CSIR COLLEGE OF SCIENCE AND TECHNOLOGY

THE EFFECT OF DIFFERENT MINERAL COMPOUND FERTILIZER BLENDS ON THE GROWTH AND YIELD OF MAIZE WITHIN THE BIRIM CENTRAL MUNICIPALITY, EASTERN REGION, GHANA

CASIMIR KYEI

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BY

CASIMIR KYEI

Thesis submitted to the Department of Soil Resources Management of the CSIR College of Science and Technology, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Soil Health and Environmental Resources Management

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this College or elsewhere.

Candidate's Signature ……………………….Date ……………………………

Name: Casimir Kyei

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the CSIR College of Science and Technology.

Principal Supervisor's Signature……………………..Date.…………………...

Name: Prof. Mohammed Moro Buri

Co-Supervisor's Signature.…………………………..Date ……………………

Name: Dr. Roland Nuhu Issaka

ABSTRACT

The Birim Central Municipality is a major maize growing area in the Eastern region of Ghana. Diverse mineral compound fertilizer blends are common in the Municipality and most of these mineral fertilizers are used in the production of maize. Common among them are NPK 15-15-15; NPK 20-10-10 +3S; NPK 15-20-20 + 0.7Zn; and NPK 15-20-20 + 1S + 0.7MgO + 0.7Zn. The effect of these compound fertilizer blends on maize growth and yield within the municipality has not been extensively studied. This study was therefore conducted to evaluate the effect of these different compound fertilizer blends and an absolute control on the growth and yield of maize (Pannar 12 variety) at Akim Oda. The experiment was a Randomized Complete Block Design (RCBD) with four replications. The recommended mineral fertilizer rate of NPK 90-60-60 kg ha^{-1} N-P_2O_5-K_2O for maize for the forest agro-ecological zone was adopted. Results obtained showed significant differences in yield and yield components due to the application of the different compound NPK mineral fertilizer blends. Grain yield showed significant differences between treatments with the least yield produced by the Control (4.12 t ha^{-1}) and the greatest from NPK 15-20-20 + 0.7Zn (10.63 t ha^{-1}). Weight of ears, un-shelled cobs, husk, stover, harvest index and biological yield all recorded significant differences. The NPK 15-20-20 + 0.7Zn proved to be economically more profitable due to the high VCR of 5.3 obtained. The study, therefore, recommends the compound mineral fertilizer blend NPK 15-20-20 + 0.7Zn should be adapted for the municipality to attain greater growth and yield of maize.

KEY WORDS

Birim Central

Grain yield

Harvest index

Mineral fertilizer blends

NPK fertilizer

Stover

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DEDICATION

To Rev. Fr. Gergont Casimir, Mrs. Dorothy Appiah, Ms. Sarah Appiah and my parents, Mr. Peter Kyei and Mrs. Regina Kyei.

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LIST OF ACRONYMS

AEZ	Agro-ecological Zone
AGRA	Alliance for Green Revolution in Africa
CSD-MoFA	Crops Service Directorate of the Ministry of Food and Agriculture
CSIR	Council for Scientific and Industrial Research, Ghana
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	The Food and Agricultural Organization Corporate Statistical Database
FOB	Free-On-Board
FSP	Fertilizer Supply Subsidy Program
FUBC	Fertilizer Use by Crops
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
MAFAP	Monitoring and Analyzing Food and Agricultural Policies
MoFA	Ministry of Food and Agriculture
MoFA-IFPRI	Ministry of Food and Agriculture- International Food Policy Research Institute
PFJ	Planting for Food and Job
SDG	Sustainable Development Goal
SRI	Soil Research Institute
SSA	Sub-Sahara Africa
SSTP	The Scaling Seeds and Technologies Partnership

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CHAPTER ONE

INTRODUCTION

Background to the Study

The ever-increasing world population calls for sustainability in food security, both quantitatively and qualitatively to meet the needs of the population growth. The world's population is projected to reach over 8 billion by 2025 and over 9 billion by 2050. Over 90% of the projected increase will occur in the developing and transitional economies where food insecurity and environmental degradation are serious challenges (Africa fertilizer summit proceedings, 2006). In confronting these challenges, the use of mineral fertilizer and associated inputs will continue to play a critical role in crop production, as it has done in the past.

The Sustainable Development Goal 2 (SDG 2), which centres on "Zero Hunger" postulates that currently our soils, freshwater, oceans, forest and biodiversity are being rapidly degraded. A profound change in the global food and agricultural system is needed if we are to nourish the 821 million people who were hungry as of 2017 and the additional 2 billion people expected to be undernourished by 2050 (United Nations, 2016). In Sub-Sahara Africa, from the year 2014, the number of undernourished people rose from 195 million to 237 million in 2017 (United Nations). Hence, the need to increase food production in a sustainable manner. Sustainability of food production for the growing world population requires using new technologies and, heightening production and management to grow more food on current croplands. Mineral fertilizer is therefore essential for accomplishing this (Mosaic Crop-Nutrition, 2019).

Nutrient mining is a major cause of low crop yields and unsustainable agriculture in parts of the developing worlds, particularly Africa (Setiyono, Walters, Cassman, Witt, & Dobermann, 2010). The Abuja summits on fertilizer declared that Sub-Saharan Africa (SSA) could only increase food production and alleviate poverty when fertilizer use is increased (Tetteh, Quansah, Adjei, & Fening, 2017a). In Ghana, maize is one of the major food crops, which can be used to meet the nutritional needs of the growing population. However, Ghana’s low soil fertility and low application of external inputs are two major factors that affect the productivity of maize and this accounts for the low yield of the crop (Kugbe, Combat, & Atakora, 2019). In accomplishing food security, farm inputs like fertilizer and improved seed play a major role. The Government of Ghana therefore passed policies in June 2006 to subsidize fertilizer cost and increase its availability to farmers to increase on-farm application (Dogor, 2013). Ministry of Food and Agriculture [MoFA] (2008) reported that there was a decline in unit fertilizer application in Ghana from 21.9 kg ha^{-1} in 1978 to 8 kg ha^{-1} 2006.

Mineral fertilizer application over the years has not been highly patronized by farmers in the Birim Central Municipality, but with the inception of the fertilizer subsidy and its positive impact on cocoa yields, farmers realized the need for fertilizer application to other crops due to yield improvements. Unfortunately, most farmers over rely on agro-chemical dealers for recommendations on mineral fertilizers use. These agro-chemical dealers’ recommendations are mainly based on what is in stock regardless of the type of crop under cultivation since their primary interest is to maximize profit. Within the Birim Central Municipality, farmers have been applying diverse NPK fertilizers to maize to enhance yield primarily based on their availability and not on agro-ecological zone requirement, soil type; research recommendation and/or cropping history of the field District MoFA Directorate -Akim Oda (J. Quarshie, personal communication, May 21, 2020).

The maize plant has a high requirement for nutrients especially nitrogen (N), phosphorus (P) and potassium (K) due to its high production of dry-matter yields (Pioneer, 2019). For every ton (t) of maize grain produced, about 15.0 to 18.0 kg of nitrogen, 2.5 to 3.0 kg of phosphorus and 3.0 to 4.0 kg of potassium are removed from the soil (Food and Agriculture Organization of the United Nations [FAO], 2005). Therefore, the application of mineral fertilizers to supplement the soil's nutrient is of prime essence. Maize yield achieved within the Birim Central Municipality in the 2019 planting season was 3.2 t ha^{-1} according to the District MoFA Directorate -Akim Oda (J. Quarshie, personal communication, May 21, 2020).

The challenge, however, is that the effect or contribution to yield of each of these various compound fertilizers has not been ascertained. Farmers are using these fertilizers because they are easily available during the planting season, but with little regard to the effect of these mineral fertilizers on total maize growth and yield.

Statement of the Problem

The impact or effect of available NPK fertilizer blends on maize yield is yet to be established in the Birim Central Municipality. This makes it difficult for farmers to choose the best fertilizer blend to apply to maize to maximize yield within the municipality. Therefore, the effect of the different types of NPK fertilizer blends on maize yield is worth determining.

Due to inadequate knowledge on fertilizer formulation, the majority of farmers are only familiar with the brand names, for instance, NPK, sulphate of ammonia and urea. Farmers pay little attention to the nutrient contents/ composition of the different NPK formulations and their impact on maize yield. Khor and Zeller (2015) reported that the farmer's choice of fertilizer is mainly based on recommendations by fertilizer sellers and other farmers. This is a major challenge as most farmers apply any type of NPK compound fertilizer available, regardless of its nutrient composition. According to Fertilizer Use by Crops (FUBC) Ghana Final Report (2015), although the nutrient levels of soils in the various agro-ecologies vary considerably, and hence require variable mineral fertilizer formulations, most farmers generally use NPK 15-15-15, Sulphate of Ammonia and Urea for all crops in all the agro-ecologies, a challenge the Ministry of Food and Agriculture is working to address.

Secondly, for years, fertilizer recommendations have been the same for all farmers across the country: two bags of NPK (regardless of the composition) and one bag of urea or sulphate of ammonia (Feed the Future, 2019). In the past few years, the CSIR-Soil Research Institute (SRI) in Kumasi has come out with site specific and suitable mineral fertilizer recommendations and blends based on the agro-ecological zone. Maize farmers adopting these sites specific and crop specific mineral fertilizer recommendations and blends can obtain optimum crop growth, optimum grain yields and high-profit margins that make maize farming attractive and profitable (Tetteh et al., 2017b).

Currently, to enhance increased crop production and ensure food security in Ghana, fertilizer subsidies and the improved seed of food crops such as maize have been introduced under the planting for food and jobs programme (MoFA, 2020b). According to Ofosu, Karlan, Kolavalli, and Udry (2015), farmers may not know what fertilizer inputs can help their crop or when and how to apply them. The common compound fertilizers currently available and applied to maize are NPK 15-20-20 + 0.7Zn; NPK 15-20-20 + 1S + 0.7MgO + 0.7Zn; NPK 15-15-15; NPK 23-10-5; NPK 25-10-10 and NPK 20-10-10 + 3S. It is upon this that it is deemed important to test the effect of the various compound fertilizer blends on maize growth and yield within the municipality.

Research Objectives

The general objective of this study is to improve maize yields and enhance food security within the Birim Central Municipality in particular and within the country as a whole.

Specific objectives

1. To determine the grain yield of maize as affected by different mineral fertilizer blends
2. To determine the most suitable NPK fertilizer blend for the Municipality

Research Questions

The study seeks to answer the following questions;

1. Do the various fertilizer blends available affect maize grain yield differently in the municipality?
2. What are the maize grain yield levels from the application of the fertilizer blends?
3. Which of these fertilizer blends/formulations is best suitable for maize production in the municipality?

Hypothesis

The specific objectives were formulated to test the null hypothesis that:

i. the application of different NPK fertilizer blends do not increase maize grain yield.

ii. the NPK fertilizer blends are equally suitable for maize production in the municipality.

Significance of the Study

The result will be used to enhance the application of the best type of NPK fertilizer to maize and to improve and increase maize grain yield. It is also expected that the result of this study will help provide specific information for extension services and farmers within the district to improve soil productivity.

Delimitation

The geographical location chosen was Akim Oda due to the numerous maize farmers within the locality. The choice of the treatments was a result of the application of these fertilizers over the years in the locality to date. Pannar

12 variety was planted due to its availability and efficient utilization of fertilizer (Dogor, 2013).

Limitations

The erratic nature of the rainfall affected the planting time. The delay in the rainfall of the major season until the last week of April delayed the planting of the maize. There was difficulty in obtaining records of the specific type of mineral fertilizers distributed to specific regions and districts from MoFA. Both the regional and district MoFA directorates found it difficult to indicate specific locations where specific types of NPK fertilizers have been distributed to.

Financial constraints and time, limited the study to only one site in the Municipality. Conducting this study at several locations within the district would have been a great benefit to many farmers; unfortunately, time and financial constraints could not allow that.

Definition of Terms

Gleysols: comprises of soil saturated with groundwater, underwater soils and soils in tidal areas.

Ultisols: These soils are deep and highly weathered, but high in soil acidity.

Fertilizer blend: it is a fertilizer made by physically mixing two or more primary plant nutrient.

Crop yield: it is the measurement of the amount of crop harvested per unit of land area.

Economic yield: it is the volume or weight per unit area of only those plant parts that have marketable value.

Biological yield: it is the total dry matter accumulation of a plant system.

Composite sample: it is soil obtained by mixing all the soil cores collected from a defined area into a single melded sample.

Organisation of the Study

The study is categorized into five (5) chapters. Chapter one entails the background of the study, objectives, significance of the study, delimitation and limitation of the study. Chapter two is about a literature review – dealing with what others have done concerning the topic. Chapter three encompasses the research methodology – this consists of the sampling method, data collection and analytical tool used for the study. Chapter four comprises the results and discussion – that is where the findings from the data analyzed are reported. Chapter five outlines the summary, conclusions and recommendations from the study.

Chapter Summary

The motive behind the study was that the increasing population of the world requires sustainability in food security. Unfortunately, the low fertility level of tropical soil is a challenge to attaining food security. The application of fertilizer will play a critical role to achieve maximum food production. Within the Birim Central Municipality, farmers apply different type of mineral fertilizer blends to maize but are uncertain of each fertilizer's effect on yield. It was upon this that the study was undertaken to determine the yield effect of the available mineral fertilizer blends.

The specific objectives the study sought to achieve were:

i. To determine the grain yield of maize as affected by different mineral fertilizer blends.

ii. To determine the most suitable NPK fertilizer blend for the Municipality.

It is expected that after the study, the best type of NPK mineral fertilizer blend is applied to maize for optimum yield. The study was constrained by delayed rainfall, finances and difficulty in obtaining information on fertilizer distribution. Some major terms like gleysols, ultisols, crop yield, economic yield was all defined. Lastly, the organization of the thesis from chapter one to five was briefly explained.

CHAPTER TWO

LITERATURE REVIEW

This chapter reviews literature related to the topic. The relevant issues covered include global mineral fertilizer use in maize production, national mineral fertilizer use in Ghana, and mineral fertilizer use in the subregion. It also entails mineral fertilizer blends in Ghana, mineral fertilizer use in the Birim central municipality, challenges to mineral fertilizer use in the Birim central municipality, origin and botany of maize, benefits of maize and ecological requirements of the maize plant.

Global Mineral Fertilizer Use in Maize Production

Increasing demand for food, fibre and biofuel have a significant impact on fertilizer consumption at both local and global scales (Setiyono, Walters, Cassman, Witt, & Dobermann, 2010). Mineral fertilizers contribute 40-60% of the world's food production (Njoroge, Otinga, Okalebo, Papela, & Merckx, 2018). The total world fertilizer consumption reached 181.9 million tonnes in 2014-2014/2015 consisting of 102.5 t N, 45.9 t P_2O_5 and 33.5 t K_2O. Out of this total, 89.6 t are applied to cereals with maize estimated to consume 16.2% of the fertilizer (HefferF, Gruère, & Roberts, 2017).

African soils are considered 16% high quality, 13% medium quality and 16% low potential and 55% unsuitable for cultivation, but large yields can be obtained when inorganic fertilizers are applied (Africa Fertilizer Summit Proceedings, 2006). Maize yield increase due to NPK fertilizer application can be as high as 150% from such soils (Africa Fertilizer Summit Proceedings, 2006). The low fertility status of most tropical soils hinders maize production as maize has a strong exhausting effect on the soil (Law-Ogbome, & Law-Ogbome, 2009).

In SSA, the nutrient depletion rate for NPK ranges between 22 and 72 kg ha $^{-1}$ year^{-1}, a reflection of low yield over the past 5 decades with cereals productivity stagnated at about 1 t ha^{-1} (Zingore, 2011). The effect of the no fertilizer maize cultivation carried out in South Africa for over a decade indicated a decline in maize yield from 5 t ha^{-1}to 1 t ha^{-1} for the first 3 years of cultivation (Zingore). Multi-location fertilizer trial across SSA revealed an increase in yield due to improvements in soil fertility status with fertilizer application (Tittonell, Vanlauwe and Corbeels, 2008; Zingore, Murwira, Delve, & Giller, 2007). That is, the decline in soil fertility with no soil improvement through the application of fertilizer caused a drop in maize yield, therefore, the need to replenish the fertility of the soil. To achieve efficient nutrient availability, synthetic fertilizer such as NPK, nitrate, ammonium and urea are applied by farmers (Arthur, 2015). For instance, the Fertilizer Association of South Africa's publication Handbook stated that 1 t of marketable maize will remove about 15 kg N, 3 kg P, 4 kg K and 0.5 kg Ca, 1 kg Mg and 4.5 kg S (Botha & Imvula, 2019). Asghar et al. (2010) reported that NPK fertilizer application at different rates resulted in maize grain yield maximization over the control with 6.03 t ha^{-1} and 5.9 t ha^{-1} at a rate of NPK 250-110-85 and NPK 175-80-60.

Maize yields can further be improved with the inclusion of secondary and micronutrients to NPK fertilizer. Sutar, Pujar, Kumar and Hebsur (2017) outlined that the yield of maize could increase drastically with the inclusion of secondary and micro-nutrients such as S, B and Zn in fertilizer blends. Kihara and Njoroge (2013) noted that the maximum maize grain yield obtained in fields under researcher management in western Kenya, a region with a potential yield of at least 10 t ha^{-1}, was stagnated at 7 t ha^{-1}. This is as a result of deficiencies in secondary and micronutrients during crop growth and the effect of low soil pH and associated toxicities (e.g., aluminium). Kihara et al. (2017) also observed that S and micronutrients resulted in 0.84 t ha^{-1} increase in maize grain yield compared to the recommended N, P, and K fertilizer alone.

Mineral Fertilizer Use in the Sub region

Soil fertility in Africa is under threat as an increasing number of farmers attempt to make a living on what the land can offer to grow plants (Smaling, Nandwa, & Janssen, 1997). Averagely nutrient loss for sub-Sahara Africa was 22 kg N, 2.5 kg P, and 15 kg K in 1982 to 1984 but it was expected to rise by the year 2000 with 26 kg N, 3 kg P and 19 kg k (Stoorvogel, Smaling, & Janssen, 1993). These nutrient losses are still expected to rise if drastic measures to improve soil fertility are not taking, which mineral fertilizer can help curtail these losses. Efforts to raise fertilizer use in sub-Sahara Africa over the last decade concentrated on fertilizer subsidies and credit facilities, which after achieving adoption of fertilizer by farmers it would be withdrawn (Jayne et al., 2015). The period between 2015-2017 fertilizer demands substantially increased in most of the main fertilizer markets in West Africa under the influence of three main factors: (i) favourable international commodity and fertilizer prices; (ii) government interventions, including subsidy programs; and (iii) private sector investments in production, distribution, and marketing of fertilizers (Feed the Future, 2019).

Ghana has a land size of 23,853,900 ha of which 57.1 % (13,628,179 ha) is suitable for agriculture, but most of these soils are low in fertility (Bationo, Fening, & Kwaw, 2018). Almost all the crop balances in Ghana show a nutrient deficit, which is the difference between the quantities removed or lost (FAO, 2004). The insufficient fertilizer application and inappropriate nutrient conservation practices by farmers are contributing factors to the rapid decline in soil fertility (Bationo, et al). Therefore, an appropriate supply of plant nutrient is an important component for crop production (Roy, Finck, Blair, & Tandon, 2006).

Mineral fertilizer is applied to different types of crops in Ghana to increase yield levels. For instance, the addition of 30 kg ha^{-1} each of nitrogen, phosphorus and potassium mineral fertilizer resulted in increased average paddy grain yield by 71%, 51% and 56% respectively (Buri, Issaka & Wakatsuki, 2008). This yield could not have been achieved if not the application of mineral fertilizer. It is also reported that one tone of rice grain harvested removes 15-20 kg N, 2-3 kg P and 15-20 kg K (Buri, et al.). Maize is also reported to remove 15 to 18 kg of nitrogen, 2.5 to 3 kg of phosphorus and 3 to 4 kg of potassium from the soil (Du Plessis, 2003). The nutrient removal by crops requires a corresponding nutrient application to either maintain or improve yield levels. Other crops like cocoa significantly increased their yield due to fertilizer application. It is reported that a two-year on-farm fertilizer trial conducted in Ghana and Cote d'Ivoire produced 1890 kg ha^{-1} while fields without fertilizer application produced 765 kg ha^{-1} (Ruf &

Bini, 2012). Other crops like yam, sweet potato, cassava, groundnut, pepper, oil palm etc cultivated under fertilizer application fields have all proved to give higher yields than the none fertilizer applied fields (FAO, 2005).

Mineral Fertilizers in Ghana are all imported with little domestic value addition, in a form of a blend (Odionye et al., 2020). Fertilizer importation in Ghana is the responsibility of government fertilizer subsidy programme (MoFA for food crops and COCOBOD for cocoa), commercial plantations and other private farmers (Feed the Future, 2019). Generally, in the fertilizer blending industry, cocoa production consumes 80,000 t of blended fertilizer, 80% of the blend market, mainly by smallholder farmers in the Western, Ashanti, Brong Ahafo, Eastern, Central and Volta regions of Ghana. The 20% left representing 20,000 t is consumed by oil palm, rubber, cotton, fruits and food crop plantations. The distribution of the imported fertilizers in Ghana to farmers is done through three (3) channels. These consist of; plantation and commercial/industrialized crops owners (into the cultivation of sugarcane, oil palm, tobacco and rubber); agricultural parastatals, such as PFJ and COCOBOD; and Smallholder farmers and producers of staple food crops (Odionye et al., 2020).

In Ghana, the adoption of mineral fertilizer is influenced by access to off-farm income, years of farming, residential status of a farmer, total farm size, use of fallow methods of soil management and household size (Martey, Kuwornu, & Adjebeng-Danquah, 2019). The adoption of mineral fertilizer must be enforced to facilitate the sustainability of food security in the subregion.

National Mineral Fertilizer Use in Ghana

Mineral fertilizers were introduced into Ghana in the early part of the 20th century. Ammonium sulfate, single superphosphate, triple superphosphate, muriate of potash and sulphate of potash were imported and used before 1960 (Fuentes, Bumb, & Johnson, 2012). Early 1960 saw the introduction of compound fertilizer, NPK (Fuentes et al.).

The Abuja summit declaration on fertilizer has been a guiding principle for fertilizer use today in Ghana, although it has not fully gained grounds. Generally, most soils in Ghana are low in fertility with pH in the range of 4.5-6.7 (Onawumi, 2016), organic carbon (< 1.5%), total nitrogen (< 0.2%), exchangeable potassium (< 100 ppm) and available P (< 10ppm) (Benneh, Agyepong, & Allotey, 1990; Adu, 1995). Despite the low fertility status of soils in maize growing areas, the fertilizer nutrient application in Ghana is approximately 15 kg ha^{-1} according to Crops Service Directorate of the Ministry of Food and Agriculture [CSD-MoFA] (as cited in Research Brief: CSIR-SRI, 2019) while depletion rates range from 40 - 60 kg of nitrogen, phosphorus, and potassium (NPK) $ha^{-1}yr^{-1}$ (FAO, 2005). The depletion is among the highest in Africa (Research Brief: CSIR-SRI). The fertilizer application in Ghana is below the expected quantities of fertilizer to be applied to farms in SSA, which is 50 kg ha^{-1} (Africa fertilizer Summit Proceedings, 2006). Maize has a high requirement for nutrients especially nitrogen (N), phosphorus (P) and potassium (K) (Boakyewaa et al., 2014). Among these major nutrients, N is the one that most often limits yield.

In 2008, the government re-introduced fertilizer subsidies through a voucher-based system to promote fertilizer use and improve crop productivity of smallholder farmers. The vouchers were worth 50% of the price of fertilizer on selected fertilizers for use on staple food crops (Tetteh et al., 2017b). The reintroduction of the Fertilizer Supply Subsidy Program (FSP) in 2015, and rolled out under the Planting for Food and Job (PFJ) in 2017 by the Government of Ghana, had fertilizer consumption increased to a tune of 330,000 t in 2019 (Ministry of Food and Agriculture & International Food Policy Research Institute [MoFA-IFPRI], 2020).

About 40% out of this fertilizer is applied to maize in Ghana due to policy design and target. Maize output due to the current fertilizer subsidy in Ghana was 3.06 million tons in 2019, the highest maize yield ever recorded in the country (MoFA-IFPRI, 2020). These measures have increased food production in Ghana especially maize. The new fertilizer blends outperformed the previous fertilizers used.

Mineral Fertilizer Blends in Ghana

Ministry of Food and Agriculture [MoFA] (2020a) reported that for the past decade, farmers apply a blanket rate of 2 bags of NPK plus 1 bag of urea or sulphate of ammonia per acre to maize. Yields from these have been poor. Feed the future (2019) stated that yields from maize have been poor from these fertilizers (NPK 15-15-15; NPK 23-10-5; NPK 20-10-10) through the blanket fertilizer application until the introduction of the new fertilizer blends, which are crop-specific and site-specific fertilizer recommendations. The compound fertilizers come with micro and secondary nutrients inclusive. Common among them are sulphur, magnesium and zinc. Kumar, Bohra, Kumawat, and Singh (2017) stated that besides the major primary nutrients that are N, P and K, secondary nutrients like sulphur and micronutrients like zinc have been recognized as essential input to sustain maize productivity and quality.

According to Feed the future (2019), yields from the blanket fertilizer recommendations for maize, which used to be (1.7 t ha^{-1}) had a 50% yield increase with the application of the balanced fertilizer blends. In northern Ghana, yield increases of over 29% were recorded with the inclusion of secondary and micro-nutrients in NPK fertilizer blends (Kugbe, Combat, & Atakora, 2019). In order to achieve food sufficiency in Ghana, farmers have embraced the new fertilizer blends. The impact on yield from these new fertilizer blends has resulted in the production of other fertilizer blends such as NPK 15-20-20+1S+0.7MgO+0.7Zn and NPK 20-10-10+3S.

Blended fertilizer is obtained by the dry physical blending of various raw fertilizers, without any chemical reaction (European Fertilizer blenders Association, 2016). In Ghana, among the implementation plan on the validation of the new mineral fertilizer recommendation and formulated blends was for CSIR-SRI to consider the inclusion of other secondary and micro-nutrients such as B, S, Mg, Mo, Zn and Mn (Ministry of Food and Agriculture, 2020a). In the Forest – Savanna transitional zone the recommended mineral fertilizer blend for maize cultivation, which was NPK 15-20-20+0.7Zn and urea was applied at a rate of 90-60-60 kg ha^{-1}. The application of NPK 15-20-20 and urea to maize was done at a rate of 100-40-40 kg ha^{-1} in the Guinea Savanna zone. Yields recorded from the first field trials had minimum and maximum yields of 3.08 t h^{-1} and 9.50 t h^{-1} respectively for Forest – Savanna transitional zone while in the Guinea

Savanna zone, 1.36 t h^{-1} and 6.54 t h^{-1} were recorded as the minimum and maximum yields respectively (Ministry of Food and Agriculture, 2020a). Obviously, these yields were far better than the previous grain yields of maize in Ghana as reported by feed the future (2019) that the average grain yield of maize in Ghana was 1.7 t ha^{-1}.

Generally, the benefits of these secondary nutrients (Mg and S) and micronutrient (Zn) include;

*Magnesium***:** this is a component of the chlorophyll molecule and is essential for photosynthesis. It is also a phosphorus carrier in plants. Plants without Mg would not be able to take up phosphorus. It is essential for phosphate metabolism, plant respiration, and the activation of enzyme systems in plants.

Sulfur: maize requires greater amounts of S because it is a high dry-matter production crop. Sulfur is essential in plants for protein synthesis, chlorophyll development, and photosynthesis. It improves crop management through its favourable effects on environmental stress, resistance against pest and diseases.

Zinc: even though zinc is required in small amounts, it has a huge impact on maize growth and ultimately how much yield is produced. It aids in the synthesis of growth hormones and proteins. It is needed in the production of chlorophyll and carbohydrate metabolism. It is essential for the transportation of calcium throughout the maize plant. Zinc is necessary for cell elongation, the increase in leaf and node size along with grain formation.

The inclusion of the secondary and micronutrients are as a result of the extensive deficiency of P, K, Ca, Mg, S, Zn, and B in the soils in Ghana mapped by the Soil Research Institute (SRI), Africa Soil Information Service (AfSIS), and International Fertilizer Development Centre (IFDC) (International Fertilizer Development Centre, 2018). This has resulted in the manufacture of different mineral fertilizer blends that are crop and agro-ecological specific. The call by MoFA in 2018, for the supply of fertilizers for the 2019 planting season, resulted in the production of new fertilizer blends by CSIR-SRI for the cultivation of maize, rice, soyabean and cassava (Research Brief: CSIR-SRI, 2019).

Mineral Fertilizer Use in the Birim Central Municipality

Maize is a major staple food crop in the municipality. In order to boost food production, the Municipality has also adopted the new fertilizer blends and recommendation of NPK 90-60-60 kg ha^{-1} as reported in Research Brief: CSIR-SRI (2019), but unfortunately, few farmers apply mineral fertilizer to their farms. According to the Ministry of Food and Agriculture (2019), the number of farmers who use organic manure and mineral fertilizer in the Birim Central Municipality is less than 50% of the farmers population.

The common NPK fertilizer blends applied to maize within the municipality are NPK 15-20-20+0.7Zn; NPK 15-20-20+1S+0.7MgO+0.7Zn; NPK 15-15-15; NPK 23-10-5; NPK 25-10-10 and NPK 20-10-10+3S as basal while sulphate of ammonia or urea is used for topdressing. Maize grain yield in the Birim Central Municipality in 2019 was 3.2 t ha^{-1} (MoFA Directorate Akim Oda, 2019). This is a vast improvement over the previous years. However, this yield achieved with the availability of subsidized fertilizer and improved seeds could be improved. NPK fertilizer recommendation for maize in the district had been two bags NPK for an acre of land.

Challenges to Mineral Fertilizer Use in the Birim Central Municipality

Constraints that limit or hinder the effective use of mineral fertilizers for crop production, particularly maize in the Municipality include, but not limited to, the following:

Lack of confidence in mineral fertilizer quality: Poor quality fertilizer is a big challenge to many farmers. This has been a concern since farmers do not have the purchasing power or testing instruments to verify the authenticity of the fertilizer (Khor & Zeller, 2015). Feed the Future (2019) stated that due to lack of trust in the quality and truth in labelling of recommended fertilizer from previous experience of fertilizer application, farmers do not see the essence of fertilizer application.

High cost of unsubsidized mineral fertilizer: Fertilizer subsidy is limited to staple crops (maize, rice, sorghum, soyabean and vegetables) and few cash crops (cocoa, oil palm, and cotton). Therefore, after soil analysis, and recommendations, when the fertilizer to be applied, is not part of the subsidized ones, then such fertilizer may cost more than twice the subsidized ones. For instance, unsubsidized NPK 15-15-15 is currently sold at GHC 132.00 (U.S $ 22.53) per 50kg as against the subsidized cost of GHC 80 (U.S $ 13.65) per 50 kg. This is too high for farmers to purchase. Besides, except for urea and sulphate of ammonia being subsidized as straight fertilizers in Ghana, almost all the others are not. For instance, Boron and Magnesium fertilizers cost GHC 249 (U. S $ 42.49) and GHC 180 (U.S $ 30.72) per 50kg respectively. These fertilizers are very costly. Feed the Future (2019) reports that retail fertilizer prices in Ghana are relatively high (nearly twice Free-On-Board -FOB prices).

Limited credit for small-scale farmers: Farmers have limited access to credit due to credit guarantees, collateral and high interest rates. These bottlenecks coupled with the poverty level of the small-scale farmer prevent them from purchasing fertilizers.

Limited reach of subsidized mineral fertilizer in adequate quantities: Fertilizer distributors and agro-dealers face poor inland infrastructure (such as poor road network), inadequate warehouses, limited logistics, and inadequate financing to extend distribution closer to the farmer (Feed the future, 2019). Therefore, whatever fertilizer is within the reach of farmers is what they use regardless of the recommended rate of application. This has a negative effect on the growth and yield of the crop.

Inadequate farmer knowledge: Farmers do not have adequate knowledge of the diverse fertilizer types available and their use on specific crops. One of the major reasons for the fertilizer subsidies was to help curb the blanket application of fertilizer, which persist among farmers despite efforts on training by extension officers of the Ministry of Food and Agriculture (MoFA). Farmer education/sensitization on mineral fertilizer use is still a major challenge.

Inadequate extension services support: The farmer to extension ratio is very wide. There are not enough extension officers to provide needed services to farmers at times needed.

Origin and Botany of Maize

Maize is a native crop of Central America, from where it spread to Asia, Europe and Africa by the effort of traders and explorers (Tange, 2018). Galinat (1995) reported that maize was domesticated from its ancestor teosinte (*Zea mexicana*). Zea is a genus of the family Graminae (Poaceae), commonly known as the grass family. Maize is a monoecious plant (that is staminate and pistillate are found on the same plant, but at different parts). Tripathi, Ranjini, Govila, and Ahuja (2011), reported that maize is generally protandrous, the male flower matures earlier than the female flower.

The leaves of the maize plant are usually long and tapering. The leaves arise from the node alternately on the opposite side of the stalk. The top surface is hairy with large stomata, but the under surface is free from hairs and has smaller, but numerous stomata. The sheath is the portion of the leaf covering the culm.

Normally, maize plants have three types of roots, i) seminal roots - which develop from the radicle and persist for long period, ii) adventitious roots-which develop from the lower nodes of stem below ground level and form the effective and active roots of plant and iii) brace or prop roots - produced by lower two nodes (Tripathi et al., 2011).

The male flowers tassel and produce pollen. The tassel arises from the growing point of the plant. After tasseling, the innermost leaf in the growing point is the last leaf produced. Pollination occurs when the female flowers receive the pollen grain from the tassels to the silks of the ear (Tripathi et al., 2011). Maize is mainly cross-pollinated with self-pollination forming not more than 5%. The pollinated female flowers develop into the kernels.

Silking stage involving the formation of the female flowers or cobs is the first reproductive stage and occurs 2-3 days after the tasseling stage. Cobs, husks and shanks are fully developed by day 7 after silking. After pollination and fertilization soft dough or milky stage starts. Grains development start, but it does not become hard. This soft dough stage is observed by the silks on the top of the cob, which remain partially green at this stage. The husk of the cobs also remains green.

Approximately 30 days after silking, the plant has reached the maximum dry weight, a stage called physiological maturity. This is where a ‘black layer is noticeable at the tip of each kernel, where cells die and block further starch accumulation into the kernel (Afuakwa & Crookston, 1984). The maturity of the grains is usually four to six weeks after fertilization (Okoroafor, et al., 2013).

At maturity or hard dough stage, the leaves and stem wither; silks get dried completely and become very brittle; the cobs then begin to drop. This necessitates the harvesting of the cobs.

Uses of maize in Ghana

Maize is cultivated worldwide and represents a staple food for a significant number of the world’s population (Bature, 2016). Globally, it has been estimated that approximately 21% of the total grain produced is consumed as food (Tripathi et al., 2011). Maize is the most important cereal crop on the domestic market in Ghana, accounting for over 50 % of the total cereal production (Darfour & Rosentrater, 2016). Fortunately, maize output for 2019 was 3.06 million tons, thus a 40 % increment than the average output achieved between 2013 to 2016 (MoFA-IFPRI, 2020).

Maize accounts for 55 percent of grain output followed by paddy rice (23 percent), sorghum (13 percent) and millet (9 percent). Maize is also an important component of poultry feed and to a lesser extent the livestock feed sector as well as a substitute for the brewing industry (MAFAP, 2012).

Maize is used mainly as food for man and livestock. Diverse dishes are prepared from the corn meal mush in Ghana, which includes Kenkey, banku, tuo zaafi, porridge, tom brown etc. The grain is very nutritious, with a high percentage of carbohydrates (76 – 88%), proteins (6-16%) fats (4-5.7%) and minerals (1.3%) (Mitiku & Asnakech, 2016). The roasted fresh cobs are also largely eaten by man. Additionally, corn flakes make good breakfast food. Not only is the grain valuable as animal feed, but also the plant as a whole is an important fodder crop. Okoruwa (1997) reports that maize gives the highest conversion of a dry substance to meat, milk and eggs as compared to other cereal grains. Maize meal is used for meal mixes, maize bread, and maize muffins. Maize flour is an ingredient for pancake mixes, baby foods, cookies, biscuits, ice cream cones, butter breading mixes and binder for loaf-type sandwich meats (Okoruwa).

Elsewhere, the industrial processing of maize by way of wet milling and dry milling have resulted in the production of different products (Okoruwa, 1997). The principal food products from the wet milling industry are corn starch, corn syrup, high fructose syrup, dextrose and corn oil. Glucose is also manufactured from the grain. The corn oil is prepared which is used for soap making, lubrication and as salad oil. The dry milling of maize basically produces maize meal, flour and maize grit. Grit fractions are used for the production of corn flakes while brewers grit is used for the production of beer.

Zein, the protein that occurs in maize grain has diverse uses including the manufacture of buttons, fibre (utilized for making artificial fibres with good tensile strength and wool-like qualities), adhesives, coating and binders (Lawton, 2002).

Maize starch is extensively used as a sizing material in the textiles and paper industries. In the food industry, it is used in the preparation of pies, puddings, salad dressings and confections. Maize starch is used for the production of dextrose and corn syrup; also employed as a diluent for pharmaceutical preparations, dusting material to prevent articles like surgeons' gloves, from sticking together, an ingredient of oil-well drilling muds, and as a depressant in the ore-floatation process. Cobs are rich in pentosans and used for furfural production. They may also be used for making building boards that are water and fire-resistant.

Maize straw is used in addition to feeding for livestock as a source of fertilizer, mushroom substrate, and fuel for cooking (Seglah, Wang, Wang, & Bi, 2019). Maize stalk is proven to be the best substrate for mushroom production in Ghana (Adjapong, Ansah, Angfaarabung, & Sintim, 2015). Maize straw serves as an equally good source of fuel for cooking in the Kumbungu District of the northern region of Ghana (Ansah & Issaka, 2018). Maize stover improves soil fertility when applied as mulch which improves the soil organic matter (Quansah, Drechsel, Yirenkyi, & Asante-Mensah, 2001). Maize stover biochar can help conserve soil moisture content between

349% - 481% especially, in sandy soil (Dugan et al., 2010). The fibres in the stalks are utilized for making paper and yarn.

Economically, maize production is highly a profitable venture in Ghana. Abawiera, Awunyo-Vitor, Mensah, and Adams (2019), reported that for every One Ghana Cedi (GHC 1.00) invested in maize production in Ghana, GHC 0.413 was gained. Maize is the most widely grown cereal in Ghana and a priority crop for the government for both food and income security due to growing domestic demand for both human and animal consumption (AGRA - SSTP for the United State Agency for International Development, 2017). It is an important cash crop for income generation by smallholder farmers and has the most commercialized seed system with active private sector participation (AGRA - SSTP for the United State Agency for International Development).

About 63% of maize consumption in Ghana is either at the household level or informally traded. The remaining 37% is formally traded for use in the animal feed industry and industrial processing sector (AGRA - SSTP for the United State Agency for International Development 2017). Maize production can therefore provide income to maize farmers on a sustainable basis if they are to remain in it. The maize industry, therefore, has great potential to help Ghana achieve sustainable development goals on no poverty and zero hunger (Abawiera et al., 2019).

The Ecological Requirement of Maize

Soil requirements of maize

Maize grows best in soil that is deep, fine-structured, well-aerated, well-drained loamy soil rich in organic matter (Boakyewaa et al., 2014). The soil must have optimal pH of 5.5-7 (Roy, Finck, Blair, & Tandon, 2006). Maize is intolerant to waterlogged conditions. Soil depth greater than 100 cm – 75 cm is highly suitable, 75 cm – 50 cm is moderately suitable and 50 cm to 20 cm is marginally suitable (Sys, 1993).

Loamy soil, clay loam or silty loam is highly suitable for maize cultivation. Sandy loam and silty clay are also moderately suitable, but clay soils are marginally suitable. Soils of texture classes between 10 % to 30 % are optimal to enhance healthy maize production (Du Plessis, 2003). Naidu, Ramamurthy, Challa, Hedge and Krishnan (2006) report that the soil must be non-saline for optimum maize growth.

Rainfall

A rainfall requirement of 250 mm to 5000 mm per annum is ideal for maize growth (Tripathi, et al., 2011). Approximately 10 to 16 kg of grains is produced for every millilitre of water used. Du Plessis (2003) reports that 3152 kg ha^{-1} of maize grain yield requires between 350 mm to 450 mm of rain per annum. In the absence of moisture stress, each plant will have used 250 litres at maturity (Du Plessis).

Temperature

Maize grows within latitude 58°N and 40°S (Tripathi, et al., 2011). It grows from sea level to about 3000 m altitude (Manpreet, Shikha, & Ramanjit, 2019). Maize is a warm-weather crop and cultivating it in areas with a mean daily temperature of less than 19°C will not grow well. Naidu, et al., (2006) report that the optimum temperature for maize seeds germination is 21°C and for growth is 32°C.

Nutrient requirements

Maize assimilates diverse soil nutrients for optimal growth, but chief among them are nitrogen, phosphorus and potassium. At maturity, the total nutrient uptake of a single maize plant is 8.7 g of Nitrogen, 5.1 g of phosphorus, and 4.0 g of potassium. Each ton of maize grain produced removes 15 to 18 kg of nitrogen, 2.5 to 3 kg of phosphorus and 3 to 4 kg of potassium from the soil (Du Plessis, 2003). Electrical conductivity (EC) less than 1.7 ds m^{-1} do not cause yield reduction but greater than 2.5 ds m^{-1} to 10 ds m^{-1} cause yield loss ranging from 10 % to 100 % (Sys, 1993). Cation exchange capacity (CEC) greater than 24 cmol (+) kg^{-1} is highly suitable, 24-16 cmol (+) kg^{-1} is moderately suitable and less than 16 cmol (+) kg^{-1} is marginally suitable for maize cultivation (Sys). Base saturation greater than 50 % is highly suitable, between 20-35 % moderately suitable, less than 20 % is marginally suitable (Adesemuyi, 2014). Organic carbon greater than 2 % is highly suitable, between 1.2 - 2 % is moderately suitable, 0.8 - 1.2 % is marginally suitable and less than 0.8 % is not suitable (Adesemuyi). Available P greater than 22 mg kg^{-1} is highly suitable, between 7-13 mg kg^{-1} is moderately suitable and between 3-7 mg kg^{-1} is marginally suitable. Total nitrogen greater than 0.15 % is highly suitable, between 0.08 % - 0.10 % moderately suitable, and 0.04-0.08 is marginally suitable (Adesemuyi).

Chapter Summary

The reviews indicate that fertilizer use is important globally including Ghana. The rate of population growth demands equal production of food and fertilizer application to crops is key. Mineral fertilizer on average has contributed to about 50% of the world's food production. The continual fertilizer use and further research by way of producing fertilizer that is crop and soil specific have been developed. The depletion rate of soil fertility in Ghana is escalating beyond the rate of soil fertility improvement. In Ghana, the development of new mineral fertilizer blends spearheaded by CSIR-SRI has been achieved. The inclusion of the secondary and micronutrients to the new fertilizer blends and its positive impact on maize grain yield confirmed how our soils deficient in these nutrients were impacting negatively on maize grain yield. There has been an improvement in the maize grain yield over the previous years when little or no fertilizer was applied to maize. The no fertilizer application to agricultural lands has resulted in gradual grain yield losses from 5 t ha^{-1} to 1 t ha^{-1} for 3 years of continued cultivation.

Despite all the effort to make fertilizer available to farmers, it is also being hindered by some challenges including lack of confidence in mineral fertilizer quality, limited credit for small - scale farmers, the limited reach of subsidized mineral fertilizer in adequate amounts etc. Central America is seen as the origin of maize and with the help of traders and explorers, it spreads to different continents. Morphologically the maize plant consists of tassels, cob, silk, stalk, leaves, nodes, and roots. Maize has different uses, which basically entails feeding, industrial uses, economic uses and environmental protection by using the straw to conserve the soil and moisture rather than burning it.

Lastly, the ecological requirements for optimum maize yield were enumerated. That is for optimum maize grain yield, loamy soil, clay loam or silty loam is ideal. The recommended rainfall ranges from 250 mm to 5000 mm per annum and the average temperature for growth is 32°C. Basically, the maize plant needs nitrogen, phosphorus, and potassium. In addition, magnesium, sulphur, and zinc also help achieve optimum grain yield better than only the primary nutrients.

CHAPTER THREE

MATERIALS AND METHODS

This section describes the study area, the material and methods used to achieve the objectives set and the analytical tool used to analyze the data.

Description of the Study Area

The study site is located at Akim Oda, at latitude 5°55′30″N and longitude 0°58′56″W in the Birim Central Municipality of the Eastern Region of Ghana (Fig 1).

The land is generally undulating and hilly. The vegetation of the municipality is a semi-deciduous rainforest zone (Ministry of Food and Agriculture, 2019). The soils are ultisol and Forest Acid Gleysols (World Reference Base for Soil Resources, 2014). These soils are deep and highly weathered, but strongly acidic (pH < 5.0). The site is located at the Oda series, which consist of clay loam and clay. They are poorly drained and are subjected to water logging during the rainy season (Seneyah et al., 2013).

The annual annual rainfall ranges from 1,200 to 1,600 mm with a mean rainfall 1400 mm. It has a bimodal rainfall pattern. The Municipality experiences a mean annual temperature of around 26°C (Ghana Statistical Service, 2014). According to the Ghana Statistical Service Housing and Population census 2010 report, the Birim Central Municipality has a population of 144,869 representing about six percent of the population of the Eastern region. There are 70, 000 farmers according to the Birim Central Municipal MoFA Directorate.

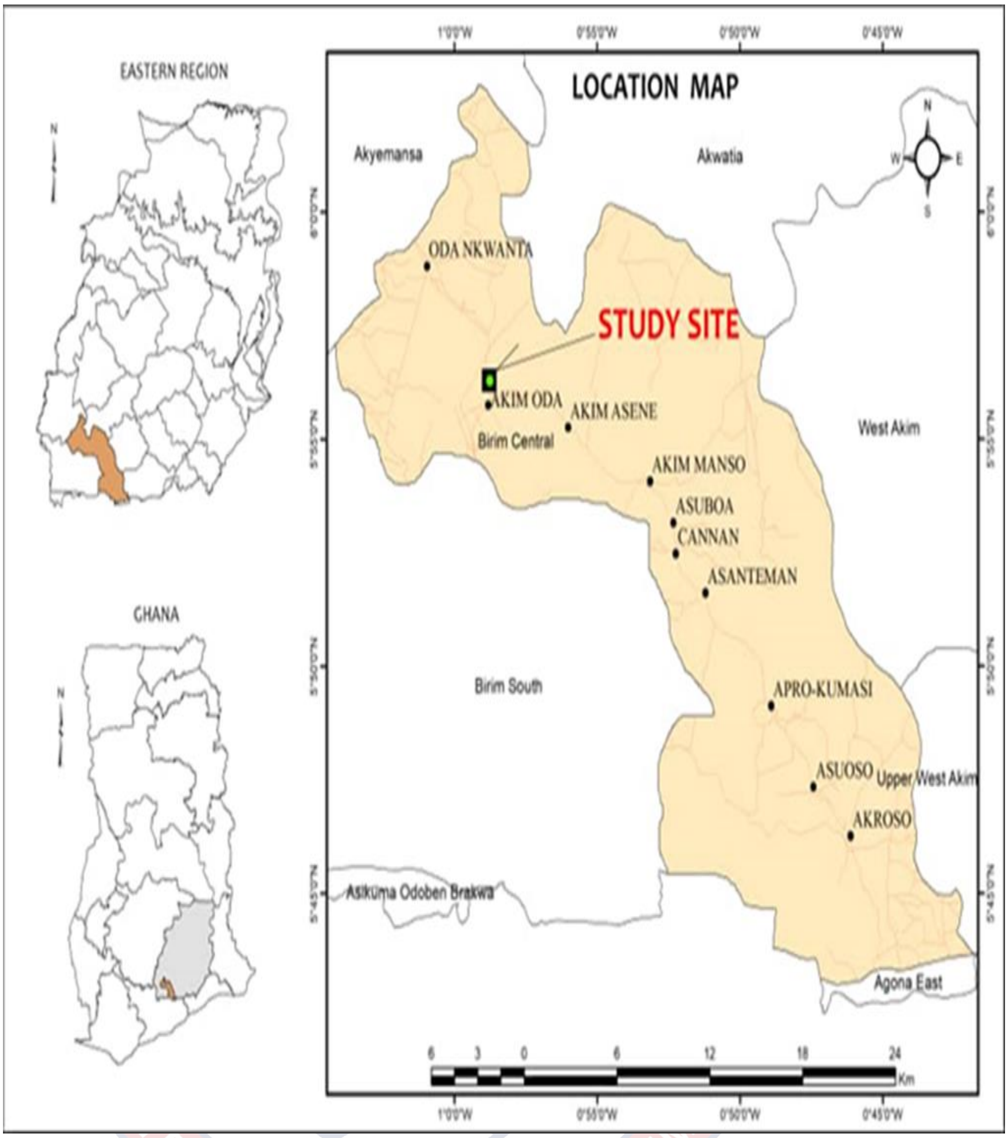

Figure 1: Map of Birim Central Municipality showing the project site

Experimental Design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with five (5) treatments and four (4) replications (Table 1). Each plot measured 4 x 3 m. Each compound fertilizer blend represented a treatment with no fertilizer applied (0 kg ha^{-1}) as the control. The research mineral fertilizer recommendation (NPK 90-60-60 kg ha^{-1}) for maize as provided by CSIR-SRI (Research Brief: CSIR-SRI, 2019) for the area was adopted for all treatments, except the Control.

Table 1 - *Field Layout of Experimental Site and their Treatment*

Sites	Treatment				
BLK I	T_2	T_5	T_4	T_1	T_3
BLK II	T_4	T_1	T_2	T_3	T_5
BLK III	T_1	T_2	T_4	T_5	T_3
BLK IV	T_4	T_5	T_1	T_3	T_2

Treatment	Fertilizer Blend
Treatment1 (T_1):	Control (No fertilizer)
Treatment 2 (T_2):	NPK 15-20-20 + 0.7Zn + Urea
Treatment 3 (T_3):	NPK 15-20-20 +1S + 0.7 MgO +0.7Zn + Urea
Treatment 4 (T_4):	NPK 20-10-10 + 3S
Treatment 5 (T_5):	NPK 15-15-15 + Urea

(**BLK** - Block; **T**- Treatment)

Source: Field data (2020)

Land preparation

The experimental site was initially slashed using cutlass without burning the debris. Two weeks prior to planting, it was sprayed with sunphosate weedicide to kill the emerging weeds. The field was then pegged to various plots. A unit plot size measured 4 x 3 m with a 1 m alley between replicates and 0.5 m between treatments.

Soil Sampling and Analysis

Composite samples were taken from the field at depths of 0-15 cm and 15- 30 cm for laboratory analysis. Soil samples were taken diagonally at

10 steps from each spot. The soil was sampled from five different spots from the field to form the composite sample. Soil surface litter was scraped before sample collection. About 1 kg soil sample per depth was put into a zip bag, labelled clearly and sent to the laboratory for analysis.

Soil Analysis: Routine soil analysis was done using the following standard procedures: Soil pH (water) using glass electrode meter in a soil: water ratio of 1: 2.5 (Motsara & Roy, 2008); Organic carbon was determined by Walkley and Black method (Motsara & Roy); Total nitrogen – was measured through the Kjeldahl Method (Bremner, 1965), while available Phosphorus was measured using the - Bray's No. 1 method (Bray and Kurtz, 1945); Exchangeable cations (Ca, Mg, Na, K) were extracted using ammonium acetate buffered at pH 7 and determined using an Atomic absorption spectrophotometer (Thomas, 1982). Exchangeable acidity was determined by titration and ECEC was calculated by the sum of exchangeable cations (bases) and acidity (Motsara & Roy). Available Sulphur was measured using a Spectrophotometer (Motsara & Roy); Available Zn was determined using the Atomic absorption spectrophotometer (Motsara and Roy) and Soil texture (sand, silt, clay) was determined by the hydrometer method (Anderson & Ingram, 1993).

Germination Test

Prior to planting, a germination test was conducted using a hundred (100) seeds. The hundred (100) seeds were sown in a seedbox filled with soil. Seeds germinated on an average of 3 days. The germinated seeds were counted. The germination percentage was calculated. The percentage of germination obtained was 85%. The germination percentage was calculated using the formula:

$$\text{Germination percentage (G \%)} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds planted}} \times 100\ \%$$

Planting Procedure

The maize variety, Pannar 12 was used. Pannar 12 is a medium maturing variety of 115-120 days to harvest, drought tolerant, outstanding on acidic soil, resistant to pests and diseases and high yield potential of 8 t ha^{-1} and higher were the main attributes for consideration in planting (Product Catalogue Ghana, 2021). Research has also indicated that Pannar 12 variety has efficient utilization of fertilizer (Dogor, 2013). Yield results in excess of 12000 kg ha^{-1} are realistic for these types of hybrids if planted early (Pannar, 2018), but yield levels of 3.2 t ha^{-1} have been reported in the municipality. It was purchased from a local licensed agro-input dealer. Planting was done soon after the germination test. Planting was done at the onset of the major rainy season, on 27th April 2020. Two seeds were planted per hill but later thinned to one after germination. The plant inter-row spacing was 75 cm and intra-row spacing was 25 cm. Seeds were planted to a depth of 5-7 cm.

Methods and Times of Fertilizer Application

After the first weeding, which was done two weeks after planting, the various fertilizers blends were applied as basal. The fertilizer was applied at a rate of 60-60-60 kg ha^{-1} as basal and later the remaining 30 kg ha^{-1} N was applied as top-dressing in order to achieve the N-P_2O_5-K_2O rate of 90-60-60 kg ha^{-1}. Urea was used for top-dressing and was applied 5 weeks after planting except for NPK 20-10-10 + 3S that split application was employed at a rate of 120-60-60 kg ha^{-1}. Apart from the control, urea was used as a top dressing in all the other mineral fertilizer blends except the NPK 20-10-10 + 3S mineral fertilizer blend, which was applied both as basal and top-dressing during the growing period of the maize plant. The sideband fertilizer application method was used at a depth of 4-5 cm and 5-7 cm away from the maize plant.

Weed control

First, weeding was manually done two weeks after planting using a cutlass. A second weeding was carried out 6 weeks after planting and the third weeding in the 11th week. Manual weeding was done in all instances.

Pest control

Major pests that affected the maize were rodents (ground squirrels), pied crow and fall army-worm. There was fall army-worm infestation during the 3rd week after planting (WAP). The field was therefore sprayed using Bypel 1 at a rate of 15 g per 15 litres of water as recommended. The spraying was repeated at weekly interval for 4 weeks. Bypel was very effective against the army-worm.

Data Collection

Data collection started from site selection to harvest. Data was collected on time of land preparation, planting, germination count, plant height, total number of plants per plot, the number of cobs per plant, weight of ear, weight of dry cobs, weight of air-dried grains, empty cob weight, husk weight, biological yield, stover weight and harvest index. Information on diseases/insect attack, rainfall days and amounts, and mean daily temperatures were all collected. Lastly, an economic analysis based on VCR of the treatments was done.

Plant height determination (cm)

Five plants were randomly selected on each plot and tagged for the data collection on plant height. Plant height was measured on the 2nd, 4th, 6th, 8th, 10th and 12th week after planting and their averages were taken. Plant height was measured in centimetres using a two-meter rule.

Maize Plant Sampling and Harvesting

Maize plants within a demarcated area, 3 m^2 per plot were counted and recorded. In addition, the number of cobs per plant was also counted and recorded. The maize cobs were then harvested.

Weight of Un-Dehusked Cobs (kg) - The ears were weighed on the field soon after harvest using a mechanical weighing scale. Cobs were then transported in labelled bags for further processing.

Weight of De-husked Cobs and husk (kg) - After de-husking, the cobs and dry husk from each plot were packed into bags and weighed separately on the mechanical weighing scale.

Weight of dry Cobs (kg ha^{-1}) - The de-husked cobs that have not been shelled were dried and weighed.

Weight of shelled cobs (kg ha^{-1}) - The dried cobs weighed using the mechanical weighing scale were then shelled and the weight of shelled cobs recorded. Total weight was then estimated on a hectare basis (kg ha^{-1}).

Weight of Dry Grains (kg ha^{-1}) - The shelled grains were dried, winnowed and weighed.

Stover Weight (kg ha^{-1}) - The stover yield was measured using the weighing scale. After harvesting, the weight of the fresh stover was taken, samples were then oven-dried and weighed again. Total weight on hectare (i.e., kg ha^{-1}) basis was then estimated. Thus:

$$\text{Stover Yield (kg ha}^{-1}) = \frac{\text{Total Dry Matter (kg)}}{\text{Harvested Area (m}^2)} \times 10{,}000 \text{ m}^2$$

Grain Yield (kg ha^{-1}) - Grain yield was determined using the air-dried grain weight per plot. The grain yield on hectare (i.e., kg ha^{-1}) basis was then estimated. Thus:

$$\text{Grain yield (kg ha}^{-1}) = \frac{\text{Total Grain yield (kg)}}{\text{Harvested Area (m}^2)} \times 10{,}000 \text{ m}^2$$

$$\text{Grain yield (kg ha}^{-1}) = \frac{\text{Grain yield (kg) subplot}^{-1}}{3 \text{ m}^2} \times 10{,}000 \text{ m}^2$$

Biological yield (kg ha^{-1}) - The biological yield was calculated by summing up the grain yield, and stover. The biological yield was expressed on hectare (i.e., kg ha^{-1}) basis. Thus:

$$\text{Biological yield} = \frac{\text{Grain yield + Stover yield}}{\text{Harvested area (m}^2)} \times 10{,}000 \text{ m}^2$$

Harvest Index - Harvest index (HI) is the ratio of economic yield to total biological yield. It was calculated as grain yield/ (grain yield + stover yield).

$$\% \text{ HI} = \frac{\text{Grain yield}}{\text{Grain yield + Stover yield}} \times 100$$

Economic Analysis on Mineral Fertilizer Blends

The value cost ratio (VCR) was calculated according to Roy et al. (2006) for the determination of the rate of profitability of applied fertilizer to maize crop. The value cost ratio (VCR) is the ratio of the value of the additional crop yield obtained from fertilizer use to the cost of fertilizer used. The VCR is calculated by dividing the value of extra crop produced by the cost of fertilizer or any other nutrient sources (Roy et al., 2006). Thus:

$$\text{VCR} = \frac{x - y}{Z}$$

where:

x = value of crop produced from fertilized plots

y = value of crop produced from unfertilized plots

z = cost of fertilizer

FAO (2005) general rule for interpretation of the VCR was used.

That is:

VCR < 1 implies negative returns on investment

VCR = 1 means a positive returns on investment, but not viable

VCR $\geq$ 2 indicates a positive return on investment that is economically viable

Weather data for the period of planting (April-August)

Daily rainfall and temperature information was obtained from the

Ghana Meteorological Agency, Akim Oda. Mean values on a monthly basis were then calculated.

Data Processing and Analysis

Data collected were subjected to analysis of variance (ANOVA) using the Genstat statistical software, 12th Edition. The mean comparison was done using LSD at a 5% level of probability.

Chapter Summary

The study area is within the semi-deciduous rainforest zone. The site was laid in a Randomized Complete Block Design with five treatments and four replications. Soil samples were collected from the study site for physical and chemical analysis. Pannar 12 maize variety was planted with two seeds per hill, but later thinned to 1 plant per hill at a planting distance of 75 cm by 25 cm. The various treatments were applied at a rate of 90-60-60 kg ha^{-1}. Other cultural practices including weeding and pest control were carried out.

Data was collected on land preparation, weather, planting, germination count, plant height, weight of ear, weight of dry cobs, grain yield, shelled cob weight, stover weight, dry husk, biological yield and harvest index. Analysis of variance was performed to determine the treatments and their interaction effects for significance. The Genstat statistical software at a 5 % level of probability was used to determine the relationships between the treatments.

CHAPTER FOUR

RESULTS AND DISCUSSION

The study was carried out purposely to determine the effect of different mineral fertilizer blends on the growth and yield of maize within the Birim Central Municipality, Eastern Region, Ghana. The field was laid out in RCBD. Results were then taken from the weather (rainfall and temperature), physicochemical properties of the soil, plant growth and yield parameters. The Genstat statistical software, 12th Edition was used to analyze the data. The outcome of the results was then presented and discussed.

Weather Data

Rainfall over the growing season

The total rainfall for the growing period was 780.2 mm (but on average for 67 rainy days is 11.645mm per rain day) from Figure 2. These rains started in April and ended in August that recorded just one rainy day (Appendix 1). Similar records are reported by the Ghana Meteorological Agency - Akim Oda (as cited in the Ghana Statistical Service, 2014) that major rains starts in April and ends in July. The month of May had the highest rainfall amounts of the growing season while the least occurred in August. According to Tripathi et al. (2011) maize requires a rainfall range between 250 mm to 5000 mm per annum. The rainfall recorded over the growing season was within the rainfall requirement for maize growth, which may have positively influenced the maize grain yield.

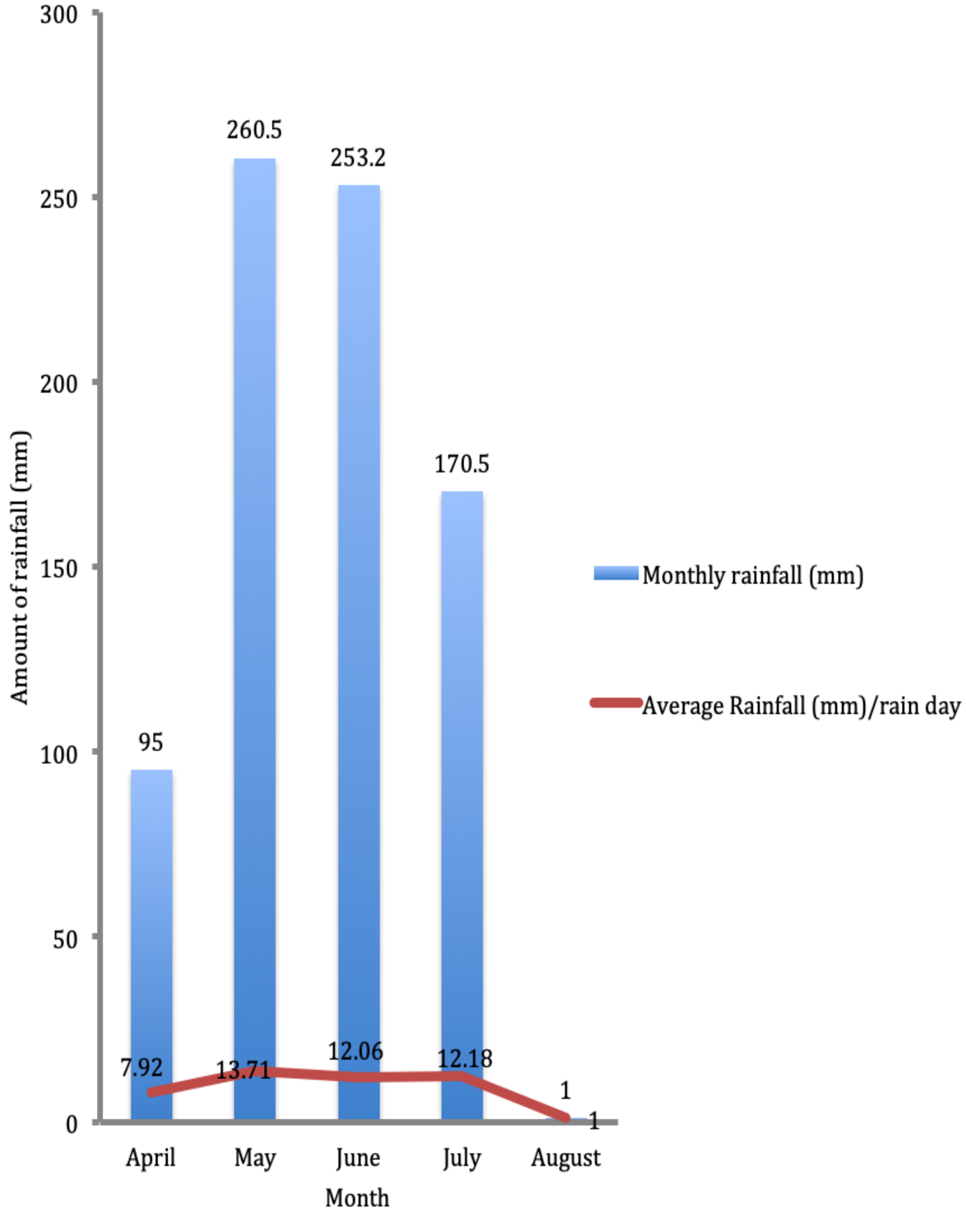

Figure 2: Monthly and average rainfall (mm) over growing season

Source: Ghana Meteorological Agency, Akim Oda

Temperature over the growing season

The temperature data is provided in Figure 3 and Appendix 2. It indicates a mean maximum temperature of 31°C and minimum of 23°C. The mean temperature across the growing period is 27°C. This value is close to the mean annual temperature of the Municipality, which is 26°C according to the Ghana Meteorological Agency, Akim Oda. The monthly maximum temperatures were recorded when the crops were at the germination and seedling stages in April, and the minimum temperatures were recorded in June during the flowering stage of the crop. Maize requires an optimum mean temperature of 21°C for germination and 32°C for growth (Naidu et al., 2006). At germination, the average temperature, which was quite high (28.8° C) may have affected the germination of the maize seeds. The average temperature recorded at the growing season (27° C) was almost equal to the recommended temperature for maize growth, therefore may have contributed to good grain formation. Naidu et al. reported that high temperature and low humidity during flowering, damage the foliage, desiccate the pollen and interfere with pollination, resulting in poor grain formation.

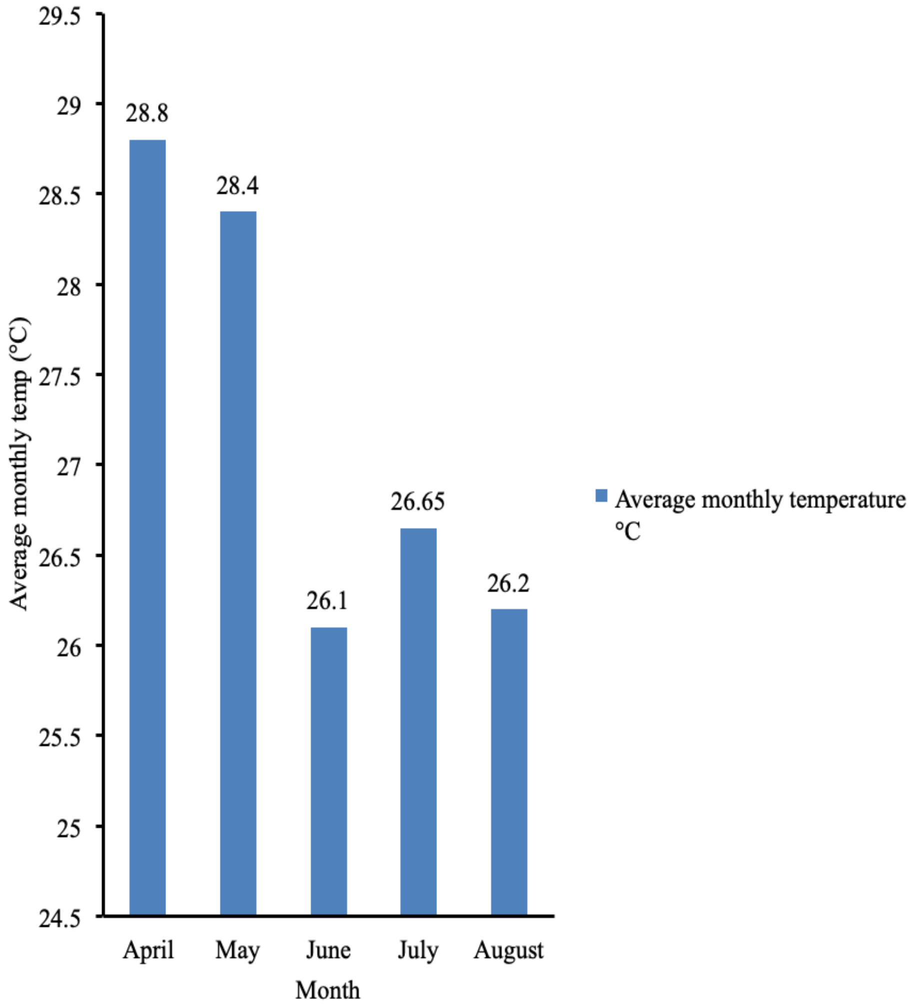

Figure 3: Monthly average temperature over the growing season

Source: Ghana Meteorological Agency, Akim Oda

Characteristics of Soils of the Experimental Site

The chemical and physical properties of the soils at the experimental site are as shown in Table 2. The soil was acidic both for the topsoil (0 -15 cm) and subsoil (15-30 cm). Organic carbon levels were quite low, thus reflecting in low N and organic matter (OM) levels. Both available phosphorus and Exchangeable potassium levels were moderately suitable, based on suitability assessment of soil for maize according to Adesemuyi

(2014). The other exchange basic cations (Ca, Mg, Na) were also very low and thus reflecting the poor and low fertility levels of the soils at the site. Topsoil secondary nutrient (S) and micronutrients (Zn and B) were also relatively low. The application of the mineral fertilizer blends significantly increased both the growth and yield parameters of the maize. Therefore, relating the soil nutrient status to Adesemuyi (2014) and Sys (1993) soil suitability assessment, maize yield would not have been better if soil amendment in a form of mineral fertilizer was not applied to the maize plants. Du Plessis (2003) reports that each ton of maize grain produced removes 15 to 18 kg of nitrogen, 2.5 to 3 kg of phosphorus and 3 to 4 kg of potassium from the soil. The state of the soil from the soil analysis cannot sustain the optimum maize grain yield. Zingore (2011) reports that the effect of no fertilizer maize cultivation over a decade indicated a decline in maize yield from 5 t ha^{-1} to 1 t ha^{-1} for the first 3 years of cultivation.

Table 2 - *Physico-chemical Properties of the Soil of Experimental Site*

Soil Parameter	Soil Depth (cm) 0-15	Soil Depth (cm) 15-30
pH 1:2.5 (water)	5.2	5.3
Organic Carbon (g kg^{-1})	11.6	6.2
Organic Matter (g kg^{-1})	20.0	10.7
Total Nitrogen (g kg^{-1})	1.3	0.7
Available Phosphorus (mg kg^{-1})	6.70	2.56
Ex. Potassium {cmol $_{(+)}$ kg^{-1}}	0.28	0.21

Source: Field data (2020)

Table 2 - *Continued*

Soil Parameter	Soil Depth (cm) 0-15	Soil Depth (cm) 15-30
Ex. Calcium {cmol $_{(+)}$ kg^{-1}}	3.20	2.98
Ex. Magnesium {cmol $_{(+)}$ kg^{-1}}	0.85	0.85
Ex. Sodium {cmol $_{(+)}$ kg^{-1}}	0.09	0.09
Ex. Acidity {cmol $_{(+)}$ kg^{-1}}	0.85	0.80
Effective CEC{cmol $_{(+)}$kg^{-1}}	5.27	4.93
Sand %	74.0	66.0
Silt %	14.0	12.0
Clay %	12.0	22.0
Texture	Sandy Loam	Sandy Clay Loam
Available sulphur (mg kg^{-1})	3.63	4.36
Boron (mg kg^{-1})	0.14	0.16
Zinc (mg kg^{-1})	2.58	11.27

Source: Field data (2020)

Effect of Fertilizer Blends on Growth Parameters

Effect of fertilizer blend type on plant height

Figure 4 shows the effect of mineral fertilizer blend type on plant height. At two weeks after basal fertilizer applications, all treatments except the control showed no significant changes in plant height. However, at 10 and 12 (eight and ten weeks after fertilizer application) there were significant changes in plant height. This is due to the uptake of the fertilizer applied, which influenced growth positively. At four week after planting, only T_3 and T_4 were taller than the control. However, at weeks 6 and 8 there were no significant differences in plant height between treatments except the control. This is due to the fact that at those times, nutrient availability for growth was enough for most treatments. Similar findings of no significant difference in maize height on week 6 and 8 have been reported for NPK (Olowoboko, Onasanya, Salami, & Azeez, 2017).

Plant height at week 10 showed a significant difference. That is the control had plants that were significantly shorter than those of T_2 and T_4. However, treatments 1, 3 and 5 were not statistically different. The NPK fertilizer blend with Zn seems to have an effect on plant height. T_4 was the second-highest may be due to the high amount of N present in the NPK mineral fertilizer blend applied through the split application both at basal and topdressing. Under low sulphur conditions, mobility is low, as the sulphur structural compound cannot be translocated and vice versa (Roy, et al., 2006). Thus with adequate sulphur, sulphate is preferentially translocated to young, actively growing leaves (Roy et al.).

However, at week 12, there were differences in plant height, as most treatments could not sustain nutrient releases for growth based on fertilizer blend type. As shown in Figure 4 during week 12 there were no differences in plant height between T_1, T_3, and T_5 on one end and T_2 and T_4 on the other. T_2 had significantly taller plants.

The NPK mineral fertilizer blends that included Zn and NPK fertilizer blend with Zinc, Sulphur and Magnesium produced similar plant height. Sulphur and magnesium had little impact on height. NPK15-20-20+0.7Zn recorded the tallest plants. Increase in plant height in response to NPK and Zn fertilizer blend application has been reported that the maximum plant height of 164.58 cm was recorded at 100% NPK + 100%Zn (Anaya, Swaroop, Smriti, & Tarence, 2019). From Figure 4, the tallest plants of maize were observed at week 12 from T_2 (15-20-20+0.7Zn), which also gave the maximum yield of grains. Law-Ogbomo and Law-Ogbomo (2009) indicated that height is directly related to grain yield. Saeed, Abbasi and Kazim (2001) also supported this claim by reporting that plant height positively correlates with plant productivity.

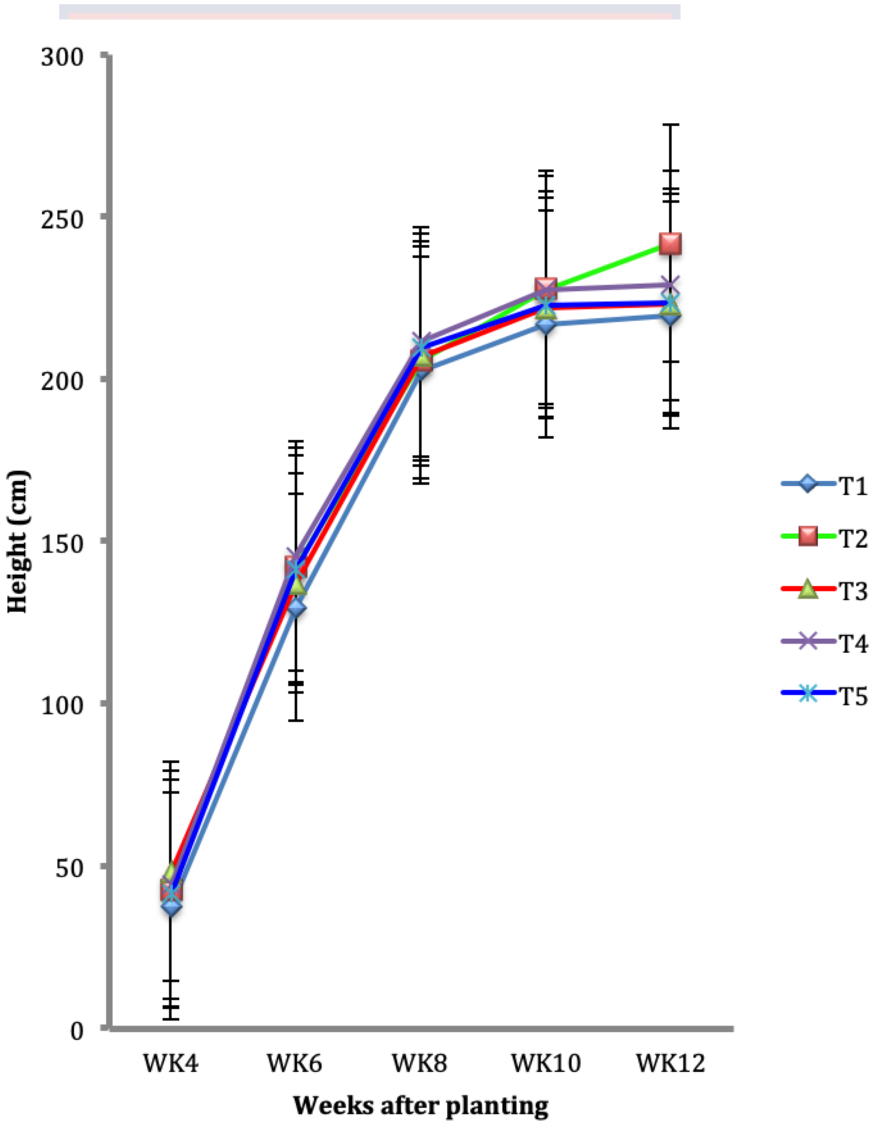

Figure 4: Effect of mineral fertilizer blend type on plant height
(T_1 - No fertilizer; T_2 - NPK 15-20-20 + 0.7Zn; T_3 - NPK 15-20-20 +1S + 0.7MgO + 0.7Zn; T_4 - NPK 20-10-10 + 3S; T_5 - NPK 15-15-15)

Stover yield

Table 3 showed that there was a significant difference in stover yield between fertilizer application and the Control ($p < 0.05$). All fertilizer-applied fields were not significantly different at the 5% probability level ($p > 0.05$). The stover yields were more similar in the fertilizer applied plots due to the NPK which better influenced the stover yield. The result showed that inclusion of the secondary and micronutrient in the NPK did not cause much influence in terms of stover yield. The nitrogen in the mineral fertilizer blends may have had equal influence on the vegetative growth of the plant hence equal stover yield. Although T_4 was split applied hence having high amount of N could not outperform the other treatments, this may be due to the S, which may rather have increased the acidity level of the soil, impacting negatively on the amount of N available for vegetative growth. Skwierawska, Zawartka and Zawadzki (1997) reported that high content of sulphur in the soil causes acidification. Leaching may have also affected sulphur influence on stover yield. Stewart (2010) reported that anions like sulfate are mobile in soils and subject to leaching.

Magnesium may also have been negatively influenced by the acidity of the soil and could not influence T_3 to outperform other treatments. Smart Fertilizer (2020) stated that in soil with low pH, the solubility of magnesium decreases reducing its availability and the tendency to leach is high because they have less exchangeable sites. Therefore, the no statistical differences between the treatments may be due to the similar synergistic interaction between the NPK causing the equal translocation of assimilates into the production of stover.

Table 3 - *Effect of Different NPK Fertilizer Blends on Stover Yield*

Treatments	Stover yield (t ha^{-1})
Control (T_1)	9.63
NPK 15-20-20 + 0.7Zn (T_2)	18.31
NPK 15-20-20 +1S + 0.7MgO +0.7Zn (T_3)	16.28
NPK 20-10-10 + 3S (T_4)	16.51
NPK 15-15-15 (T_5)	17.09
LSD (5%)	3.13
CV (%)	13.1

Source: Field data (2020)

Effect of Mineral Fertilizer Blend on Yield Components

Weight of ear (kg ha^{-1})

Table 4 shows a significant difference in weight of ears among the treatments ($p < 0.05$). Ear weight decreased in order as follows: T_2 (18708 kg ha^{-1}) > T_3 (16167 kg ha^{-1}) > T_5 (14267 kg ha^{-1}) > T_4 (10900 kg ha^{-1}) > T_1 (7767 kg ha^{-1}). The highest weight from T_2 is probably due to Zn blended with the NPK 15-20-20 influencing both ear yield of the maize. Shaikh, Susheela, Sreelatha, Shanti and Hussain (2017) reported that Zinc fertilization increased husk yield from 13.2% to 37.1% kg ha^{-1} and cob yield from 10% to 35.5% either by soil or foliar application.

Kumar, Bohra, Kumawat and Singh (2015) also reported that Zn application improved cob yield at a rate of 5 and 10 kg ha^{-1} by increasing immature cob to the tune of 7.8 and 12.8% respectively over control. Salem and El-Gizway (2012) reported that Zn singly recorded the second highest ear weight of 261.1 g and 263.7 g in 2007 and 2008, respectively after the superior performance by the combination of Zn + Mn + Fe which had ear weight of 270.7 g and 269.5 g in 2007 and 2008 respectively. T_3 (NPK 15-20-20 +1S + 0.7MgO + 0.7Zn) though had secondary and micronutrients than other treatments, it could not outperform T_2. This may be due to the sulfur increasing the acidity of the soil hence influencing negatively the availability of the other nutrients. The optimal levels of S for maize growth is between 0.2 – 0.5 % (Jones 2012). Maize responds to sulphur fertilizer application when the S value is less than the critical value of 9 mg kg^{-1} (Van Biljon, Fouche, & Botha, 2004). In addition, the acidity of the soil pH could be the cause of the declining ear weight of T_3. Thus from Table 2, the pH of the soil was 5.2 to 5.3. Jones reported that S and Mg are best available to plant roots at pH between 6.5 and 7.5, unlike Zn which is available at a pH < 5.5 but decreases at a pH of 6.5, thus increase with decreasing pH.

Table 4 - *Effect of Different NPK Fertilizer Blends on Ear Yield*

Treatments	Ear Weight ($kg\ ha^{-1}$)
Control (T_1)	7767
NPK 15-20-20 + 0.7Zn (T_2)	18708
NPK 15-20-20 +1S + 0.7MgO +0.7Zn (T_3)	16167
NPK 20-10-10 + 3S (T_4)	10900
NPK 15-15-15 (T_5)	14267
LSD (5%)	2238.8
CV (%)	10.7

Source: Field data (2020)

Weight of dry cob (unshelled) (kg ha^{-1})

The unshelled dry cob weight showed significant differences among the treatments as indicated in Table 5. The weight of T_2 (14875 kg ha^{-1}) was significantly higher than all the treatments. This was followed by T_3, T_5 and T_4 in decreasing order. The drop in weight of the dry cobs in Table 5 indicates the impact of moisture on cobs after harvesting. Drying before the shelling of cobs showed a significant drop in weight. Agoda, Saburi, Usanga, Ikotun and Isong (2011) reported that freshly harvested maize contain a large amount of moisture, and the exchange of moisture continuous between the maize grain and the surroundings until the equilibrium is reached. This will ensure that the cobs are stored for a long duration since the decrease also decreases microbial damage to the cob. Adekanye, Adegbenro and Saliu (2016) further indicated that grain drying is the process for conditioning the grains for safe storage.

Table 5 - *Effect of Different NPK Fertilizer Blends on Weight of Dry Cob*

Treatments	Weight of Unshelled Dry Cob (kg ha^{-1})
Control (T_1)	6125
NPK 15-20-20 + 0.7Zn (T_2)	14875
NPK 15-20-20 +1S + 0.7MgO +0.7Zn (T_3)	12875
NPK 20-10-10 + 3S (T_4)	8683
NPK 15-15-15 (T_5)	11483
LSD (5%)	1929.7
CV (%)	11.6

Source: Field data (2020)

Grain yield

Maize grain yield as shown in Table 6 has significant differences ($P < 0.05$) between treatments. T_2 (10625 kg ha^{-1}) gave the highest grain yield, which was significantly higher than all the other treatments. T_3 (9292 kg ha^{-1}) and T_5 (8067 kg ha^{-1}) gave grain yields, which were significantly similar but significantly higher than T_4 (6325 kg ha^{-1}) and T_1 (4117 kg ha^{-1}). Treatment 1 produced the least grain yield. The highest yield by T_2 could be probably due to Zn included in NPK fertilizer blend alone without S and Mg. Shaikh et al. (2017) reported that zinc fertilization has a beneficial effect on the physiological processes, plant metabolism and plant growth, resulting in higher yield. Liu, Zhang, Liu, Chen and Zou (2020) reported that Zinc application significantly increased maize yield by 4.2-16.7% compared with no Zn. Palai, Jena and Lenka (2020) also pointed out that maize responded positively to zinc fertilization as average yields from different locations increased from 10540 kg ha^{-1} without Zn to 11530 kg ha^{-1} with Zn at a rate of 11.21 kg Zn ha^{-1} applied as a physical blend. In addition, Palai et al. further indicated that Zn enhances dry matter and grain yield. Earlier Abunyewa and Mercer-Quarshie (2004) reported that maize grain yield increased significantly by applying 5 kg Zn ha^{-1} but increasing it to 10 kg Zn ha^{-1} did not give a corresponding yield increase.

Treatment 3 (NPK 15-20-20 +1S + 0.7 MgO +0.7Zn) though having both secondary and micronutrients could not cause the highest significant increase in yield compared to treatment two (NPK 15-20-20+0.7Zn). The magnesium in T_3 could not outperform T_2 probably due to the pH level (5.2 to 5.3 – acidic) of the site coupled with high rainfall during the growing season of the crop. Gransee and Führs (2012), and Grzebisz (2013) reported that Mg^{2+} ion easily leaches from root zones by heavy rainfall mostly in acidic soils reducing its assimilation by crops and yield increase. Also, this may be due to the low Mg level from the initial soil analysis making it less available to the maize plant. Furthermore, adequate nitrogen level in T_3 could negatively influence magnesium availability to maize. This was corroborated by Grzebisz (2013) who reported that the optimal yield from magnesium fertilizer application occur when nitrogen supply is low, but high supply of magnesium, thus magnesium induced nitrogen.

The favourable climatic conditions (temperature and rainfall) during the growing season may have also influenced the greater grain yields recorded. Optimum rainfall amounts were recorded during the reproductive phase of the crop that is from the sixth to the eighth week of growth as shown in Figure 2. Pannar (2018) indicated that the most critical time for water requirement for maize was one week before pollination up to the completion of grain filling. Yield results in excess of 12000 kg ha^{-1} are realistic for these types of hybrids if planted early (Pannar).

Table 6 - *Effect of Different NPK Fertilizer Blends on Grain Yield*

Treatments	Grain Yield (kg ha^{-1})
Control (T_1)	4117
NPK 15-20-20 + 0.7Zn (T_2)	10625
NPK 15-20-20 +1S + 0.7MgO +0.7Zn (T_3)	9292
NPK 20-10-10 + 3S (T_4)	6325
NPK 15-15-15 (T_5)	8067
LSD (5%)	1310.2
CV (%)	11.1

Source: Field data (2020)

Weight of shelled cobs

The weight of the shelled cobs showed a significant difference among treatments ($p < 0.05$) as observed in Figure 5. Cob weight increased in the order T_1 (2008 kg ha^{-1}) < T_4 (2358 kg ha^{-1}) < T_5 (3417 kg ha^{-1}) < T_3 (3585 kg ha^{-1}) < T_2 (4250 kg ha^{-1}).

Treatment 2 and 3 statistically indicated no significant differences. T_2 and T_3 although not statistically different produced the greatest empty cob weight, which could be due to the equal translation of the nutrients in the mineral fertilizer to most of the yield components especially the influence of Zn and nitrogen interaction. The increasing shelled cob weight (Figure 5) directly corresponds to the grain yield (Table 6). Thus grain yield increased with increasing shelled cob weight.

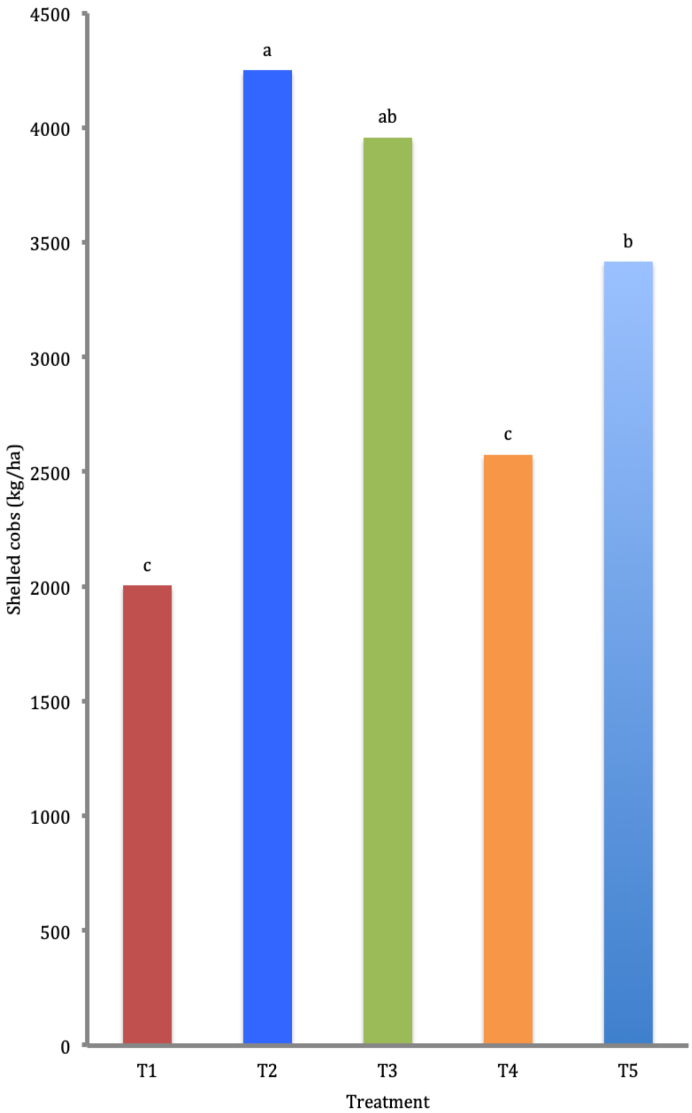

Figure 5: Effect of mineral fertilizer blend type on empty cob weight

Dry weight of husk

The maize husk (Table 7) indicated significant differences among treatments. There also exist statistical similarities between T_1 and T_4; and T_3 and T_5. The NPK 15-20-20 + 0.7Zn (T_2) produced the greatest maize husk weight, which may be due to the synergistic interaction among the nutrients.

Table 7 - *Effect of Different NPK Fertilizer Blends on Weight of Maize Husk*

Treatments	Weight of Husk (kg ha^{-1})
Control (T_1)	3650
NPK 15-20-20 + 0.7Zn (T_2)	8083
NPK 15-20-20 +1S + 0.7MgO +0.7Zn (T_3)	6875
NPK 20-10-10 + 3S (T_4)	4575
NPK 15-15-15 (T_5)	6200
LSD (5%)	1203.2
CV (%)	13.3

Source: Field data (2020)

Biological yield

There exist statistical differences between treatments (Table 8). T_3, T_4, and T_5 were statistically similar. T_1, produced the lowest biological yield while T_2 produced the greatest, although it was statistically similar to T_3 and T_5. The biological yield increase of maize may be attributed to the better interaction between the NPK. NPK interaction seems to have influenced the biological yield of maize, but with only Zn inclusion better biological yield of maize was achieved though it is statistically similar to T_3 and T_5. Alloway (2008) and Cakmak et al. (1999) outlined that Zn plays an important role in the plant by enhancing photosynthesis, improves resistance to biotic and abiotic stresses and aids in nitrogen metabolism. Therefore, Zn may have impacted positively on maize dry matter and grain yield. Palai et al. (2020) stated that maize dry matter and grain yield increase with Zn application. Also the sulphur and magnesium component in the mineral fertilizer blends could not outperform the other treatments possibly due to the leaching and pH of the soil. Karimizarchi, Aminuddin, Khanif and Radziah (2014) reported that the application of sulphur at a rate of 0.5 g kg^{-1} soil decreased soil pH level from 7.03 to 6.29, but significantly increased Mn and Zn availability by 0.38 % and 0.91 % respectively. This increased total dry weight of maize to 45.06 %. Unlike other cations, Mg is highly mobile in the soil with the tendency of leaching because it is less bound to the exchangeable site (Senbayram, Gransee, Wahle, & Thiel, 2016).

Table 8 - *Effect of Different NPK Fertilizer Blends on Biological Yield of Maize*

Treatments	Biological Yield ($kg\ ha^{-1}$)
Control (T_1)	13742
NPK 15-20-20 + 0.7Zn (T_2)	28933
NPK 15-20-20 +1S + 0.7MgO +0.7Zn (T_3)	25567
NPK 20-10-10 + 3S (T_4)	22833
NPK 15-15-15 (T_5)	25158
LSD (5%)	4062.8
CV (%)	11.3

Source: Field data (2020)

Harvest index (HI %)

There are statistical differences between the treatments (Table 9). T_2 and T_3 were statistically similar and higher than the other treatments. T_4 gave the lowest HI. T_2 (NPK 15-20-20 + 0.7Zn) and T_3 (NPK 15-20-20 +1S + 0.7MgO + 0.7Zn) produced the greatest harvest index because of the synergistic interactions between NPK and Zn especially. S and Mg could not influence treatment three to record the highest harvest index compared to other treatments, possibly due to soil pH (as explained earlier) and leaching. Acid soil with pH less than 5.4 declines in Mg availability while Al and Fe adsorb S at a lower pH (Jones, 2012). Zn plays an important role in maize pollination and that could be accounting for the higher maize yield in T_2 and T_3 (Abunyewa & Mercer-Quarshie, 2004), which will influence the economic yield of maize and impacting the same on HI. Generally, the harvest index for most tropical maize crop is 0.5 (Hay & Gilbert, 2001) while that of Pannar variety is 43% (Asselt, Battista, Kolavalli and Udry, 2018). Maize hybrid Pioneer 30-Y-87 with Zn application (2.0%) on sandy loam soil significantly improved the harvest index from 35.1% of no zinc application to 37.29% zinc application in 2010 as reported by Mohsin, Ahmad, Farooq and Ullah (2014). Bender, Haegele, Ruffo and Below (2013) also reported that Zn removal with maize grain and harvest index is the largest among all micronutrients. For instance, 308 g ha^{-1} were removed with the grain and a 62% harvest index on average for six hybrids that yielded 12 t ha^{-1} was reported (Bender et al., 2013).

Table 9 - *Effect of Different NPK Fertilizer Blends on Harvest Index*

Treatments	Harvest Index (%)
Control (T_1)	30.8
NPK 15-20-20 + 0.7Zn (T_2)	36.7
NPK 15-20-20 +1S + 0.7MgO +0.7Zn (T_3)	36.4
NPK 20-10-10 + 3S (T_4)	27.9
NPK 15-15-15 (T_5)	32.1
LSD (5%)	3.7
CV (%)	7.4

Source: Field data (2020)

Economic Analysis on Mineral Fertilizer Blends

Generally, all fertilizer treated plots (Table 10) produced a high Value cost ratio (VCR) indicating that each fertilizer will produce a viable economic return. In reference to the FAO (2005) interpretation on VCR, the fertilizer applied plots indicated a positive return on investment that is economically viable. FAO reported that VCR $\geq$ 2 indicates a positive return on investment that is economically viable.

However, the value cost ratio increased in the order of $T_4 < T_5 < T_3 < T_2$. This showed that within the municipality the economic viable return was highest in T_2, which gave VCR of 5.3. This may be due to the nutrients in T_2 translating more into grain yield than the other treatments, therefore impacting more positively on the maize grain yield. In all the mineral fertilizer blends applied, T_4 had the least VCR of 2.4. In order to achieve profit maximization in the municipality, NPK 15-20-20 + 0.7Zn at a rate of 90-60-60 kg ha^{-1} is ideal. Guo, Koo and Wood (2009) reported that a VCR > 4 help curtail price and climatic risk and ensures profitability to farmers on their investment.

Table 10 - *Economic Analysis of the Mineral Fertilizer Blends on Maize by Net Returns and Value Cost Ratio*

Treatments	Value/Cost ratio	Net Return (GHC)
Control (No fertilizer)	-	-
NPK 15-20-20 + 0.7Zn	5.3	8230
NPK 15-20-20 +1S + 0.7 MgO +0.7Zn	4.3	6658.4
NPK 20-10-10 + 3S	2.4	3514
NPK 15-15-15	3.6	5350.4

Source: Field data (2020)

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The study investigated the effect of different NPK fertilizer blends on maize yield within the Birim Central Municipality of the Eastern region. The main purpose of the study was to assess the impact of different NPK fertilizer blends on maize yield. The diversity of NPK mineral fertilizer within the municipality informed the study to be conducted in Akim Oda.

All the NPK mineral fertilizer blends positively and variedly influenced maize growth and grain yields. The blend that influenced maize growth and yield, the greatest/highest was NPK 15-20-20 + 0.7Zn (10625kg ha^{-1}). This may be due to the NPK and Zn synergistic interactions and the optimal soil pH. The NPK 15-20-20 +1S + 0.7 MgO +0.7Zn (T_3) and also NPK 15-15-15 (T_5) diversely influenced the growth and yield components of maize but were relatively inferior to NPK 15-20-20 + 0.7Zn (T_2). The blend that influenced maize growth and yields, the least/lowest was NPK 20-10-10 + 3S (6325 kg ha^{-1}). The sulphur may have increased the soil acidity, which may have negatively influenced NPK 15-20-20 +1S + 0.7 MgO +0.7Zn and NPK 20-10-10 + 3S. The rainfall positively affected the maize yield recorded, since all the critical stages of the maize growth coincided with the rains.

Economically, VCR gave varying levels of profitability from the mineral fertilizer blends ranging from 5.3 (NPK 15-20-20 + 0.7Zn) to 2.4 (NPK 20-10-10 + 3S). The mineral fertilizer blend (NPK 15-20-20 + 0.7Zn) produced the best results amongst the lot for maize production in the Birim Municipality.

These findings reject the null hypothesis that different NPK fertilizer blends have no significant effect on maize grain yield and also the fertilizer blends are equally suitable for maize production in the municipality.

Conclusions

The initial soil analysis indicated low nutrient levels. The sulphur may have increased the soil acidity. Therefore, may have negatively affected the yield of NPK 15-20-20 +1S + 0.7 MgO + 0.7Zn and NPK 20-10-10 + 3S.

The NPK mineral fertilizer blend containing Zn positively influenced all the growth and yield components of the crop. This may be as a result of the optimal pH of the soil, which enhanced better nutrient interactions of the NPK and Zn fertilizer blend.

The NPK 20-10-10 + 3S and also NPK 15-15-15 diversely influenced the growth and yield components of maize, but were not better than the other treatments. However, the NPK 15-15-15 could have outperformed the other treatments in the study area if it was blended especially with Zn.

NPK 15-20-20 + 0.7Zn produced optimum maize growth and yield components and was economically viable than the other mineral fertilizer blends.

Recommendations

From the key observations of this study, and considering the various mineral fertilizer blends in the market within the study area, it is recommended that the compound mineral fertilizer (NPK 15-20-20 + 0.7Zn) at a rate of 90-60-60 kg ha^{-1} recommended by the CSIR-SRI, should be adopted for maize production for greater grain yield. Lastly, it is also suggested that similar studies could be conducted across the different districts within the region.

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APPENDICES

Appendix 1 - *Summary of Rainfall Data over the Growing Season*

Month	Total Monthly rainfall (mm)	Number of rainy days
April	95.0	12
May	260.5	19
June	253.2	21
July	170.5	14
August	1.0	1.0

Source: Ghana Meteorological Service (2020), Akim Oda.

Appendix 2 - *Summary of Temperature Data over the Growing Season*

Month	No. of days	Monthly Average Temp °C (max)	Monthly Average Temp °C (min)	Monthly Max and Min Average Temp °C
April	30	33.8	23.8	28.8
May	31	33.6	23.2	28.4
June	30	29.4	22.8	26.1
July	31	29.8	23.5	26.65
August	20	30.7	21.7	26.2

Source: Ghana Meteorological Service (2020), Akim Oda.

Appendix 3 - *Ghana Meteorological Agency-Akim Oda Year, 2020 Rainfall and Temperature Data*

GHANA METEOROLOGICAL AGENCY YEAR 2020

STATION: AKIM - ODA **LATITUDE:** 05° 59, N **LONGITUDE:** 00° 59, W
MONTH: APRIL

Day of the month										
	Max	Min	0900		12:00		15:00			
	27.1	23.8	Dry	Wet	Dry	Wet	Dry	Wet	Rainfall	
1.	27.1	23.8							30.3	
2.	33.0	22.0							0.0	
3.	35.0	22.1							0.0	
4.	31.7	23.4							0.0	
5.	36.5	22.9							TR	
6.	33.5	25.0							0.0	
7.	34.2	25.3							0.0	
8.	35.0	25.2							0.5	
9.	35.0	24.3							TR	30.8/
10.	34.4	24.6							TR	2 DAYS
11.	34.7	23.0							TR	
12.	34.3	23.3							14.8	
13.	34.9	23.0							5.1	
14.	35.0	24.1							11.2	
15.	35.3	24.7							1.2	
16.	34.5	24.3							7.9	
17.	33.0	24.0							0.4	
18.	34.5	23.9							0.0	
19.	34.2	23.4							19.0	
20.	33.1	24.9							0.0	59.6
21.	35.0	23.5							0.3	7 DAYS
22.	33.8	23.5							TR	
23.	33.0	22.1							0.0	
24.	35.2	24.1							0.0	
25.	34.6	25.0							0.0	
26.	28.0	25.1							TR	
27.	33.0	25.7							0.0	
28.	33.4	22.8							0.0	
29.	33.5	24.5							2.5	
30.	34.6	21.9							1.8	4.6
31.	—	—							—	2 DAYS
SUM	1013.0	715.7							95.0	/12 DAYS
MEANS	33.8	23.8								

PREPARED BY: ADUAMAH JOSHUA *CHECKER BY:*

GHANA METEOROLOGICAL AGENCY YEAR 2020

STATION: AKIM-ODA **LATITUDE:** 05°56IN **LONGITUDE:** 00° 59IW
MONTH: MAY

Day of the month	Max	Min	0900 Dry	Wet	12:00 Dry	Wet	15:00 Dry	Wet	Rainfall	
1.	35.2	23.6							0.0	
2.	36.0	24.1							0.0	
3.	34.5	24.0							11.4	
4.	32.5	23.4							0.9	
5.	34.5	23.4							0.0	
6.	34.1	24.9							2.8	
7.	35.4	24.9							1.3	
8.	34.5	23.6							8.4	
9.	34.0	23.9							5.2	
10.	35.0	23.6							8.5	38.5
11.	32.7	23.6							TR	7 DAYS
12.	33.1	23.3							0.0	
13.	34.8	24.1							0.0	
14.	35.2	24.6							0.0	
15.	35.2	24.4							10.4	
16.	34.6	23.4							5.8	
17.	33.8	23.0							1.1	
18.	33.5	22.8							1.0	
19.	34.2	23.5							21.9	
20.	32.9	23.1							0.0	40.2
21.	32.8	24.5							0.0	5 DAYS
22.	32.4	21.1							11.2	
23.	33.9	23.4							11.8	
24.	32.4	24.3							3.0	
25.	29.5	24.3							65.6	
26.	32.3	21.1							6.0	
27.	32.9	24.5							4.0	
28.	33.1	23.8							56.2	
29.	31.2	22.2							TR	
30.	32.0	23.6							30.0	
31.	32.7	22.1							0.0	181.8
SUM	1041.1	719.2							260.5mm	7 DAYS
MEANS	33.6	23.2							19 DAYS	

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GHANA METEOROLOGICAL AGENCY YEAR 2020

STATION: AKim - ODA LATITUDE: 05° 56'N LONGITUDE: 00° 59'W
MONTH: JUNE

Day of the month										
	Max	Min	0900		12:00		15:00			
			Dry	Wet	Dry	Wet	Dry	Wet	Rainfall	
1.	33.5	24.8							3.8	
2.	30.5	22.8							0.0	
3.	33.7	22.3							0.0	
4.	33.4	24.2							3.5	
5.	31.1	22.9							0.0	
6.	32.3	22.9							1.6	
7.	31.1	22.6							0.0	
8.	34.0	23.9							0.3	
9.	30.5	25.1							20.0	
10.	30.9	21.9							83.5	112.7
11.	30.5	21.9							0.0	6 DAYS
12.	30.5	21.6							2.6	
13.	29.4	24.0							3.1	
14.	31.6	23.8							0.0	
15.	32.0	23.9							0.0	
16.	32.9	24.9							0.0	
17.	31.1	24.6							1.0	
18.	29.1	24.4							6.7	
19.	30.5	23.8							0.4	
20.	31.7	24.4							22.8	36.6
21.	30.2	21.6							0.0	6 DAYS
22.	29.2	23.8							2.0	
23.	29.7	23.7							16.7	
24.	31.0	24.1							0.4	
25.	32.0	24.3							0.7	
26.	30.2	24.5							43.4	
27.	29.5	21.5							10.4	
28.	28.6	22.4							20.4	
29.	26.2	23.2							9.2	
30.	26.5	22.8							0.7	103.9
31.	—	—							—	9 DAYS
SUM	923.4	727.0							253.2mm	
MEANS	29.8	23.5							21 DAYS	

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GHANA METEOROLOGICAL AGENCY YEAR 2020

STATION: AKIM-ODA **LATITUDE:** 05°56'N **LONGITUDE:** 00°59'W
MONTH: JULY

Day of the month										
	Max	Min	0900		12:00		15:00			
			Dry	Wet	Dry	Wet	Dry	Wet	Rainfall	
1.	29.5	23.4							1.0	
2.	30.5	23.7							0.0	
3.	29.5	23.2							1.9	
4.	27.4	23.5							102.5	
5.	30.3	21.9							0.1	
6.	30.1	23.4							0.0	
7.	308	23.1							0.0	
8.	28.0	23.5							0.2	
9.	27.5	23.4							0.4	
10.	28.2	23.1							1.5	113.6
11.	27.9	23.0							1.5	7 DAY
12.	27.9	22.8							3.0	
13.	289	22.9							5.8	
14.	28.0	23.5							TR	
15.	29.4	22.1							3.0	
16.	29.9	21.3							0.0	
17.	27.6	21.1							0.0	
18.	30.0	22.6							TR	
19.	31.0	23.1							4.6	
20.	31.6	23.0							0.7	18.6
21.	29.6	23.2							38.3	6 DAY
22.	30.0	22.8							0.0	
23.	30.6	23.2							0.0	
24.	30.7	23.2							0.0	
25.	31.5	22.6							0.0	
26.	28.0	22.1							0.0	
27.	28.5	22.2							0.0	
28.	30.6	22.2							0.0	
29.	29.8	22.1							TR	
30.	29.8	21.8							0.0	
31.	29.8	22.8							0.0	38.3
SUM	9129	7058							170.5	1 DA
MEANS	29.4	22.8							14DAYS	

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GHANA METEOROLOGICAL AGENCY YEAR 2020

STATION: AKIM – ODA LATITUDE: 05°56IN LONGITUDE: 00°59'IW
MONTH: AUGUST

Day of the month										
	Max	Min	0900		12:00		15:00			
			Dry	Wet	Dry	Wet	Dry	Wet	Rainfall	
1.	30.5	22.7							0.0	
2.	31.0	22.1							0.0	
3.	30.4	22.1							0.0	
4.	32.8	18.5							0.0	
5.	29.9	20.0							0.0	
6.	31.1	18.7							0.0	
7.	28.0	21.4							0.0	
8.	29.0	21.8							0.0	
9.	31.5	22.0							0.0	
10.	30.0	21.3							0.0	0.0
11.	30.2	21.3							0.0	
12.	29.9	21.3							0.0	
13.	33.0	21.1							0.0	
14.	28.4	21.9							TR	
15.	29.8	23.4							1.0	
16.	33.9	22.2							0.0	
17.	31.1	22.4							0.0	
18.	30.4	22.8							TR	
19.	32.8	23.5							0.0	
20.	31.2	23.1							0.0	1.0
21.										1 DAY
22.										
23.										
24.										
25.										
26.										
27.										
28.										
29.										
30.										
31.										
SUM	614.9	433.6								
MEANS	30.745	21.68								

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Appendix 4 - *Analysis of Variance-Plant Height (cm)*

Variate: Height (2)

Variation	d.f.	s.s	m.s	v.r	F.pr
Rep	3	59.66	19.89	1.09	
Treatment	4	98.61	24.65	1.35	0.308
Residual	12	219.34	18.28		
Total	19	377.61			

Source: Field data (2020)

Appendix 4 -*Continued*

Variate: Height (4)

Variation	d.f.	s.s	m.s	v.r	F.pr
Rep	3	151.57	50.52	2.41	
Treatment	4	237.50	59.37	2.84	0.072
Residual	12	251.09	20.92		
Total	19	640.16			

Source: Field data (2020)

Appendix 4 - *Continued*

Variate: Height (6)

Variation	d.f.	s.s	m.s	v.r	F.pr
Rep	3	2371.2	790.4	2.83	
Treatment	4	587.3	146.8	0.52	0.720
Residual	12	3356.7	279.7		
Total	19	6315.2			

Source: Field data (2020)

Appendix 4 - *Continued*

Variate: Height (8)

Variation	d.f.	s.s	m.s	v.r	F.pr
Rep	3	839.25	279.75	6.06	
Treatment	4	184.67	46.17	1.00	0.445
Residual	12	553.54	46.13		

Total	19	1577.46

Source: Field data (2020)

Appendix 4 - *Continued*

Variate: Height (10)

Variation	d.f.	s.s	m.s	v.r	F.pr
Rep	3	6.83	2.28	0.08	
Treatment	4	309.15	77.29	2.78	0.076
Residual	12	334.17	27.85		
Total	19	650.15			

Source: Field data (2020)

Appendix 4 - *Continued*

Variate: Height (12)

Variation	d.f.	s.s	m.s	v.r	F.pr
Rep	3	408.3	136.1	1.23	
Treatment	4	1205.3	301.3	2.73	0.080
Residual	12	1326.5	110.5		
Total	19	2940.2			

Source: Field data (2020)

Appendix 5 - *Analysis of Variance on Stover Weight (kg ha^{-1})*

Variation	d.f.	s.s	m.s	v.r	F.pr
Rep	3	29739278	9913093	2.40	
Treatment	4	186136444	46534111	11.26	<.001
Residual	12	49598222	4133185.		
Total	19	265473944.			

Source: Field data (2020)

Appendix 6 - *Analysis of Variance on Cob weight (Ear weight) kg ha^{-1}*

Variation	d.f.	s.s	m.s	v.r	F.pr
Rep	3	1533056	511019	0.24	
Treatment	4	297750889	74437722	35.25	<.001
Residual	12	25338889	2111574.		
Total	19	324622833			

Source: Field data (2020)

Appendix 7 - *Analysis of Variance on Dry cob/Unshelled Dry Cob wt (kg ha^{-1})*

Variation	d.f.	s.s	m.s	v.r	F.pr
Rep	3	1201056.	400352.	0.26	
Treatment	4	190855000	47713750.	30.41	<.001
Residual	12	18825889	1568824.		
Total	19	210881944.			

Source: Field data (2020)

Appendix 8 - *Analysis of Variance on Grain yield / Dry Grain Yield (kg ha^{-1})*

Variation	d.f.	s.s	m.s	v.r	F.pr
Rep	3	725056.	241685	0.33	
Treatment	4	103813000.	25953250	35.89	<.001
Residual	12	8678556.	723213		
Total	19	113216611.			

Source: Field data (2020)

Appendix 9 - *Analysis of Variance on Empty Cob (kg ha^{-1})*

Variation	d.f.	s.s	m.s	v.r	F.pr
Rep	3	1531819	510606	1.97	
Treatment	4	14147278	3536819	13.65	<.001
Residual	12	3108944	259079		
Total	19	18788042			

Source: Field data (2020)

Appendix 10 - *Analysis of Variance on Husk weight (kg ha^{-1})*

Variation	d.f.	s.s	m.s	v.r	F.pr
Rep	3	365111	121704	0.20	
Treatment	4	50491889	12622972	20.70	<.001
Residual	12	7318778	609898		
Total	19	58175778			

Source: Field data (2020)

Appendix 11 - *Analysis of Variance on Biological yield (kg ha^{-1})*

Variation	d.f.	s.s	m.s	v.r	F.pr
Rep	3	32969333	0989778	1.58	
Treatment	4	527563667	131890917	18.97	<.001
Residual	12	83447889.	6953991		
Total	19	643980889			

Source: Field data (2020)

Appendix 12 - *Analysis of variance on Harvest Index (HI)*

Variation	d.f.	s.s	m.s	v.r	F.pr
Rep	3	0.0068399	0.0022800	3.88	
Treatment	4	0.0227523	0.0056881	9.67	<.001
Residual	12	0.0070583	0.0005882		
Total	19	0.0366505			

Source: Field data (2020)

Appendix 13 - *Calculation of Fertilizer Application Rate*

Amount of fertilizer (Q) required for a given area is

$$\frac{R\ (kg/ha) \times Area\ (m^2)}{100 \times C}$$

Where;

R= Recommended rate

C= % concentration of nutrient element

A= Area to be fertilized in m^2

Using the rate 90-60-60 kg ha^{-1}

Treatment 2

NPK 15-20-20 + 0.7Zn + Urea

$$\frac{60}{0.2}$$

= 300 kg ha^{-1}

```
  90-60-60
- 45-60-60
  45-00-00
```

45 kg must be supplied by urea

$$\frac{45 \times 100}{46}$$

= 97.8261 kg

Treatment 3

NPK 15-20-20 +1S + 0.7 MgO +0.7Zn + Urea

$$\frac{60}{0.2}$$

= 300 kg ha^{-1}

```
  90-60-60
- 45-60-60
  45-00-00
```

45 kg must be supplied by urea

$$\frac{45 \times 100}{46}$$

= 97.8261 kg

Treatment 4 (Split Application)

Rate 120-60-60

NPK 20-10-10 + 3S

$$\frac{60}{0.1}$$

= 600 kg ha^{-1}

120-60-60

- 120-60-60

000-00-00

Treatment 5

NPK 15-15-15 + Urea

$$\frac{60}{0.15}$$

= 400 kg ha^{-1}

90-60-60

- 60-60-60

30-00-00

30 kg must be supplied by urea

$$\frac{30 \times 100}{46}$$

= 65.2174 kg

Appendix 14 - *Fertilizer Manufacturers Application Rate*

Crop (Maize) and Fertilizer	Rate of Application kg ha^{-1}	Basal kg ha^{-1}	Top Dressing kg ha^{-1}
NPK 15-20-20 + 0.7Zn Urea	90-60-60	300	 100
NPK 15-20-20 + 1S + 0.7MgO + 0.7Zn Urea	90-60-60	300	 100
NPK 20-10-10 + 3S Spit Application	120-60-60	300	 300
NPK 15-15-15 Urea	90-60-60	400	 65

Source: Chemico Ghana, Omnifert Ghana and Yara Ghana (2020)

Appendix 15 - *Economic Analysis (Value Cost Ratio)*

Treatment	T1	T2	T3	T4	T5
Grain yield (kg ha^{-1})	4117 kg ha^{-1}	10625 kg ha^{-1}	9292 kg ha^{-1}	6325 kg ha^{-1}	8067 kg ha^{-1}
Converting grain yield to 100kg per bag	41.17 bags	106.25 bags	92.92 bags	63.25 bags	80.67 bags
Sales from maize for each treatment (2019) 100kg per bag =GHC120	T1= 4940.4	T2= 12750	T3= 11150.4	T4= 7590	T5= 9680.4
Material cost	566	1776	1776	1418	1638
Labour cost	1450	1600	1600	1600	1600
Other costs	884	1144	1116	1058	1092
Total production cost (GHC)	2900	4520	4492	4076	4330
Gross profit (GHC)	4940.4	12750	11150.4	7590	9680.4
Net profit (GHC)	2040.4	8230	6658.4	3514	5350.4
Cost of Fertilizer (fertilizer + transportation + application cost)		1210+250 = 1460	1210+250 =1460	852+250 = 1102	1072 + 250 = 1322
VCR = $\frac{x - y}{Z}$	_	$\frac{12750-4940.4}{1460}$	$\frac{11150.4-4940.4}{1460}$	$\frac{7590-4940.4}{1102}$	$\frac{9680.4-4940.4}{1322}$
VCR	_	5.3	4.3	2.4	3.6

VCR- value cost ratio

Source of maize price – Esoko food prices database in Ghana (2019)

(100kg per bag =GHC120), Dollar rate (August, 2019) $1 = GHC5.859