and seedling height. Coincidentally, this treatment also resulted in the highest chlorophyll content. Similarly, Rehman *et al.* (2013) observed greater leaf chlorophyll content from priming solution had very low levels of boron (0.001 %).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Experimental sites and Location

3.1.1 Introduction

Two field experiments were conducted at different sites. The first experiment was carried out at the multipurpose Crop Nursery, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development Mampong - Ashanti Campus during the major rainy season, from April to August, 2021. The second field experiment was carried out at Ejura Agricultural College crop farm during the same period with a week interval between them.

3.1.2 Mampong-Ashanti Experimental Site

Mampong-Ashanti lies at the transitional zone between the forest in the South and northern savannah of Ghana. Mampong - Ashanti lies at an altitude of 402 m above sea level and occurs within latitude 01.45 north of equator and longitude 7° 4 ° '0” N east and 1° 24 ° '0” west of the Greenwich Meridian. Mampong-Ashanti has a bimodal rainfall pattern with annual rainfall between 1094.4 mm and 1200 mm and monthly mean rainfall of about 91.2 mm. (Ghana Meteorological Department, 2005). The major rainy season occurs from March to July while minor rainy season occurs from September to November (Ghana Meteorological Department, 2005). Between the two seasons is a short dry spell in August (Ghana Meteorological Department, 2005). Mampong Ashanti has a daily temperature of about 30.5 °C. The area consists of patches of tall elephant grass to the north and mixed patches of dry forest and grassland to the south.

3.1.3 Ejura-Sekyedumase Experimental Site

The second field experiment was conducted at the Ejura Agricultural College crop farm, which is located in the Ejura-Sekyedumase Municipality of Ashanti Region. Ejura lies on latitude of about 228 meters above sea level. The flat and undulating topography allows for mechanized agriculture. High temperature with a mean monthly of 21-30 ^{o}C is generally experienced. The area has bimodal rainfall. The major rainy season occurs from April to July and minor rainy season occurs from August to November (Ghana Meteorological Department, 2005). The annual rainfall for the area varies between 1200-1500 mm. The area consists of tall grasses, interspersed with short fire-resistant tree species. The vegetation is thus a mixture of Savanna and semi-deciduous forest cover.

3.2 Soil type and vegetation at the experimental sites

The soil at the Mampong-Ashanti experimental site is derived from the Voltaian sandstone of Afram plains. It belongs to the savannah Ochrosol class and is characterized by deep sandy loam; free from pebbles. It is well drained and contains moderate organic matter. The soil has a good water holding capacity. It has been classified by FAO (2013) legend as chromic Luvisol and locally as Bediesi series. The pH ranges from 6.0 to 6.5. The experimental site had been used for the cultivation of various crops such as carrot, tomatoes, maize, cowpea, okra and sweet potato. Grasses such as nut grass (*Cyperus rotundus*), giant star grass (*Cynodon plectostachus*) and guinea grass (*Panicum maximum*) are common. The soil at Ejura in the Sekyedumase Municipality of Ashanti region experimental site has been classified by FAO (2013) legend as Haplic Lixisol. The soil is deep, light in colour, well aerated and drained with moderate supply of organic matter and plant nutrients. It has good water holding capacity and is well adapted to mechanized cultivation. The soil ranges from sandy, loam or clay. The pH ranges from

5.3 to 6.5. It is suitable for the growing of cereals, especially maize and other legumes such as cowpea, as predominant crops.

3.3 The Experimental design, treatments and Field Layout

The experimental design used was a randomized complete block design (RCBD) with eight-treatment and each treatment with four (4) replications. Each plot measured 5 m x 5 m. A total of 32 plots were used for the trial at each location. A 1.0 m path was left between the plots and the blocks.

The treatments applied in this experiment were as follows:

T1- NPK 23-10-5 (NPK 276-40-20 kg/ha)

T2- NPK 23-10-5+ (RP) (NPK 276-40-20 (40) kg/ha)

T3 - NPK 23-10+5 + (RP + P) + K+S (NPK 276-40-20 (40+40) +40+6.2 kg/ha)

T4 - NPK 23-10-5 (RP + P) + K + S+ Zn (NPK 276-40-20 (40+40) +40 +6.2+2.5 kg/ha)

T5- NPK 23-10-5 (RP + P) (NPK 276-40-20 (40+40 kg/ha)

T6- NPK 23-10-5 (RP +P) + S (NPK 276-40-20 (40+40) +6.2 kg/ha)

T7 - NPK 23-10-5+P+S+K (NPK 276-40-20 (40+40+6.2 kg/ha)

T8 - NPK 23-10-5+P+S (NPK 276-40-20 (40+6.2 kg/ha)

Table 3.1 Ratios of amounts for briquetting (weight units)

Maize -NPK	PR	Urea	TSP	MOP	$(NH_4)_2SO_4$	$ZnSO_4.7H_2O$	NPKSZnB	UREA
NPK 15-15-15							50.0	
NPK 15-15-15+ Zn						4.6	45.4	
NPK 15-15-15+ S					10.0		40.0	
NPK 15-15-15+ PR	16.7						33.3	
NPK 15-15+15+PR+TSP	15.0		5.0				30.0	
NPK 15-15-15+PR+TSP+S	12.5		4.2		8.3		25.0	
NPK 15-15-15+PS+TSP+S+K	11.5		3.8	3.8	7.7		23.1	
NPK 15-15-15+PR+TSP+S+K+Zn	10.9		3.6	3.6	7.2	2.9	21.7	
UREA								300.0

Note: 4 replications, plot area 25m$^{2;}$ 2 briquettes Urea top dressing per hill; weight briquette3.4gr.

3.4 Land preparation and sowing

The experimental fields were cleared, ploughed and harrowed and divided into four (4) blocks and 32 plots before planting on a total land area measuring 40 m x 24 m for the major cropping season. The seeds of *Wang-Data* maize variety were sown manually on 1st May 2021 at Mampong and 8th May 2021 at Ejura. Three seeds were sown per hill and after seedling emergence, thinned to two seedlings per stand at two weeks after sowing. Seeds were sown at a depth of 3-5 cm and planting distance of 75 cm x 40 cm. Seedling emergence was determined seven days after sowing for each treatment for both trials. . Each plot had six (6) rows with twenty-four (24) plants per row. The total number of plants per experimental plot was one hundred and forty- four (144).

3.5 Protocol for soil physical and chemical properties

3.5.1 Soil chemical Analysis

3.5.1.1 Measured parameters

In order to assess the improving effect of inorganic fertilizer briquette on soil properties, the following parameters were measured:

3.5.1.2 Determination of pH

The soil pH was determined by the potentiometric method (1:1 soil water ratio) proposed by (Mclean *et al.,* 1982). A 50 g of dried soil were weighed into a plastic flask and 50 ml of distilled water was added. The mixture was thoroughly shaken on reciprocating shaker for 1hour. Just before measuring pH, the bottles were shaken by hand. The pH meter was standardized with buffer solutions of pH 4.0 and 10. After standardization, the electrode of the pH meter was inserted into the suspension and read.

3.5.1.3 Determination of available phosphorus

Available phosphorus was determined using the Bray P1 method (Athokpam *et al.,* 2016). The method is based on the production of a blue complex of molybdate and orthophosphate in an acid solution. A 10 μg P/mL standard sub-stock solution was diluted to produce standard series of 0, 0.8, 1.6, 2.4, 3.2, and 4.0 μg P/mL. These were subjected to colour development and their respective absorbance values read on a spectrophotometer at a wavelength of 660 nm. A standard line graph was constructed using the readings.

A 2.0 g of soil sample was then weighed into a 50 ml shaking bottle and 20 ml of Bray-1 extracting solution (0.03 *N* NH_4F + 0.025 *N* HCl) added. The sample was shaken for one minute and then filtered through No. 42 Whatman filter paper. Ten millilitres of the filtrate was pipetted into a 25 ml volumetric flask and 1 ml each of molybdate reagent and reducing agent added for colour development. The absorbance was measured at 660 nm wavelength on a spectrophotometer. The concentration of P in the extract was obtained by comparing the results with the standard curve.

3.5.1.4 Determination of total nitrogen

Kjeldahl (1883) digestion method was used to determine Total N. Ten grams (10 g) of distilled water was added to 10 g of soil in a Kjeldahl flask and allowed to stand for 10 minutes to moisten it. One spatula of Kjeldahl catalyst (1part selenium + 10 parts $CuSO_4$ + 100 parts Na_2SO_4) and 20 ml conc. H_2SO_4 was then added to the mixture. The solution was then digested until it was clear and colourless. The flask was allowed to cool and the solution transferred into a 100 ml volumetric flask and make up to the mark with distilled water. Twenty millilitres (20 ml) of 40 % NaOH was then added and distil over 10 ml of 4 % Boric acid and three drops of indicator for 4 minutes. This changed the solution to light blue colour. The distillate was then titrated with 0.1 N HCl until the light blue colour changed to grey and then back to pink. Weight of soil sample used, considering the dilution and the aliquot taken for distillation was expressed as:

$$1g = \frac{10\mathrm{g} \times 10\mathrm{ml}}{100\mathrm{ml}}$$

The percentage N content of the soil was calculated using the relation:

$$N = \frac{14 \times (\mathrm{A} - \mathrm{B}) \times \mathrm{N} \times 100}{1000 \times 1}$$

Where: A = volume of standard HCl used in the sample titration

B = volume of standard HCl used in the blank titration

N = Normality of standard HCl

3.5.1.5 Indophenol blue method

A sample volume of 25ml was transferred into a 50-ml Erlenmeyer flask, then 1ml phenol solution, 1ml sodium nitroprusside solution and 2.5 ml oxidising solution was added with thorough mixing after each addition. The sample was covered with plastic wrap or parafilm and kept in the dark at room temperature (22 to 25 ^{o}C) for at least 1 hour. The absorbance was measured at 640 nm. Six standards were used to prepare the calibration graph. The blank was treated like the standards. The result was expressed in NH_4 mg /L.

3.5.1.6 Exchangeable Cations

The exchangeable metallic cations which are those cations on colloid surfaces that are replaceable by other cations from the soil solution were measured as described by Moss (1961). Hundred millilitres of 1.0N NH_4OAc solution was added to 10 g of soil in an extraction bottle. The mixture was then placed on a mechanical shaker for an hour. It was then filtered with No.42 Whatman filter paper and the aliquots of the filtrate used to determine Calcium (Ca), Magnesium (Mg), Potassium (K) and Sodium (Na).

3.5.1.6.1 Calcium and Magnesium

Ten milliliters (10 ml) of 10 % KOH solution followed by 1ml of 30 % triethanolamine were added to a 10 ml of aliquot sample solution (as prepared above). Three drops of 10 % KCN solution and few crystals of Cal-red indicator were added and shaken vigorously for a uniform mixture. The mixture was then titrated with 0.02 N EDTA solutions to obtain change from red to blue endpoint to determine Ca. Magnesium was determined by finding the Ca + Mg value and subtracting the value of Ca from it. The Ca + Mg was determined by adding 5 ml of ammonium chloride-ammonium hydroxide buffer solution followed by 1 ml of triethanolamine in a 10 ml aliquot solution (prepared above). Three drops of 10 % KCN and a few drops of EBT indicator were added and shaken vigorously for uniform mixture. The mixture was titrated with 0.02 N EDTA solutions to obtain a change from red to blue endpoint.

3.5.1.6.2 Potassium and Sodium

Ten milliliters of the aliquot solution was used to determine for K and Na by reading from a flame photometer. The emission values were read on the flame analyzer. A standard curve was obtained by plotting the emission values against their respective concentrations. The amount of K and Na were determined using the formula below:

Y= Therefore K and Na C mol/kg =

$X=(Y/B) \div 39.1$

X= K and Na Cmol/kg

Y= flame photometer reading of the sample = BX (3.8)

B= constant value from the curve

39.1= atomic weight of K and Na

3.6 Agronomic Practices

3.6.1 Fertilizer Application

The inorganic fertilizer was applied according to treatment to each plot at two (2) weeks after planting and at the rate according to ratio of amounts for fertilizer briquetting and at two (2) briquettes per hill. The fertilizer was directly applied to the crop using side placement method and worked into the soil by using a cutlass. Urea was applied six weeks after planting using side placement method, according to the rate as specified in Table 3.1.

3.6.2 Weed control

Weed control was done three (3) times. The first weeding was done manually using a hoe, two weeks after seedling emergence. The second and third weeding were done using a hoe just before tasseling and before harvesting. This was to ensure that weeds do not compete with the maize crop for soil nutrients and water. Hand pulling of weeds was additionally done two weeks after planting and continued at two weeks interval for the rest of the period of experiment, especially to those very close to maize plants.

3.6.3 Pest and Disease control

Incidence of pests and diseases were monitored periodically by frequent visit to the experimental site to check for pests such as rodents, birds, stem borers and fall army worm (FAW). Insecticide (Rain top-M) (70 WP) at the rate of 80 g-150 g/ 16 L and Bypel 1 *Basilus thuringensis* (16000/N/mg at the rate applied (180-170 product per acre 15-20 g- per knapsack) was applied four weeks after planting using CP 15 knapsack sprayer on maize plants to control all insects apart from FAW. This is expected to keep down pest and to protect the plants from any disease attack. Fall army worm was controlled with Pirimiphos methyl and Permethrin at a rate of 30 ml per 15 litres at 3 weeks after planting and every other week, until the 7th week after planting.

3.7 Data Collection and Statistical Analysis

Data was collected on phenology, vegetative growth, yield and yield components at harvest and plant and grain nutrient content after harvest. The following records were taken.

3.7.1 Phenological data

3.7.1.1 Days to 50% Emergence

This was determined as the number of days when 50% or half of the plants within the 3 m × 3 m area from the four central rows per plot had emerged from the day of planting.

3.7.1.2 Percentage Plant Establishment

The percentage plant establishment was determined by counting the number of plants that had established within the 3 m × 3 m area from the four (4) central rows per plot (harvestable area) at twenty-one (21) days after planting and the percentage plant establishment subsequently estimated.

3.7.1.3 Days to 50% Tasseling

This was determined as the number of days when 50% of the plants within 3 m× 3 m area from the four (4) central rows per plot (harvestable area) have tasselled from the day of planting.

3.7.1.4 Days to 50 % Silking

This was measured as number of days when 50% of the plants within the 3 m× 3 m area (harvestable area) have silked from the day of planting.

3.7.1.5 Days to 50 % maturity

This was determined as the number of days when 50 % of the when plants within the 3 m× 3 m area (harvestable area) have fully matured from the day of planting.

3.7.1.6 Days to maturity

This was determined as the number of days when all plants within the harvestable areas have fully matured from the day of planting.

3.7.2 Vegetative Growth

3.7.2.1 Plant height

Plant height was measured on five (5) randomly selected tagged plants from the harvestable area from the base to the plant apical leaf using a meter rule at five (5) weeks after planting (5 WAP) and at every 2 weeks interval over the growing period and the mean recorded.

3.7.2.2 Number of leaves per plant

The total number of leaves per plant was counted separately from the five (5) randomly selected tagged plants from the harvestable area five weeks after planting (5 WAP) and at every 2 weeks interval over the growing period and the mean recorded.

3.7.2.3 Dry Matter Accumulation

Six (6) plants were randomly selected and uprooted from second and the fifth row and before and were separated into root and shoot. The fresh root and shoot weight was determined using electronic weighing scale and then oven dry at 70^{o}C to constant weight. This was done before tassel initiation stage and at three weeks after tasseling.

3.7.2.4 Leaf chlorophyll content

The leaf chlorophyll content was measured on 5 randomly selected tagged plants from the 3 m × 3 m area at five (5) weeks after planting and at two (2) weeks interval until the sixteen weeks after planting using Calibrated SPAD meter and the mean was computed.

3.7.2.5 Leaf Area

Leaf length was measured from the base of the leaf blade and before the leaf sheath and leaf width was measured at the widest part of the leaf using meter rule. Leaf area was calculated according to the following equation.

Leaf area = LL×LW×K

Where LL = Leaf Length

LW = Leaf width

K is a constant (0.75)

According to (Stewart and Dwyer, 1999)

3.7.2.6 **Internode length**

The internode length was measured on five randomly selected tagged plants in the harvestable area between the fifth and the sixth nodes using a meter stick from 7 WAP at every 2 weeks interval to 13 WAP and the mean recorded.

3.7.3 Yield and yield components

3.7.3.1 Number of plants harvested

The total number of plants from the 3 m × 3 m area from the four (4) central rows per plot was counted and the mean recorded.

3.7.3.2 Number of lodged plants

The total number of lodged plants from the harvested area was counted on the day of harvest and the mean recorded.

3.7.3.3 Number of total cobs per plot

The total number of cobs was counted from the harvestable area after harvest and the mean was recorded.

3.7.3.4 Number of filled cobs

The total number of filled cobs per plot was counted from the harvestable area after harvest and the mean was computed.

3.7.3.5 Number of seeds per cob

The total number of seeds from the five (5) randomly selected cobs from the harvestable was counted and the mean calculated.

3.7.3.6 Biomass yield weight per plant (g)

Five plants were randomly selected from the entire bundle (plants harvested from the harvestable area) and weighed using electronic weighing scale and the mean estimated.

3.7.3.7 Grain weight per plant

Five plants randomly sampled per plot was separated into cobs and stalk. The cobs were dehusk and de-grain and place in pre-weight labelled bags and weighed, using an electronic scale and the mean estimated. This was done at harvest.

3.7.3.8 Dehusk Cob weight per plot (kg)

The cob weight per plot from the harvestable after harvest and dehusk was weighed with an electric weighing scale and the mean was computed.

3.7.3.9 **Undehusked cob weight per plot**

The total number of undehusked cob per plot from the harvestable area was weighed using electronic weighing scale and the mean was estimated.

3.7.3.10 Cob length (cm)

The cob length was measured on the five (5) randomly selected cobs from the harvested area from the base to the tip of the cob using meter rule and the mean was recorded.

3.7.3.11 Cob diameter

The cob diameter was measured using the vernier calliper from the widest part of the five randomly selected cobs per plot after harvest and dehusked and the mean computed.

3.7.3.12 100-Seed weight

The 100-seed weight was determined by weighing hundred (100) seeds randomly selected from matured shelled cobs from the harvestable area using electronic weighing scale and the mean computed.

3.7.3.13 **Harvest index**

Harvest index is the ratio of grain yield to plant biomass produced. It was determined by dividing the grain yield by the total biomass yield.

HI =Grain Yield /Total Biomass Yield

3.7.3.14 Stover weight per plant (g)

Five plants were randomly selected from the entire bundle (plants harvested from the harvestable area) and weighed using electronic weighing scale and the mean estimated.

3.7.3.15 Number of diseased cobs per plot

The total number of diseased cobs was counted from harvested area after harvest and the mean was computed.

3.5 Statistical Analysis

The data collected were analyzed using the analysis of variance (ANOVA) method with the aid of R statistical software. The treatment means were separated using the Tukey's Honestly Significant Difference (HSD)

CHAPTER FOUR: RESULTS

4.1 Overview

The results of the study are presented chronologically as per the research objectives and geographical locations of Ejura and Mampong sites where the experiments were conducted. Raw data collected from both fields on the treatment effects on the maize were analysed and presented in results table as data measurements.

4.2 Background soil chemical analysis

Table 4.1 indicates the background soil conditions at Mampong and Ejura. The soil at Mampong and Ejura were moderately acidic. The organic matter of the soil at Mampong and Ejura were low. The total Nitrogen content of both soils used were low. The soils at both locations were low in Ca, Mg and potasium and exchangeable cations. Effective cation exchange capacity for both locations were low. The available P and K for both experimental sites were also low (Table 4.1).

Table 4.1: Background Soil Chemical Properties for Mampong and Ejura

Location	**Exchangeable Cations (meq/100g)**											**Available Nutrients (ppm)**	
	pH (1:1 H_2O)	Org C (%)	Total N (%)	Org Matter (%)	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	TEB	ECEC	Base Sat (%)	P	K
Mampong	5.86	1.02	0.10	1.2	0.26	0.02	0.20	0.01	0.49	0.95	55.20	8.34	0.19
Ejura	5.8	0.72	0.1	1.16	0.2	0.03	0.08	0.01	0.32	0.57	90.83	7.64	11.0

4.3 Initial Soil Physical Properties

The soil physical properties are shown in Table 4.2 for both experimental sites. The results showed that the soil at Mampong was sandy loam and that of Ejura was clayey loam. The bulk density at Ejura was higher (1.7 g/cm^3) than at Mampong (1.4 g/cm^3) density. The total porosity, volumetric moisture content and air-filled porosity for Mampong were higher than at Ejura. Total porosity was greater in loamy soils than in clayey loam soils. The infiltration rate for Mampong site was greater than at Ejura site (Table 4.2).

Table 4.2: Soil physical properties at the Experimental Sites

Variable	Mampong	Ejura
Bulk density (g/cm^3)	1.4	1.7
Volumetric moisture content (cm^3)	18.1	16.6
Total porosity (%)	65.4	35.0
Air filled porosity (%)	26.2	18.4
Clay	15	60
Silt	3	5
Sand	78	35
Degree of saturation (%)	40.8	47
Infiltration (mm)	11.1	5.5
Available water content (%)	10.7	6.8

4.4 Climatic conditions at the experimental sites

Differences in climatic factors (temperature, rainfall and relative humidity) were observed at Mampong and Ejura (Tables 4.3 and 4.4). The total monthly rainfall for Mampong was 789.2 mm and it occurred from April to August 2021 with the peak in May. The mean monthly temperature for the area ranged between 23.4 °C to 31.7 °C with the highest daily temperature of 33.8 °C occurring in April 2021. The mean monthly relative humidity ranged from 54.8 to 72.0 % with the peak occurring between June and August. At Ejura, the total monthly rainfall was 866 mm and it occurred from April to August, with the peak in August. The mean monthly temperature of the area ranged between 23.4 °C to 31.1 °C with the highest daily of 33.8 °C occurring in April. The mean monthly relative humidity ranged from 60.8 to 79.8 % with the peak occurring between June and August.

Table 4.3: Climatic Data at the Mampong and Ejura experimental Sites during the 2021 cropping season

		Mampong			
Month	***Monthly Total Rainfall (mm)***	***Relative Humidity (%)***		***Mean Temperature (^{O}C)***	
		06.00hrs	***15.00hrs***	***Min.***	***Max.***
April, 2021	148.9	67	43	24.2	33.8
May	196.9	68	55	24.2	33.4
June	129.7	73	62	23.1	31.5
July	144.2	75	60	22.9	30.1
August	169.5	77	54	22.7	29.7
Total	***789.2***				
		Ejura			
April, 2021	121.0	73	52	24.6	33.8
May	185.4	78	58	24.2	33.4
June	109.1	83	64	22.9	31.1
July	117.1	82	67	22.6	31.1
August	333.4	83	63	22.6	31.1
Total	***866***				

4.5 Phenology

4.5.1 Percentage plant establishment

Percentage plant establishment as influenced by different inorganic fertilizer briquette at the two experimental sites, Ejura and Mampong is presented in Table 4.4. There was no significant difference ($P \geq 0.05$) among treatments in both locations. However, there was a significant difference ($P \leq 0.05$) that exist between the two locations, with Mampong having a higher percent plant establishment (57.69 %) than Ejura (48.38 %). The interaction between treatment and location was not significant in percent plant establishment (Table 4.4).

Table 4.4: Effect of different inorganic fertilizers briquette application on percentage plant establishment

Treatment	Percentage plant establishment		
	Ejura	**Mampong**	**Mean**
NPK-23-10-5 (NPK 276-40-20 kg/ha)	55.00	55.75	55.38
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	47.75	56.50	52.12
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	44.75	55.75	50.25
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40 +6.2+2.5 kg/ha)	47.75	60.25	54.00
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	47.50	62.50	55.00
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	43.25	55.75	49.50
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	49.50	55.50	52.50
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	51.50	59.60	55.50
Mean	48.38	57.69	
HSD ($P \leq 0.05$)	16.15	38.52	
CV (%)	15.3	7.0	

HSD ($P \leq 0.05$)

Location 2.93 *
Treatment 9.7N
Location x Treatment 14.97NS

4.5.2 Days to 50 % tasseling

Days to 50 % tasseling as influenced by the different inorganic fertilizers briquette of the two experimental sites Ejura and Mampong is presented in (Table 4.5). The results showed no significant difference ($P \geq 0.05$) among the treatments in days to tasseling in Ejura and Mampong. There were also no significant difference between location × treatments interaction (Table 4.5).

4.5.3 Days to 50% silking

The results on days to 50 % silking as influenced by different inorganic fertilizers briquette are presented in Table 4.5. At Ejura, there were no significant differences among treatments in days to 50 % silking. At Mampong, maize that received NPK 23-10-5+ P+S+K (NPK 276-40-20 (40 + 40 + 6.2) kg/ha) briquette fertilizer were earliest to silk (64.72 days). There was no significant difference between location × treatments interaction in days to 50 % silking (Table 4.5). There were significant difference between the location.

Table 4.5: Effect of different inorganic fertilizers briquette application on days to 50 % tasseling and silking at Ejura and Mampong

Treatment	**Days to 50% tasseling**		**Mean**	**Days to 50% Silking**		**Mean**
	Ejura	**Mampong**		**Ejura**	**Mampong**	
NPK-23-10-5 (NPK 276-40-20 kg/ha)	53.25	53.50	53.38	67.75	68.50	68.12
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	53.00	54.75	53.88	68.50	68.75	68.62
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	52.75	52.75	52.75	68.50	66.75	67.62
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40 +6.2+2.5 kg/ha)	53.75	51.50	52.62	70.00	65.50	67.75
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	54 00	54.25	54.12	69.50	68.25	68.88
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	53.75	54.25	54.00	69.25	68.25	68.75
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	52.75	50.75	51.75	68.25	64.75	66.50
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	52.25	52.25	52.25	68.00	66.25	67.1
Mean	53.19	53.00		68.72	67.12	
HSD (P ≤ 0.05)	5.65	7.17		5.48	7.01	
CV (%)	4.0	5.5		3.4	4.3	

HSD (P ≤ 0.05):	Tasseling	Silking
	Location = 1.35 NS	1.33*
	Treatment = 4.28 NS	4.21NS
	Location x Treatment = 6.92NS	6.80NS

4.5.4 Days to 50 % maturity

Table 4.6 shows the number of days to 50 % maturity. The results at both locations showed no significant ($P \geq 0.05$) difference among treatments in days to 50 % maturity. However, there was significant difference between Ejura and Mampong in days to 50 % maturity. Maize planted at Ejura was the earliest to matured with location mean value (68.72 days) while maize at Mampong mature late with mean value (110.19 days). There was no significant difference among the treatments for both sites in days to 50 % maturity. There were no significant difference in location × treatments interaction effect in days to 50 % maturity (Table 4.6).

4.5.5 Days to 100 % maturity

Table 4.6 shows the effect of different inorganic fertilizers briquette on number of days to 100 % maturity. There was a highly significant difference between the locations (Ejura and Mampong) in days to 100 % maturity. There were no significant ($P \leq 0.05$) difference between treatments at both locations in days to 100 % maturity.

Table 4.6: Effect of different inorganic fertilizers briquette application on days to 50 % maturity and 100 % maturity on maize

Treatment	**Days to 50 % Maturity**		**Mean**	**Days to 100 % maturity**		**Mean**
	Ejura	**Mampong**		**Ejura**	**Mampong**	
NPK-23-10-5 (NPK 276-40-20 kg/ha)	67.75	110.50	89.12	116.00	122.00	119.00
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	68.50	109.50	89.00	116.00	122.00	119.00
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	68.50	110.75	89.62	116.00	122.00	119.00
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40+ 6.2+2.5 kg/ha)	70.00	111.00	90.50	116.00	122.00	119.00
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	69.50	110.25	89.88	116.00	122.00	119.00
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	69.25	110.75	90.00	116.00	122.00	119.00
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	68.25	108.00	88.12	116.00	122.00	119.00
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	68.00	110.75	89.38	116.00	122.00	119.00
Mean	68.72	110.19		116.00	122.00	
HSD ($P \leq 0.05$)	5.48	5.47		1.16	1.53	
CV (%)	3.4	1.9		0.43	0.46	

HSD ($P \leq 0.05$):	Days to 50 % Maturity	Days to 100 % maturity
Location	= 1.21 *	0.23 *
Treatment	= 0.72NS	3.82NS
Location x Treatment	= 1.17NS	6.17NS

4.6 Vegetative Growth

4.6.1 Plant height (cm)

The results of plant height as influenced by different inorganic fertilizer briquette at the two experimental sites (Mampong and Ejura) are presented in Table 4.7. Evidence from Table 4.7 at Mampong shows that maize that received NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha) had produced the tallest plants from 7 WAP to 9 WAP and at 13 WAP. The treatment NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha) produced the shortest plants. At Ejura, maize that received NPK 23-10-5(NPK 276-40-20 kg/ha) produced the tallest plants from 9 WAP to 11 WAP, while NPK 23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha) produced the shortest plants (Table 4.7). Generally, all amended treated plant at Mampong produced taller plant than that of Ejura for the entire growing period.

Table 4.7: Effect of different inorganic fertilizers briquette application on plant height (cm) for Ejura and Mampong from 5 WAP to 13 WAP

Treatment	Plant Height (cm)									
	5 WAP		**7 WAP**		**9 WAP**		**11 WAP**		**13 WAP**	
	E	**M**	**E**	**M**	**E**	**M**	**E**	**M**	**E**	**M**
NPK-23-10-5 (NPK 276-40-20 kg/ha)	27.32	44.70	75.7	134.80	143.80	183.80	147.10	185.00	146.70	185.10
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	21.12	44.23	67.10	139.20	120.60	196.70	141.50	188.00	151.80	190.10
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	28.19	42.85	69.50	134.90	129.30	163.60	136.50	164.70	150.80	164.80
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40 +6.2+2.5 kg/ha)	27.42	43.77	44.60	129.90	119.30	186.80	131.80	189.70	137.60	189.20
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	31.50	38.10	61.00	118.90	122.00	172.90	119.90	174.50	126.40	175.10
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	24.51	38.49	43.50	123.50	130.30	175.30	135.30	176.20	138.10	176.40
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	30.49	37.85	66.50	117.00	133.30	170.10	136.70	171.40	141.00	172.20
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	30.04	41.06	69.80	126.10	120.80	181.00	126.50	182.90	139.00	183.00
HSD ($P \leq 0.05$)	14.52	17.80	42.69	43.71	27.44	41.72	18.19	40.83	28.36	40.81
CV (%)	21.80	16.70	30.50	14.30	10.10	10.40	8.00	9.60	9.00	9.70

E- Ejura M- Mampong

4.6.2 Number of leaves per plant

Number of leaves per plant produced by the maize plants during the experimental period at Mampong and Ejura sites, presented in (Figure 4.1). The results indicate that in Mampong from 5 WAP to 13 WAP, there was no significant ($P \geq 0.05$) impact of the treatments on number of leaves per plant. However, at 9 WAP maize planted on NPK 23-10-5 (NPK 276-40-20 kg/ha) recorded the highest number of leaves as compared to the other treatment (Figure 4.1). At Ejura, the number of leaves per plant of maize across different fertilizer treatments were not significantly ($P \geq 0.05$) different from each other from 5 WAP to 11 WAP although the highest number of leaves per plant was recorded in NPK 23-10-5 (RP+P) S+K (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha) plot at 7 WAP and 11 WAP whilst other treatments recorded mixed results with NPK 23-10-5+ P + S +K (NPK 276-40-20 (40 +40+ 6.2) kg/ha) producing the highest number of leaves per plant at 13 WAP (Figure 4.1). The number of leaves produced at Ejura experimental site was few compared to the Mampong experimental site.

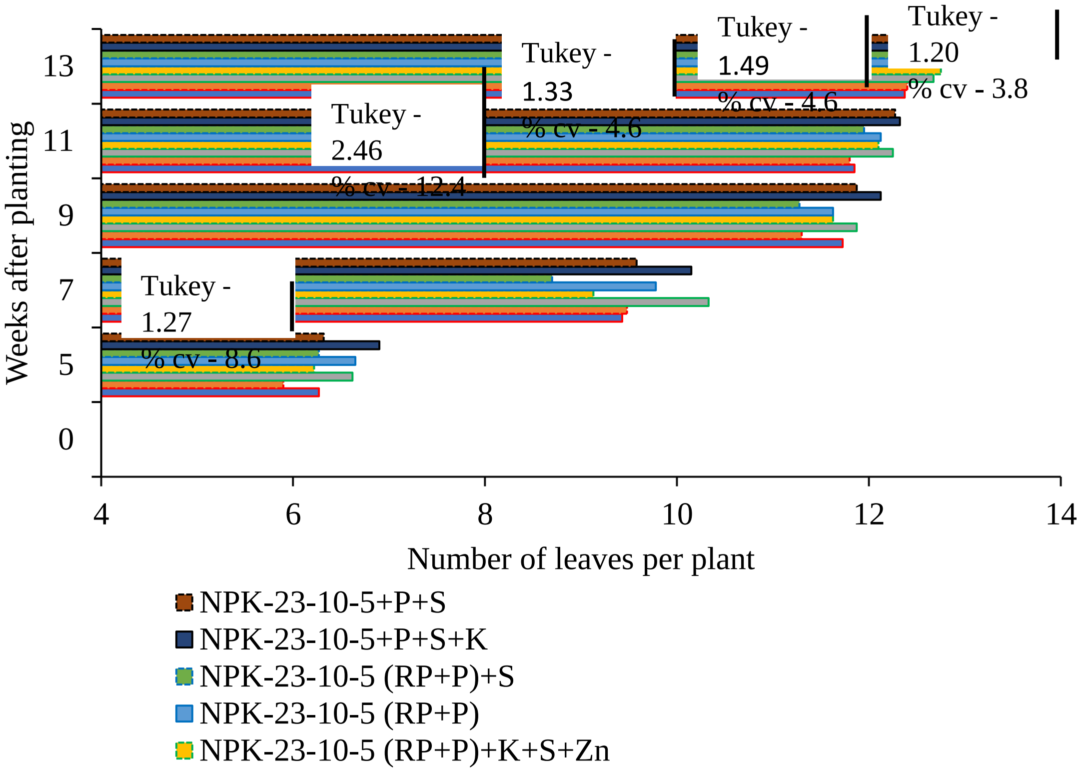

Figure 4.1: Number of leaves per plant produced by the maize plants during the experimental period at Mampong and Ejura sites

4.6.3 Stem diameter (cm)

The result in Table 4.8 indicates that, there were no significant (P>0.05) differences among the treatments from 5 WAP to 13 WAP at Mampong.

Table 4.8: Effect of different inorganic fertilizers briquette application on stem diameter (cm) for Ejura and Mampong from 5 WAP to 13 WAP

Treatment	Stem Diameter (cm)									
	5 WAP		**7 WAP**		**9 WAP**		**11 WAP**		**13 WAP**	
	E	**M**	**E**	**M**	**E**	**M**	**E**	**M**	**E**	**M**
NPK-23-10-5 (NPK 276-40-20 kg/ha)	1.52	1.99	1.66	2.05	1.72	2.22	1.79	2.24	1.63	2.45
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	1.32	2.03	1.55	2.09	1.65	2.19	1.67	2.21	1.64	2.25
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	1.57	1.90	1.69	1.94	1.77	2.06	1.84	2.36	1.98	2.44
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40) +40+ 6.2+2.5 kg/ha)	1.56	1.95	1.67	2.07	1.74	2.12	1.76	2.16	1.78	2.19
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	1.34	1.95	1.83	2.01	1.77	2.02	1.90	2.06	1.84	2.13
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	1.41	1.92	1.52	2.05	1.65	2.09	1.76	2.15	1.66	2.19
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	1.72	1.76	1.80	1.93	1.93	1.97	2.08	2.00	2.00	2.44
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	1.61	1.92	1.68	2.08	1.74	2.09	1.81	2.11	1.71	2.37
HSD ($P \leq 0.05$)	0.60	0.46	0.53	0.40	0.43	0.51	0.46	0.65	0.40	0.83
CV (%)	16.8	11.0	12.6	8.7	10.0	10.8	10.9	12.4	13.7	15.0

E: Ejura; M: Mampong

4.6.4 Chlorophyll Content for the 5th and 6th Leaf

The results on leaf chlorophyll content on the 5th leaf of maize is presented in Tables 4.9. At both locations, the 5th leaf chlorophyll content did not differ (P ≥ 0.05) significantly among treatments from 5 WAP through to 13 WAP (Table 4.10). At Mampong NPK-23-10-5 (RP) NPK 276-40-20 (40) kg/ha produced significantly higher chlorophyll content on 5th leaf and least at Ejura from 11 to 13 WAP. The result on chlorophyll content of the 6th leaf chlorophyll content is presented in Table 4.9. There was no significant difference (P ≥ 0.05) between treatments from 5 to 13 WAP in the 6th leaf chlorophyll content at both locations.

Table 4.9: Effect of different inorganic fertilizers briquette application on Chlorophyll content (µmolm^{-2}) 5th leaf for Ejura and Mampong from 5 WAP to 13 WAP

Treatment	Chlorophyll content for the fifth leaf (µmolm^{-2})									
	5 WAP		**7 WAP**		**9 WAP**		**11 WAP**		**13 WAP**	
	E	**M**	**E**	**M**	**E**	**M**	**E**	**M**	**E**	**M**
NPK-23-10-5 (NPK 276-40-20 kg/ha)	25.69	28.90	44.92	44.04	47.96	50.04	49.56	53.56	51.3	55.7
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	27.39	26.13	46.38	46.93	49.93	50.11	53.17	56.10	55.2	61.3
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	26.44	26.34	43.94	46.93	49.27	51.65	53.32	53.47	56.5	56.5
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40 6.2+2.5 kg/ha)	27.25	27.26	42.76	46.14	47.46	49.18	51.38	52.68	54.7	55.0
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	25.44	26.56	44.08	42.66	47.61	48.58	52.08	51.52	55.0	55.5
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	23.34	30.21	44.59	45.01	46.48	49.27	51.56	52.69	54.8	55.8
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	25.93	27.58	45.85	45.47	48.34	48.98	52.10	52.62	52.6	55.1
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	24.43	25.28	44.59	46.59	51.57	51.66	53.07	53.79	56.2	61.8
HSD ($P \leq 0.05$)	10.91	10.47	3.38	5.92	5.54	5.85	5.88	6.33	6.91	19.12
CV (%)	6.6	16.8	3.8	6.4	5.6	4.7	5.2	4.9	6.6	13.3

E:Ejura; M:Mampong

Table 4.10: Effect of different inorganic fertilizers briquette application on Chlorophyll content (µmolm^{-2}) 6th leaf for Ejura and Mampong from 5 WAP to 13 WAP

Treatment	Chlorophyll content for the leaf (µmolm^{-2})									
	5 WAP		**7 WAP**		**9 WAP**		**11 WAP**		**13 WAP**	
	E	**M**	**E**	**M**	**E**	**M**	**E**	**M**	**E**	**M**
NPK-23-10-5 (NPK 276-40-20 kg/ha)	22.81	25.42	42.41	44.47	48.45	46.75	51.00	49.2	53.9	53.2
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	27.71	29.09	43.74	45.79	47.45	47.73	48.68	51.43	52.8	60.1
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	21.16	31.24	42.43	46.59	45.67	48.33	48.09	50.47	51.7	54.6
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40 6.2+2.5 kg/ha)	29.02	28.33	45.07	44.04	48.84	46.03	50.18	46.86	53.6	54.0
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	24.25	27.31	40.34	45.89	45.72	48.73	49.29	51.12	50.2	55.8
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	20.57	26.69	40.56	44.08	43.96	48.31	47.19	50.20	49.1	53.3
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	25.97	21.82	39.43	46.21	47.99	48.05	50.38	49.43	54.1	56.2
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	26.08	30.27	40.77	45.86	47.41	47.54	49.59	49.73	51.5	59.8
HSD ($P \leq 0.05$)	14.28	17.29	8.70	4.52	5.24	3.92	4.34	6.87	6.63	14.91
CV (%)	6.1	7.4	8.8	4.1	5.3	3.4	3.9	5.6	5.7	10.6

E: Ejura; M: Mampong

4.6.5 Fifth (5th) Leaf length (cm^2)

The results of 5th leaf length for Mampong and Ejura sites are presented in Table 4.11 respectively. The results indicate significant variations ($P \leq 0.05$) in 5th Leaf length of maize from 5 WAP through to 13 WAP at Mampong experimental site. Maize planted with NPK 23-10-5 (RP+P) +K+S+Zn (NPK 276-40-20 (40+40+40) 6.2+2.5 kg/ha) had the longest 5th leaf length during the sampling periods at 5 WAP and from 9 WAP to 13 WAP at Mampong (Table 4.11). At Ejura, results indicate significant variations ($P \leq 0.05$) in 5th Leaf length of maize from 5 WAP through to 13 WAP.

Table 4.11: Effect of different inorganic fertilizers briquette application on 5th Leaf length for Ejura and Mampong from 5 WAP to 13 WAP

Treatment	5th Leaf length *(cm^2)*									
	5 WAP		**7 WAP**		**9 WAP**		**11 WAP**		**13 WAP**	
	E	**M**	**E**	**M**	**E**	**M**	**E**	**M**	**E**	**M**
NPK-23-10-5 (NPK 276-40-20 kg/ha)	73.29	63.10	75.78	70.75	77.11	74.74	79.74	76.58	83.57	78.00
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	69.24	68.20	73.09	70.24	74.36	72.13	78.20	73.31	80.77	75.43
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	69.23	66.50	69.42	71.41	73.79	73.04	77.14	74.49	77.83	75.94
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40 6.2+2.5 kg/ha)	66.34	68.58	69.17	70.46	69.90	75.04	75.88	75.94	78.72	79.29
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	74.50	67.00	76.03	70.68	77.86	71.14	80.47	75.15	82.03	79.23
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	70.87	62.91	73.88	71.28	77.38	73.49	80.58	74.91	81.07	78.96
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	65.64	66.71	67.88	70.43	69.78	72.17	74.39	73.25	77.68	76.60
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	66.45	63.70	68.15	69.01	72.34	72.25	74.14	75.08	74.81	79.44
HSD ($P \leq 0.05$)	11.74	8.42	10.59	8.35	9.54	7.62	7.83	7.92	8.35	9.74
CV (%)	10.7	6.6	9.7	4.5	9.4	4.2	8.3	4.2	7.4	5.2

E: Ejura: M: Mampong

4.6.6 Sixth (6th) Leaf length (cm)

The results on 6^{th} leaf length for Mampong and Ejura sites are presented in Table 4.12. There were no significant differences among the treatments for the sixth leaf length measurement over the period for Mampong site. The treatment NPK 23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha) recorded the shortest sixth leaf length from at 5 WAP to 7 WAP as compared to NPK 23-10-5 (RP+P)+K+S+Zn NPK 276-40-20 (40+40+40) 6.2+2.5 kg/ha which produced the longest leaf length (Table 4.12) at 5WAP and 11 WAP. The leaf length increased in the seventh week and the treatment NPK 23-10-5 (RP+P) +K+S (NPK 276-40-20 (40+40) +40+ 6.2 kg/ha) had the longest sixth leaf length and differ significantly higher than all the other treatments at 7WAP. The NPK 23-10-5 (RP+P) + K +S + Zn (NPK 276-40-20 (40+40) 6.2+2.5 kg/ha) amended plot produced longer sixth leaf length at 13 WAP at Mampong.

At Ejura, the treatment NPK 23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha) recorded the longest sixth leaf length at 5 WAP compared to NPK 23-10-5 (RP+P) +K+S+Zn NPK 276-40-20 (40+40+40) 6.2+2.5 kg/ha which produced the shortest leaf length (Table 4.12). At 7WAP the leaf length increased with treatment NPK 23-10-5 (NPK 276-40-20 kg/ha) had the longest sixth leaf length. The NPK 23-10-5 (RP) NPK 276-40-20 (40) kg/ha) plot produced longest leaf length on sixth leaf at 11 and 13WAP at Ejura.

Table 4.12: Effect of different inorganic fertilizers briquette application on 6th Leaf length for Ejura and Mampong from 5 WAP to 13 WAP

Treatment	6th Leaf length									
	5 WAP		**7 WAP**		**9 WAP**		**11 WAP**		**13 WAP**	
	E	**M**	**E**	**M**	**E**	**M**	**E**	**M**	**E**	**M**
NPK-23-10-5 (NPK 276-40-20 kg/ha)	67.96	66.18	75.83	70.84	77.26	74.67	79.61	77.11	83.55	80.58
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	68.14	68.88	74.01	72.38	78.29	73.92	82.17	76.73	84.64	78.40
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	65.62	65.39	70.50	73.40	73.90	74.15	75.90	75.40	77.90	82.34
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40 6.2+2.5 kg/ha)	64.03	70.96	70.02	72.02	73.30	74.72	76.90	78.71	77.95	81.52
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	66.67	68.69	74.21	71.93	78.32	75.46	79.91	77.23	81.50	82.63
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	66.74	66.47	71.89	73.22	76.57	74.38	79.75	75.48	84.06	78.20
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	68.99	63.23	72.88	70.70	76.82	73.47	77.51	77.42	80.95	80.55
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	67.92	68.28	69.06	71.25	74.52	72.99	77.80	75.73	79.59	79.04
HSD ($P \leq 0.05$)	15.29	12.50	13.71	10.81	13.22	8.36	10.09	6.88	8.70	6.68
CV (%)	8.6	7.7	8.3	5.5	7.9	4.0	6.5	3.4	6.2	3.9

E: Ejura: M: Mampong

4.6.7 Internode length (cm)

At Mampong, the treatment NPK 23-10-5 (NPK 276-40-20 kg/ha) recorded the longest internode length from 5 WAP to 13 WAP except at 9 WAP. The treatment NPK 23-10-5 (RP+P) NPK 276-40-20 (40+40) kg/ha which produced the shortest internode length from 5WAP to 11 WAP. The NPK 23-10-5 P+S (NPK 276-40-20+40+6.2 kg/ha) amended plot produced the highest internode length at 9 WAP at Mampong.

At Ejura, the treatment NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha) recorded the longest internode length whilst NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha) produced the shortest internode length at 5 WAP. Maize plant that received NPK 23-10-5 (NPK 276-40-20 kg/ha) increased in internode length at 7 WAP and from 11 WAP to 13 WAP whilst NPK 23-10-5 + (RP+P) (NPK 276-40-20 (40+40) kg/ha) produced the shortest internode length from 5 to 11 WAP.

Table 4.13: Effect of different inorganic fertilizers briquette application on internode length (cm) Ejura and Mampong from 5 WAP to 13 WAP

Treatment	Internode length (cm)									
	5 WAP		7 WAP		9 WAP		11 WAP		13 WAP	
	E	M	E	M	E	M	E	M	E	M
NPK-23-10-5 (NPK 276-40-20 kg/ha)	5.21	17.45	11.45	17.48	12.01	18.38	12.73	18.51	12.90	18.56
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	5.22	16.75	10.68	17.13	11.71	17.71	12.48	18.08	12.77	18.30
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	5.22	15.76	10.90	16.51	11.33	17.59	12.14	17.68	12.56	17.69
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40 6.2+2.5 kg/ha)	5.43	17.00	10.17	17.26	11.85	18.09	12.02	18.19	12.37	18.24
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	5.32	15.45	10.64	15.64	11.47	17.22	11.98	17.43	12.28	17.86
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	5.27	16.82	10.50	17.19	12.09	17.68	12.54	17.79	12.64	17.80
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	5.15	15.76	11.00	16.50	11.98	17.58	11.97	17.95	12.48	18.18
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	5.54	17.08	10.20	17.77	11.60	18.40	12.19	18.46	12.36	18.61
HSD ($P \leq 0.05$)	0.84	2.76	1.81	2.58	1.92	2.91	1.72	2.70	1.78	2.87
CV (%)	7.9	8.0	7.9	7.4	6.9	6.4	6.6	6.0	6.5	6.1

E: Ejura; M: Mampong

4.6.8 Shoot dry weight (g) per plot at 7 WAP and 11 WAP

The results in Table 4.14 shows the shoot dry weight measured at 7WAP and 11 WAP across the two experimental sites. There was no significant ($P \geq 0.05$) difference between treatments in shoot fresh weight at 7 weeks after planting. The maize plants planted at Mampong produced greater shoot dry weight than those planted in Ejura (Table 4.15). The shoot dry weights of both experimental sites were not significantly ($P \geq 0.05$) different for within treatments and the interaction effect of location x treatment.

The results in Table 4.14 shows the shoot dry weight measured at 11WAP across the two experimental sites. There were no significant difference between the treatments in shoot dry weight at 11 WAP for both Ejura and Mampong experimental fields. There were no significant difference between the treatments and interactive effects of location x treatment in shoot dry weight at 11 WAP. A significantly higher shoot dry weight between location occurred (Table 4.15).

Table 4.14: Effect of different inorganic fertilizers briquette application on *s*hoot dry weight (g) per plot at 7 WAP and 11 WAP.

Treatment	**Shoot dry weight (g) at 7 WAP**		Mean	**Shoot dry weight (g) at 11 WAP**		Mean
	Ejura	**Mampong**		**Ejura**	**Mampong**	
NPK-23-10-5 (NPK 276-40-20 kg/ha)	56.50	46.25	51.38	47.50	37.50	42.50
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	52.75	46.75	49.75	44.75	39.50	42.12
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	48.00	46.50	47.25	42.25	39.75	41.00
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40+ 6.2+2.5 kg/ha)	51.25	47.00	49.12	48.75	49.25	49.00
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	52.50	46.75	49.62	49.50	42.50	46.00
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	48.75	44.75	46.75	42.25	44.50	43.38
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	46.25	45.50	45.88	42.50	46.00	44.25
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	54.25	47.50	50.88	47.75	44.75	46.25
Mean	51.28	46.38		45.66	42.97	
HSD ($P \leq 0.05$)	22.02	6.74		12.95	10.86	
CV (%)	16.9	5.94		12.2	12.5	

HSD ($P \leq 0.05$):		7 WAP	11 WAP
	Location	3.39 *	2.56*
	Treatment	10.71NS	8.11NS
	Location x Treatment	17.29NS	13.10NS

4.6.9 Root fresh and dry weight (g) per plot

The root dry weight recorded for Mampong experimental site at 7 WAP was significantly higher than those at Ejura. There was highly significant difference across the two locations, however, there was no significant difference between the treatment and the location interaction effect in root dry weight (Table 4.15). The root dry weight of Mampong fields for the 11 WAP was significantly higher than that of Ejura field. There was no significant difference between treatments and interaction effect between location and treatments for root fresh weight for both experimental sites for the eleventh week after planting (Table 4.15).

Table 4.15: Effect of different inorganic fertilizers briquette application on Root dry weight (g) per plot at 7 WAP and 11 WAP

Treatment	Root dry weight (g) per plot at 7 WAP		Mean	Root dry weight (g) per plot at 11 WAP		Mean
	Ejura	Mampong		Ejura	Mampong	
NPK-23-10-5 (NPK 276-40-20 kg/ha)	56.2	161.5	108.9	63.5	154.0	108.8
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	53.8	156.0	104.9	61.0	179.2	120.1
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	58.8	143.5	101.1	79.0	149.5	114.2
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40+ 6.2+2.5 kg/ha)	47.0	138.8	92.9	86.8	175.5	131.1
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	52.2	152.5	102.4	52.0	145.5	98.8
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	47.8	158.8	103.2	65.8	162.2	114.0
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	61.0	170.5	115.8	77.8	159.5	118.6
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	58.0	161.8	109.9	65.5	145.2	105.4
Mean	54.3	155.4		68.9	158.8	
HSD value ($P \leq 0.05$)	40.41	90.88		52.16	154.76	
CV (%)	11.7	13.4		10.9	12.8	

HSD ($P \leq 0.05$):	7 WAP	11 WAP
	Location 17.60 *	25.84 *
	Treatment 55.65NS	81.68NS
	Location x Treatment 89.85NS	131.88NS

4.7 Yield and Yield Components

4.7.1 Number of plants harvested

The effect of the different treatments on number of plants harvested per plot is presented in Table 4.16 for both sites. The results showed no significant ($P \geq 0.05$) difference in the mean number of plants harvested for both Ejura and Mampong. The number of plants harvested per plot was significantly higher at Mampong site compared to Ejura. There was no significant difference between treatments in number of plants harvested per plot in Ejura and Mampong sites as well as the effect between location × treatments interaction (Table 4.16).

4.7.2 Number of lodged per plot

The number of plants lodged per plot under the different fertilizers at Ejura and Mampong is presented in Table 4.16. There were no significant difference ($P \geq 0.05$) among treatments and the interactive effect between location × treatments (Table 4.16). However, location had a significant effect ($P \leq 0.05$) on the mean value of number of lodged plants per plot at Ejura and Mampong experimental sites (Table 4.16).

Table 4.16: Effect of different inorganic fertilizers briquette application on number of plants harvested and number of lodged plants per plot of maize

Treatment	**Number of plants harvested per plot**		**Mean**	**Number of lodged plants per plot**		**Mean**
	Ejura	**Mampong**		**Ejura**	**Mampong**	
NPK-23-10-5 (NPK 276-40-20 kg/ha)	52.75	55.25	54.00	10.00	5.00	7.50
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	46.00	56.75	51.38	9.50	4.75	7.12
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	43.50	56.50	50.00	10.75	5.25	8.00
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40+ 6.2+2.5 kg/ha)	44.75	60.00	52.38	11.25	3.75	7.50
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	46.00	60.75	53.38	12.75	4.25	8.50
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	42.50	55.25	48.88	10.50	6.50	8.50
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	49.25	53.00	51.12	11.25	5.75	8.50
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	49.75	58.75	54.25	11.75	3.25	7.50
Mean	46.81	57.03		10.97	4.81	
HSD ($P \leq 0.05$)	19.68	9.84		4.48	4.30	
CV (%)	8.3	7.9		9.5	7.8	

HSD ($P \leq 0.05$):		
	Location 3.56 *	0.96 *
	Treatment 11.27NS	3.05NS
	Location x Treatment 18.19NS	4.93NS

4.7.3 Number cobs per plot

The results of number of cobs per plot for the Ejura and Mampong experimental sites are presented in Table 4.17. The result in Ejura indicated that, the number of cobs per plot were significantly higher ($P \leq 0.05$) in the NPK-23-10-5 (NPK 276-40-20 kg/ha) whilst NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha) recorded the least number of plants per plot harvested. At Mampong, NPK-23-10-5+P+S recorded the highest number of cobs per plot whilst NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha) had the least number of cobs per pot. The Mampong experimental site maize plant produced significantly higher ($P \leq 0.05$) cobs per plot than the Ejura site in terms of location. There were no significant difference ($P \geq 0.05$) between the interactive effect of location x treatment in number of cobs per plot in both experimental sites (Table 4.17).

4.7.4 Dehusked cob weight per plot

Table 4.17 shows dehusked cob weight per plot for Ejura and Mampong experimental sites as influenced by different inorganic fertilizer briquette. The result in Ejura indicated that, maize plants that received NPK-23-10-5+ P+S (NPK 276-40-20 40+6.2 kg/ha) produced higher dehusked cobs weight per plot whilst NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha) recorded the least dehusked cob weight per plot. At Mampong, NPK-23-10-5+(RP+P) +K+S+Zn (NPK 276-40-20 (40+40+40) 6.2+2.5 kg/ha) recorded the highest dehusked cob weight whilst NPK-23-10-5 (RP+P) +K +S (NPK 276-40-20 (40+40) +40+ 6.2 kg/ha) had the least dehusked cob weight per plot. There were no significant difference between the interactive effect of location x treatment in dehusked cob weight per plot in both experimental sites (Table 4.17).

Table 4.17: Effect of different inorganic fertilizers briquette application on Number cobs per plot and Dehusk cob weight cobs per plot of maize

Treatment	Number cobs per plot		Mean	Dehusked cob weight per plot (kg)		Mean
	Ejura	Mampong		Ejura	Mampong	
NPK-23-10-5 (NPK 276-40-20 kg/ha)	51.25	56.25	53.75	3.72	8.88	4.50
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	45.25	55.00	50.12	2.62	8.70	5.00
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	44.25	58.50	51.38	3.92	7.35	3.50
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40+ 6.2+2.5 kg/ha)	45.00	64.00	54.50	3.35	9.57	5.25
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	47.25	61.25	54.25	2.92	8.67	2.50
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	43.50	57.75	50.62	2.85	8.47	4.25
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	47.75	57.75	52.75	3.77	7.73	4.25
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	50.50	67.25	58.88	4.00	9.03	4.25
Mean	46.84	59.72		3.40	8.55	
HSD ($P \leq 0.05$)	19.47	12.76		3.72	2.67	
CV (%)	17.7	11.9		41.6	18.2	

HSD ($P \leq 0.05$):	Number cobs per plot	Dehusked cob weight per plot (kg)
Location	3.99 *	0.76*
Treatment	12.63NS	2.42NS
Location x Treatment	20.39NS	3.92NS

4.7.5 Undehusked cob weight per plot

Table 4.18 shows the undehusked cob weight per plot for Ejura and Mampong experimental sites as influenced by different inorganic fertilizer briquette. At Ejura NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha) had the highest undehusked cob weight per plot whilst the least was NPK-23-10-5 (RP+P) +S (NPK 276-40-20 (40 +40 +6.2 kg/ha). At Mampong NPK-23-10-5 (NPK 276-40-20 kg/ha) had the highest undehusked cob weight per plot whilst the least were NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha). The undehusked cob weight per plot for Mampong site was significantly higher ($P \leq 0.05$) than that of Ejura (Table 4.18). There were however, no significant differences ($P \geqq 0.05$) between other treatments and location × interaction in undehusked cob weight per plot. There were also, significant differences ($P \leq 0.05$) between locations.

4.7.6 Number of diseased cobs per plot

Table 4.18 shows number of diseased cobs per plot as influenced by different inorganic fertilizer briquette at Ejura and Mampong. At Ejura NPK-23-10-5(RP+P) +K+S+Zn (NPK 276-40-20 (40+40+40) 6.2+2.5 kg/ha) had the greatest number of disease cobs whilst the least were NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha). At Mampong NPK-23-10-5 (RP+P) +K+S (NPK 276-40-20 (40+40) +40+ 6.2 kg/ha) and NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha) the greatest number of disease cobs whilst the least were found NPK-23-10-5+P+S+K (NPK 276-40-20 (40+40+6.2) kg/ha). There were also, significant differences ($P \leq 0.05$) between locations. There were however, no significant differences ($P \geq 0.05$) between the interactive effects between location × treatments in number of disease cobs.

Table 4.18: Effect of different inorganic fertilizers briquette application on undehusked cob weight per plot and number of diseased cobs per plot (kg) per plot of maize

Treatment	Undehusked cob weight per plot (kg)		Mean	Number of diseased cobs		Mean
	Ejura	Mampong		Mampong	Ejura	
NPK-23-10-5 (NPK 276-40-20 kg/ha)	4.38	11.65	8.01	4.75	4.50	8.01
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	3.50	11.45	7.47	5.00	5.00	7.47
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	4.58	9.47	7.02	5.25	3.50	7.02
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40+ 6.2+2.5 kg/ha)	3.88	11.45	7.66	4.25	5.25	7.66
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	3.62	10.70	7.16	5.00	2.50	7.16
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	3.30	10.30	6.80	4.50	4.25	6.80
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	4.93	9.45	7.19	3.75	4.25	7.19
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	4.62	11.27	7.95	5.25	4.25	7.95
Mean	4.10	10.72		4.72	4.19	
HSD (P ≤ 0.05)	3.97	2.79		4.68	4.67	
CV (%)	16.5	16.1		19.2	16.7	

HSD (P ≤ 0.05)	Undehusked cob weight per plot (kg)	Number of diseased cobs
Location	0.80 *	0.96 *
Treatment	2.53NS	3.05NS
Location x Treatment	4.09S	4.93NS

4.7.7 Cob length

The results of cob length at Ejura and Mampong are presented in Table 4.19. There was no significant ($P \geq 0.05$) difference between treatments at both locations in cob length. The cob length measured for the Mampong location were significantly longer than the cob lengths for Ejura. There were no significant differences between treatments and the interactive effect between location x treatment for both experimental sites (Table 4.19).

4.7.8 Cob diameter

Table 4.20 shows cob diameter as influenced by different inorganic fertilizer briquette at Ejura and Mampong. The cob diameter did not vary significantly ($P \geq 0.05$) among the fertilizer treatments at Ejura and Mampong. The cob diameter at Mampong experimental site were not significantly different ($P \geq 0.05$) than the cob diameter for Ejura. There were no significant differences between the location, treatment and location x treatment interaction effect for both experimental sites in cob diameter (Table 4.19).

Table 4.19: Effect of different inorganic fertilizers briquette application on cob length and cob diameter of maize

Treatment	Cob length (cm)		Mean	Cob diameter (cm)		Mean
	Ejura	Mampong		Ejura	Mampong	
NPK-23-10-5 (NPK 276-40-20 kg/ha)	12.97	16.05	14.51	3.97	4.65	4.31
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	13.85	17.11	15.48	6.92	4.69	5.80
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	14.26	17.39	15.83	4.02	4.58	4.30
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40+ 6.2+2.5 kg/ha)	13.74	16.54	15.14	3.91	4.63	4.27
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	12.93	15.93	14.43	3.72	4.65	4.19
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	13.08	16.19	14.64	4.04	4.60	4.32
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	14.68	15.96	15.32	4.31	4.55	4.43
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	14.86	17.17	16.01	4.08	4.50	4.29
Mean	13.79	16.54		4.37	4.60	
HSD ($P \leq 0.05$)	4.00	2.68		5.07	0.30	
CV (%)	11.4	7.7		48.5	2.8	
HSD ($P \leq 0.05$):	**Location** 0.71 *			0.75NS		
	Treatment 2.26NS			2.40NS		
	Location x Treatment 3.65NS			3.87NS		

4.7.9 Number of filled cobs

Table 4.20 presents the results on number of filled cobs per plot for the two experimental sites. There was a significant difference ($P \leq 0.05$) between both the two locations. However, there was no significant difference ($P \geq 0.05$) between location x treatments interaction for both sites (Table 4.20).

4.7.10 Total grains weight (kg)

Table 4.20 shows the total grain weight per plot as influenced by different inorganic fertilizer briquette at Ejura and Mampong. The total grain weight per plot for Mampong experimental site was significantly higher ($P \leq 0.05$) than the total grain weight per plot for Ejura experimental site. There were significant differences between the location, however no significant difference occurred with no interactive effect of location x treatments in grain weight per plot (Table 4.20).

Table 4.20: Effect of different inorganic fertilizers briquette application on number of filled cobs per plot and total grains weight (kg) of maize

Treatment	Number of filled cobs per plot		Mean	Total grain weight (kg)		Mean
	Ejura	Mampong		Ejura	Mampong	
NPK-23-10-5 (NPK 276-40-20 kg/ha)	51.25	56.25	53.75	2.37	4.17	3.27
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	45.25	55.00	50.12	2.12	4.47	3.30
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	44.25	58.50	51.38	2.12	3.67	2.90
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40+6.2+2.5 kg/ha)	45.00	64.00	54.50	2.05	3.62	2.84
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	47.25	61.25	54.25	2.42	3.88	3.15
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	43.50	57.75	50.62	1.87	3.67	2.77
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	47.75	57.75	52.75	2.67	3.82	3.25
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	50.50	67.25	58.88	2.52	4.62	3.57
Mean	46.84	59.72		2.27	3.99	
HSD (P ≤ 0.05)	19.47	12.76		2.01	2.11	
CV (%)	17.7	11.9		15.6	13.6	

HSD (P ≤ 0.05)

Location 3.99 * 0.44 *
Treatment 12.63NS 1.40SN
Location x Treatment 20.39NS 2.26NS

4.7.11 100-seed weight (g)

Table 4.21 shows 100-seed weight as influenced by different inorganic fertilizer briquette at Ejura and Mampong. There was no significant difference between treatments in one hundred seed weight for the two experimental sites. There was significant difference between location. Mampong experimental site produced significantly ($P \leq 0.05$) higher mean of hundred seed weight while Ejura produced significantly least mean of the hundred seed weight (Table 4.21). There was no significant ($P \geq 0.05$) difference in interactive effect between location x treatment in hundred seed weight (Table 4.21).

4.7.12 Yield (t/ha)

Table 4.21 present results on yield of maize in per hectare as influenced by different inorganic fertilizer treatment at Ejura and Mampong experimental sites. Ejura NPK-23-10-5 +P+S+K (NPK 276-40-20 (40+40+6.2) kg/ha) had the highest (3.61) yield per hectare whilst NPK-23-10-5 (RP+P) +S (NPK 276-40-20 (40 +40 +6.2 kg/ha) recorded the least (3.08). At Mampong NPK-23-10-5 +P+S had the highest number (3.97) of filled cobs per plot whilst NPK-23-10-5 (RP+P) +K+S+Zn (NPK 276-40-20 (40+40) + 40 + 6.2+2.5 kg/ha) recorded the least (3.15). There was a significant difference ($P \leq 0.05$) in yield per hectare between the two locations. However,there was no significant difference ($P \geq 0.05$) between treatment, location x treatments interaction for both sites (Table 4.21).

Table 4.21: Effect of different inorganic fertilizers briquette application on hundred seed weight (g) and yield (t/ha) of maize

Treatment	**100-seed weight (g)**		**Mean**	**Yield (t/ha)**		**Mean**
	Ejura	**Mampong**		**Ejura**	**Mampong**	
NPK-23-10-5 (NPK 276-40-20 kg/ha)	25.50	28.75	27.12	2.64	4.64	3.64
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	25.25	29.25	27.25	2.36	4.97	3.67
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	25.00	29.00	27.00	2.36	4.08	3.22
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40+40) 6.2+2.5 kg/ha)	23.75	26.75	25.25	2.28	4.03	3.15
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	23.00	29.25	26.12	2.69	4.31	3.50
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	24.50	30.00	27.25	2.08	4.08	3.08
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	28.00	28.50	28.25	2.97	4.25	3.61
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	26.25	28.75	27.50	2.81	5.14	3.97
Mean	25.16	28.78		2.52	4.44	
HSD (P ≤ 0.05)	9.18	5.60		2.23	2.35	
CV (%)	14.1	8.0		35.6	23.6	

HSD (P ≤ 0.05):	**Location** 1.60 *	0.49 *
	Treatment 5.08NS	1.56NS
	Location x Treatment 8.21NS	2.52NS

4.7.13 Harvest index

Table 4.22 shows the harvest index as influenced by different inorganic fertilizer briquette at Ejura and Mampong. The harvest index recorded for the two experimental sites were not significantly different in terms of treatments. Although the NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha) and NPK-23-10-5 (RP+P) +K+S (NPK 276-40-20 (40+40) +40+ 6.2 kg/ha) recorded the highest harvest index of 0.29 for Ejura whilst NPK-23-10-5 (NPK 276-40-20 kg/ha) recorded the least. There was significant difference ($P \leq 0.05$) in harvest index between the two locations. There was no significant difference between location x treatments interaction for both sites (Table 4.22)

4.7.14 Total Stover weight per plot at harvest

Table 4.22 shows total Stover weight per plot at harvest for Ejura and Mampong sites after the different fertilizer briquettes were applied. The total Stover weight per plot recorded for the two experimental sites were not significantly different among the treatment for both sites, although the NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha) recorded the highest total stover weight per plot whilst NPK-23-10-5 (RP+P) +S (NPK 276-40-20 (40 +40 +6.2 kg/ha) recorded the least for Ejura. At Mampong site, NPK 23-10-5 (RP+P) + K+S+Zn (NPK 276-40-20 (40+40) +40+ 6.2+2.5 kg/ha) had the highest total stover weight per plot whilst NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha) recorded the least total Stover weight per plot. There were significant difference ($P \leq 0.05$) in harvest index between the two locations. However, there was no significant difference ($P \geq 0.05$) between location x treatments interaction for both sites (Table 4.22).

Table 4.22: Effect of different inorganic fertilizers briquette application on harvest index and total Stover weight per plot at harvest

Treatment	**Harvest index**		Mean	**Total Stover weight per plot at harvest (kg)**		Mean
	Ejura	Mampong		Ejura	Mampong	
NPK-23-10-5 (NPK 276-40-20 kg/ha)	0.21	0.18	0.25	2.87	12.05	7.46
NPK-23-10-5 (RP) (NPK 276-40-20 (40) kg/ha)	0.29	0.25	0.27	2.37	12.62	7.50
NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha)	0.29	0.24	0.27	3.20	9.62	6.41
NPK-23-10-5(RP+P)+K+S+Zn (NPK 276-40-20 (40+40)+40+ 6.2+2.5 kg/ha)	0.22	0.22	0.22	2.87	12.92	7.90
NPK-23-10-5 (RP+P) (NPK 276-40-20 (40+40) kg/ha)	0.27	0.24	0.25	2.12	11.22	6.67
NPK-23-10-5 (RP+P)+S (NPK 276-40-20 (40 +40 +6.2 kg/ha)	0.25	0.25	0.19	2.10	12.00	7.05
NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha)	0.24	0.21	0.22	3.27	8.97	6.12
NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha)	0.22	0.20	0.23	3.05	9.35	6.20
Mean	0.22	0.21		2.73	11.10	
HSD (P ≤ 0.05)	0.11	0.12		2.70	4.65	
CV (%)	20.1	12.5		11.0	18.4	
HSD (P ≤ 0.05):	**Location** 0.02*			1.43 *		
	Treatment 0.40NS			4.53NS		
	Location x Treatment 0.120NS			7.32 NS		

CHAPTER FIVE: DISCUSSION

5.1 Phenology of maize as influenced by NPK briquettes fertilizer blended with RP, S and Zn at Mampong and Ejura

The non-significant difference between treatments in percentage plant establishment could be that the treatment had no effect on maize during its establishment. The Mampong site had a significantly higher percentage plant establishment compared to Ejura. This may be attributed to the high rainfall recorded at Mampong during the early growth period, and also a moderately high soil organic matter. This is an indication that at Mampong experimental site, there were conducive environmental factors such as soil pH, temperature and soil moisture required for nutrients availability for plant growth, development and early establishment. The number of seeds that emerged had a significant effect on plant establishment.

The days to 50% tasseling was not significantly influenced by the treatments in both locations of the experiment. This implies that, the impact of the inorganic (NPK) fertilizer briquettes did not improve soil fertility at both experimental fields. Generally, days to 50% tasseling is a key parameter relevant to maize plant because exponential plant growth stage towards grain production, plants need much nutrient for growth and grain production (Echarte and Tollenaar, 2006). The non- significance observed might be due to inadequate nutrients which would results in delayed tasseling in response to the interaction effect of the minimum amount of blended fertilizer which was provided to give a balanced micro and macronutrients. This would have aided in enhancing the assimilation process in the seedling growth stage which in turn would have enhanced the overall growth and extended through the vegetative stage at tasseling (Molla *et al.*, 2019). Results are in line with Chandrakar *et al*. (2023) who discovered that raising fertilizer rates had no significant effect on the number of days for maize to 50% tassel. Chimdessa (2016) also reported similar results where the application of blended NPK fertilizers significantly did not affect days to tasseling.

The number of days to 50% silking was not affected by the treatments in both locations. Generally, plants treated with NPK-23-10-5 (NPK 276-40-20 kg/ha) was earliest to silk at Ejura and significantly differed from NPK-23-10-5+P+S+K (NPK 276-40-20 (40 +40+ 6.2 kg/ha) in Mampong which also performed better. The days to 50% Silking followed a similar trend to that of tasseling, with location by interactive effect having a key role in the non-significance effect on the days to 50% silking. It was recognized that NPK blended fertilizers with varying concentrations of P, S and K may have accelerated plant growth and development, reducing the time until silking. Ashenafi *et al.* (2023) also observed that the use of blended fertilizers greatly impacted the days of silking. Tekulu *et al.* (2019) found that 50% of silking is significantly influenced by the use of mixed fertilizer rates. The outcomes are consistent with those of Makinde and Ayoola (2009); Uwah *et al.,* (2014) who noticed that maize's 50% silking days were shorter when fertilizer rates were higher. In contrast to the results of this experiment, results from several studies confirmed that NPK blended fertilizer with varying amounts of N, P, S, Zn, and K had no discernible impact on the silking of the maize crop (Tekulu *et al.,* 2019).

5.2 Vegetative growth of maize as influenced by NPK briquettes fertilizer blended with RP, S and Zn at Mampong and Ejura

The differences in plant height between the two locations could be attributed to several factors including; genetic characteristics variability, management practices, soil type, environment and climate. Similar results were observed by Knaofmone *et al.* (2021) where they reported sorghum plants reacting differently due to environment, climate and genetic characteristics of variety. The treatment NPK-23-10-5 (RP+P) +K+S+Zn (NPK 276-40-20 (40+40+40) 6.2+2.5 kg/ha) producing the tallest plants in Mampong from 11 to 13 WAP. This was contrary to what transpired in Ejura as the shortest plants was produced by the NPK- 23-10-5 (RP+P) (NPK 276-40-20 (40+40 kg/ha) treatment. This could be attributed to the fact that the performance of NPK fertilizer briquettes in combination with other primary fertilizers notably soil moisture, made nutrient absorption difficult for plant roots which might have resulted in decreased nutrient availability, especially nitrogen (N). The taller growth performance in maize given briquette combined with potassium and rock phosphate could be attributed to the synergy that is generated in nutrient uptake.

Findings of taller plant height as influenced by fertilizer with macronutrient were also reported by Kapoor *et al. (*2018), Cantliffe *et al.* (2019) and Nkebiwe *et al.* (2016). However, results indicated that different inorganic fertilizer briquettes had no significant ($P \geq 0.05$) effect on number of leaves per plant at weeks 5, 7 and 13 weeks after planting at both locations but also not significant in Ejura at 7 and 11 after planting. This could be attributed to the performance of NPK fertilizer briquettes. Variations in the soil moisture levels made nutrient absorption difficult for plant roots which might have resulted in decreased nutrient availability, especially nitrogen (N) to improve plant growth and therefore caused leaves formation to be delayed. According to Abu *et al.* (2021), nitrogen is the primary nutrient that most often controls output, as it determines the quantity of leaves produced by the plant. The application of NPK-23-10-5 (NPK 276-40-20 kg/ha) only can increase stem diameter as compared to plants treated with NPK-23-10-5 (NPK 276-40-20 kg/ha), this could be as a result of the varying rates of NPK and heavy rainfalls in the middle belt of Ghana which cause leaching of the available nutrients to plants in Ejura. Ali *et al.* (2006) suggested that increasing nitrogen fertilization accelerates growth of the roots, above ground parts and bulk up the maize plants. Chlorophyll is a very important component of plant growth; serving as a precursor of photosynthesis and the formation of carbohydrate in plants. The record of the vital pigment was relevant as several minerals play vital roles in its formation.

From the results, it is observed that chlorophyll content was not affected by the treatments among all the treatments on both 5th and 6th leaf in both locations. On the 5th leaf chlorophyll content gave a general increase trend from the 5th week to 13th week with much chlorophyll almost doubled between 5th and 7th week. This finding is in corroboration with that of Wang *et al.* (2020) who reported an increasing trend and then decreasing in chlorophyll content towards maturity of dry land maize when treated with selenium fertilizer. The reason behind the treated plants producing much of chlorophyll in 5th and 7th week could be attributed higher photosynthetic activity within the 5th and 7th weeks which resulted in higher chlorophyll content. Generally, chlorophyll content was higher in Mampong than in Ejura on both 5th and 6th leaves sampled. The chlorophyll content of some plants treated with the different NKP-23-10-5 (NPK 276-40-20 kg/ha) mixed different varying levels of formulations was higher than that of the NPK-23-10-5 (NPK 276-40-20 kg/ha) treatment only in Ejura. This is due to the fact that

NPK-23-10-5 (NPK 276-40-20 kg/ha), increases the availability of soil macronutrients, which are digested by plants and used for different metabolic processes to synthesis chlorophyll, which is essential for appropriate plant growth and development (Kombat, 2015). The treatment fertilizer formulations.

The NPK-23-10-5+P+S (NPK 276-40-20 40+6.2 kg/ha) had the maximum chlorophyll content on the fifth leaf in Mampong, but the second-lowest on the fifth leaf in Ejura. In general, N supply and availability are critical for the production of proteins, enzymes, and chlorophyll, whereas P and K play roles in robust root system growth and N absorption, respectively.

There was no indication of the treatments significantly impacting on both leaf length and width though numerically, distinctions occurred on the various leaf lengths and widths of the sampled leaves from both locations. There was a general increasing trend from the 5th to 13th week that ran through the sampled leaves for both length and width in both Mampong and Ejura. Averagely, the treatments with rock phosphate and phosphorous added to fertilizers in Mampong performed best in the 6th leaf length. This could have resulted from the soil that has a high concentration of nitrogen (Sumi and Katayama, 2000). There is a strong correlation between light interception by the leaf length, canopy and dry matter productivity, where leaf length and width contribute more than 80% to the dry matter productivity of a crop (Bonhomme, 2000). Due to the importance of adequate N levels in leaf growth, negative N deficits in maize fields result in low yields. The deficiency of phosphorus is a common factor limiting yield and crop growth in unfertilized soils (Ibrikci *et al.,* 2005). In terms of nutrient P, Rehman *et al.* (2011)

discovered observations on the growth dynamics of maize leaves. Plants treated with NPK only had less leaves in both site of the trials.

Amanullah (2009) noted that P is one of the most critical elements influencing maize crop development and production. According to Alias *et al.* (2003) increasing the quantity of phosphorus dramatically enhanced leaf number and the leaf parameters. Shoot biomass was not influenced by the treatments applied in both locations for both shoot fresh and dry weights. Despite the non-significance in both fresh and dry weights of the shoots, there were improvement in the application of the treatments with massive increase in weight with the treatment NPK-23-10-5 (RP+P)+K+S (NPK 276-40-20 (40+40)+40+ 6.2 kg/ha) at 7 WAP for both Mampong and Ejura. The NPK with the other nutrient added to fertilizer promotes rapid growth of maize plants at the right time as well as the right quantity. This may lead to be an increase in leaf area, which improved photosynthesis, and increased dry shoot. It is evident that the results revealed longer and broader leaves which correlate to the amount of sunlight received by the leaves for photosynthesis. The shoot biomass weight reported here revealed that the combination NPK-23-10-5 (NPK 276-40-20 kg/ha) and added nutrient had a good benefit, notably in Mampong. The major function of photosynthesis is to provide the carbohydrates required for crop growth and biomass output (Hossain *et al*. 2012). The enhanced photosynthetic rate, which may have led in high biomass production were lacking in the soil. When the N rate increased and spurred more growth, the increases in shoot dry matter yield became more positive. The non- significant ($P \leq 0.05$) difference between treatment in shoot and dry weight as well as root and dry weight for both experimental sites is an indication that the treatment were similar and had no effect on shoot and root fresh and dry weight.

5.3 Yield and yield components of maize as influenced by NPK briquettes fertilizer blended with RP, S and Zn at Mampong and Ejura

The results showed that number of plants harvested per plot and number of lodged plants per plot in both locations were not influenced by the treatments. This might be due to differences in rainfall experienced and nutrient content of soil. The mean values of number of plants lodged as influenced by the different inorganic fertilizer treatment under the two experimental sites indicate no significant difference between treatment and interaction effects. This is an indication that the treatment was similar and had no effect on number of plants lodged. Relative to the combined NPK-23-10-5 (NPK 276-40-20 kg/ha) fertilizer application with the other nutrient such as rock phosphate and sulphur enhanced 100-seed weight, total grain yield and that of biomass yield per plot were not influenced by the treatments at Mampong and Ejura. Generally, plants in Mampong produced heavier 100-seeds weight as compared to the counterparts in Ejura. Increased in 100-seed weight with among the NPK-23-10-5 (NPK 276-40-20 kg/ha) application might be attributed to larger leaf area intercepting more light and producing more carbohydrates in the source, which was translocate into the sink (the grain) and resulting in more increased seed weight in Mampong than in Ejura. This is consistent with the findings of Kombat (2015), testified that 100-seeds weight was higher in NPK fertilizer blended with other nutrient than NPK fertilizers applied alone. In Mampong the application of the Zn did not have an effect on biomass but the situation in Ejura gave different performance with the treatment NPK-23-10-5 (RP+P)+K+S+Zn (NPK 276-40-20 (40+40+40) 6.2+2.5 kg/ha) produced the highest biomass yield weight. This finding is in line with that of Wainaina (2023) who reported non-significance yield of biomass of maize when Zn were applied but however, Kaur and Nelson (2014) reported that significance impact of Zn on the yield of maize biomass.

There was no instance the application of Zn significantly impacted total grain yields at either location although there were numerical differences in grain yield among the treatments. There was a noticeable pattern of response, with the lowest mean grain yields being recorded for the plants treated in Ejura. In Mampong, the treatment NPK-23-10-5 P+S (NPK 276-40-20 40+6.2 kg/ha) produced the highest grain yield; however, it was only able to produce the second-best grain yield in Ejura, behind the treatment NPK-23-10-5 P+S+K (NPK 276-40-20 (40 +40+ 6.2) kg/ha) that achieved the highest grain yield. The non-significant difference in yield could be attributed to unforeseen environmental factors such as low rainfall that interfered with the absorption and proper utilization of the applied micronutrients in the soil. This is in line with Kapoor *et al.* (2018) who reported that rainfall enhances the utilization of other primary and secondary nutrients and also involves in various physiological processes such as synthesis of protein and carbohydrates (Daphade *et al.*, 2019) and this is likely to influence fruiting. There were significant difference between treatment in the number of cobs, un-dehusked, cob weight, and dehusked cob weight. This could be due to application of the other primary nutrients in addition to NPK significantly influenced the number of cobs, dehusked cob weight. This finding is in contrary to those of Tahir and Yasin (2016) where micronutrient (Zn) application on maize plants did not have effect on the number of cobs produced per plant. The treatment NPK-23-10-5 P+S (NPK 276-40-20 40+6.2 kg/ha) produced the highest number of cobs per plot, number of diseased cobs per plot and dehusked cob weight per plot in Mampong. The minerals (Urea, Tsp, Mop) with composition 23-10-5 have more nitrogen which increases the chloroplast formation and leaf photosynthetic efficiency which may transform into formation of husks in maize (Uddin *et al.,* 2023). This has been reported in Liu (2020). At Ejura least number of cobs, un-dehusked cob weight and dehusked cob weight was recorded.

This indicates Zn had no effect on the cobs produced per plot in Ejura. Cob length is the most decisive yield factor. The difference in cob length, cod diameter and number of filled cobs per plot among the location was in disagreement with Hussein *et al.* (2011) that mutual use of Zn significantly enhanced seeds/cob and weight of maize seed. NPK-23-10-5 combined with micronutrient treatment enhanced maize cob length due to the combined action of micronutrient in appropriate quantity and administered at proper time and technique.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The findings of this study showed that NPK -23-10-5 combine with macro and micro nutrient did not show significant difference in the growth parameters and yield components, although numerically differences occurred among the various treatments in both locations studied.

In terms of locations Mampong outperformed Ejura in phenology vegetative growth and yield Components.

6.2 Recommendations and further research

From the results the following recommendations further research were made:

1. Based on the results the different inorganic NPK fertilizer briquettes especially NPK 23-10-5+P+K and NPK 23-10-5 +P+S are recommended under condition as it has the potential to supply much needed total grain weight .
2. Farmers should also endeavor to buy and apply NPK fertilizer briquettes since it easier to apply.
3. Further study repeated to this should cover cost and economic benefit analysis to identify the most economic and cost-effective fertilizer blend.
4. Further research must be conducted at different agro ecological zones in Ghana or on different crop to ascertain the overall effectiveness of the different inorganic (NPK) fertilizer briquettes.

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APPENDICES

Appendix 2: Soil test categories (SRI soil analytical services division)

Organic matter

<1.5%	low
1.5 - 3.0	medium
>3.0	high

Total nitrogen

<0.1%	low
0.1 - 0.2	medium
>0.2	adequate

Bray’s No.1 Phosphorus (Available)

<3.0 ppm	very low
3 – 10	low
11 – 20	medium
>20	high

Exchangeable Ca

<5.0 m.e/100g soil	low
5 – 10	medium
>10.0	high

Exchangeable Mg

<1.0 m.e/100g soil	low
1.0 – 3.0	medium
>4.0	high

Exchangeable K

<0.15 m.e/100g soil	low
0.15 – 0.25	medium
>0.25	high

Cation exchange capacity (CEC)

<7.5	low
7.5 – 15	moderate 15
– 25	high
>25	very high

Base saturation

< 50 %	low
50 – 70	medium
70 – 90	high
>90	v. high

Soil pH

<5.0	very strongly acidic
5.1 – 5.4	acidic
5.5 – 6.0	moderately acidic
6.1 – 6.4	slightly acidic
6.5 – 7.0	neutral
7.1 – 7.4	slightly alkaline
7.5 – 8.0	moderately alkaline
>8.0	alkaline

EDTA Extractable Mn

<10	very low
11 – 25	low
26 – 35	moderate
>35	high

EDTA Extractable Fe

<2.0	very low
2.0 – 5.0	low
5.0 – 10.0	medium
>10.0	high