

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

**EFFECTS OF DIFFERENT RATES OF GRANULAR AND
BRIQUETTE NPK AND UREA FERTILIZERS ON
GROWTH AND YIELD OF MAIZE (*Zea mays* L.)**

**BOAKYE, FRANCIS ASMAH
(MASTER OF PHILOSOPHY CROP SCIENCE
(AGRONOMY))**

2024

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



**EFFECTS OF DIFFERENT RATES OF GRANULAR AND BRIQUETTE NPK AND
UREA FERTILIZERS ON GROWTH AND YIELD OF MAIZE (*Zea mays* L.)**

**BOAKYE, FRANCIS ASMAH
(8211970018)**

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

JULY, 2024

DECLARATION

STUDENT'S DECLARATION

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

Candidate's Name: Boakye, Francis Asmah

Signature.....

Date.....

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 Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

Principal Supervisor's Name: Prof. (Mrs.) Margaret Esi Essilfie

Signature.....

Date.....

Co-supervisor's Name: Prof. Harrison Kwame Dapaah

Signature.....

Date.....

ACKNOWLEDGEMENTS

I thank the Almighty God for protection, guidance, care and mercy in enabling me to complete my studies. I wish to acknowledge my thesis supervisors, Prof. (Mrs.) Margaret Esi Essilfie and Prof. Harrison K. Dapaah who found time out of their busy schedule to offer constructive criticism and also gave words of encouragement to make this thesis complete. To my brother Prophet Jacob Obeng I am much grateful to you for physical and spiritual encouragement you gave during my academic journey, I say God richly bless you. I cannot forget to thank you to my best friend and a sister Owusua Antwi Baah. God bless you so much for your advice and love you showed to me.

To my wonderful course mate and friends, I am very grateful to you all, I say God bless you for your guidelines and moral support you gave me during the research work.

My sincere appreciation goes to Mr. William Asante Asiedu, a Principal Chief Technician in the Department of Crop Science, University of Ghana, Legon, Accra who assisted in data analysis and contributed meaningfully to this thesis. I say God richly bless you.

Finally, my special thanks go to my research work sponsors Fertilizer Research and Responsible Implementation (FERARI) in collaboration with International Fertilizer Development Centre (IFDC), who gave me this opportunity under the FERARI Project funds and inputs for the field trials provided through IFDC.

DEDICATION

This thesis is dedicated to the Almighty God and my mentor Prof. (Mrs.) Margaret Esi Essilfie and my lovely mother Akosua Manu.

TABLE OF CONTENTS

DECLARATION	iii
ACKNOWLEDGEMENTS	iv
DEDICATION	v
TABLE OF CONTENTS	vi
LIST OF TABLES	xi
LIST OF FIGURES	xiii
LIST OF ABBREVIATIONS	xiv
ABSTRACT	xvi
CHAPTER ONE: INTRODUCTION	1
1.1 Background of study	1
1.2 Problem statement and Justification	2
1.3 Objectives of the study.....	5
<i>1.3.1 Main objective</i>	5
<i>1.3.2 Specific objectives</i>	5
CHAPTER TWO: LITERATURE REVIEW	6
2.1 Origin and Distribution	6
2.2 Botany	7
<i>2.2.1 Leaves</i>	8
2.3 Varieties	10
2.4 Uses and Nutritional value	12
2.5 Production Estimate	14
2.6 Climatic and Soil Requirements	15
<i>2.6.1 Climatic Requirements</i>	15
<i>2.6.2 Soil Requirement</i>	17
2.7 Crop Propagation	17
2.8 Agronomic Practices	18
<i>2.8.1 Fertilizer Application</i>	18
2.8.2 Pest and disease control	20
<i>2.8.3 Fall Armyworm</i>	21
<i>2.8.4 Weed Control</i>	22

2.9 Harvesting	22
2.10 Effect of Inorganic Fertilizer (NPK) on Chemical Properties	23
2.11 Effect of Nitrogen on growth and yield of maize	23
2.12 Effect of phosphorus	25
2.13 Effect of potassium	26
2.14 Effect of inorganic fertilizer briquette on maize yield	26
CHAPTER THREE: MATERIALS AND METHODS	31
3.1 Experimental sites and Location	31
3.1.1 Bunuso Experimental Site	31
3.1.2 Ejura Sekyedumase Experimental Site	31
3.2 Soil type and vegetation	32
3.2.1 Soil type and vegetation at Bunuso experimental site	32
3.2.1 Soil type and vegetation at the experimental site of Ejura	32
3.3 Experimental Design and Treatment	33
3.4 Planting material	35
3.5 Land Preparation and Planting	35
3.6 Soil Sampling	35
3.7 Protocol for soil physical and chemical properties	36
3.7.1 Soil physical properties	36
3.7.1.1 Bulk Density	36
3.7.1.2 Total Porosity	36
3.7.1.3 Volumetric Moisture	36
3.7.2 Soil chemical Analysis	37
3.7.2.1 Measured parameters	37
3.7.2.2 Determination of pH	37
3.7.2.3 Determination of available phosphorus	37
3.7.2.4 Determination of total nitrogen	38
3.7.2.5 Indophenol blue method	39
3.7.2.6 Exchangeable Cations	39
3.7.2.6.1 Calcium and Magnesium	39
3.7.2.6.2 Potassium and Sodium	40
3.8 Cultural Practices	40
3.8.1 Weed control	40

3.8.2 Fertilizer Application	41
3.8.3 Pest and Disease control.....	41
3.9 Data Collected.....	42
3.9.1 Phenological data	42
3.9.1.1 Percentage Plant Establishment	42
3.9.1.2 Days to 50% Tasseling.....	42
3.9.1.3 Days to 50 % Silking	42
3.9.1.4 Days to 50 % maturity	42
3.9.2.1 Crop Growth Rate (CGR)	42
3.9.3 Vegetative Growth Data.....	43
3.9.3.1 Plant height	43
3.9.3.2 Number of leaves per plant	43
3.9.3.4 Dry Matter Accumulation	44
3.9.3.5 Leaf chlorophyll content	44
3.9.4 Yield and Yield Components	44
3.9.4.1 Number of plants harvested	44
3.9.4.2 Number of cobs per plot.....	44
3.9.4.3 Number of damaged cobs per plot	44
3.9.4.4 Number of seeds per cob	45
3.9.4.5 Cob length (cm).....	45
3.9.4.6 Cob diameter.....	45
3.9.4.8 Dehusked cob weight per plot.....	45
3.9.4.9 Stover weight per plant (g).....	45
3.9.4.10 Total stover weight (g) per plot.....	46
3.9.4.11 100-Seed weight (g)	46
3.9.4.12 Total grain weight per plot	46
3.9.4.13 Grain Yield (tons/ha).....	46
3.10 Statistical Analysis.....	46
CHAPTER FOUR: RESULTS	48
4.1 Initial soil chemical properties	48
4.2 Initial Soil Physical Properties	49
4.4 Climatic Conditions during the experimental period.....	53
4.5 Phenology of maize.....	54

4.5.1 Percentage plant establishment	54
4.5.2 Days to 50% tasseling	55
4.5.4 Days to 50% silking	56
4.5.5 Days to 50 % maturity	57
4.6 Growth Analysis	58
4.6.1 Crop growth rate (CGR).....	58
4.6.2 Relative Growth Rate	60
4.7 Vegetative Growth	61
4.7.1 Plant height	61
4.7.2 Number of leaves per plant	63
4.7.4 Sixth (6 th) Leaf chlorophyll content.....	66
4.7.5 Shoot dry weight two weeks before and after tasseling of maize.....	68
4.7.6 Root dry weight two weeks before and after tasseling of maize	69
4.8 Yield and yield components of maize.....	71
4.8.1 Number of plants harvested per plot.....	71
4.8.2 Number of cobs per plot.....	72
4.8.3 Number of damaged cobs per plot	73
4.8.4 Number of seeds per cob	74
4.8.5 Cob length (cm).....	75
4.8.6 Cob diameter (cm)	75
4.8.7 Undehusked cob weight per plot.....	76
4.8.8 Dehusk Cob weight per plot.....	77
4.8.9 Stover weight per plant at harvest	78
4.7.10 Total stover weight per plot at harvest	79
4.8.11 100-seed weight (g).....	80
4.8.12 Total grain weight per plot (kg).....	81
4.8.13 Grain Yield.....	82
CHAPTER FIVE: DISCUSSION.....	84
5.1 Effect of different rates of granular briquette NPK and Urea fertilizers on Soil Conditions at both Experimental Sites.....	84
5.2 Phenology of maize as influenced by different rates of granular and briquette NPK and Urea fertilizers.....	85

5.3 Effect of different rates of granular and briquette NPK and Urea fertilizers on vegetative growth of maize	88
5.4 Effect of different rates of granular and briquette NPK and Urea fertilizers on yield and yield components of maize.....	89
CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS	92
6.1 Conclusion	92
6.2 Recommendations	94
REFERENCES.....	96
APPENDICES	121

LIST OF TABLES

Table 3.1: Treatment details of granule and Briquette fertilizers	34
Table 4.1: Initial Soil Chemical Properties at Bunuso and Ejura Experimental Sites.....	49
Table 4.2: Initial Soil physical properties at Bunuso and Ejura Experimental Sites	50
Table 4.3: Soil Chemical Properties at Bunuso and Ejura experimental sites after application of NPK briquette and granular fertilizer during 2022 major season.....	51
Table 4.4: Soil Chemical Properties at Bunuso and Ejura experimental sites after application of NPK briquette and granular fertilizer during 2022 major season.....	52
Table 4.5: Climatic Data for Bunuso Site during 2022 major season	53
Table 4.6: Climatic Data for Ejura during 2022 major season	54
Table 4.7 Percentage plant establishment as influenced by different rates of briquette and granule NPK fertilizers at Bunuso and Ejura during 2022 major season	55
Table 4.8 Days to 50% tasseling and days to 50% silking as influenced by different rates of briquette and granule NPK fertilizers at Bunuso and Ejura during 2022 major season	57
Table 4.9: Effect of different rates of briquette and granular NPK fertilizer on days to 50 % maturity of maize at Bunuso and Ejura during 2022 major season.....	58
Table 4.10 Crop growth rate as influenced by different rates of briquette and granule NPK fertilizers at Bunuso and Ejura from 0-8 WAP and 8-10 WAP during 2022 major season	60
Table 4.11 Relative growth rate as influenced by different rates of briquette and granule NPK fertilizers at Bunuso and Ejura from 0-8 WAP and 8-10 WAP during major season	61
Table 4.12 Shoot dry weight two weeks before and after tasseling of maize as influenced by different rates of briquette and granule NPK fertilizers at Bunuso and Ejura during 2022 major season	69
Table 4.13 Root dry weight two weeks before and after tasseling of maize as influenced by different rates of briquette and granular NPK fertilizer at Bunuso and Ejura during 2022 major season	71

Table 4.14 Number of plants harvested per plot and number of cobs per plot as influenced by different rates of briquette and granule NPK fertilizer at Bunuso and Ejura during 2022 major season	73
Table 4.15 Number of damaged cobs per plot and number of seeds per cob as influenced by different rates of briquette and granularNPK fertilizer at Bunuso and Ejura during 2022 major season	74
Table 4.16 Cob length (cm) and cob diameter (cm) as influenced by different rates of granular and briquette NPK fertilizer at Bunuso and Ejura during 2022 major season	76
Table 4.17 Undehusked cob weight per plot (kg) and dehusk cob weight per plot (kg) as influenced by different rates of granular and briquette NPK fertilizer at Bunuso and Ejura during 2022 major season.....	78
Table 4.18 Stover weight per plant (kg) and total stover weight per plot (kg) as influenced by different rates of briquette and granular NPK fertilizer at Bunuso and Ejura during 2022 major season	80
Table 4.19 100-seed weight (g) and total grain weight per plot as influenced by different rates granular and briquette of NPK fertilizer at Bunuso and Ejura during 2022 major season	82
Table 4.20 Grain yield (t ha ⁻¹) and harvest index as influenced by different rates of briquette and granular NPK fertilizer at Bunuso and Ejura	83

LIST OF FIGURES

Fig 4.1: Plant height of maize as influenced by different rates of briquette and granule NPK fertilizer at Bunuso during 2022 major season	62
Fig 4.2: Plant height of maize as influenced by different rates of briquette and granules NPK fertilizer at Ejura during 2022 major season	63
Fig 4.3: Number of leaves per maize plant as influenced by different rates of briquette and granule NPK fertilizer at Bunuso during 2022 major season	64
Fig 4.4: Number of leaves per maize plant as influenced by different rates of briquette and granule NPK fertilizers at Ejura during 2022 major season	64
Fig 4.5: Fifth (5 th) Leaf chlorophyll content of maize as influenced by different rates of briquette and granule NPK fertilizer at Bunuso during 2022 major season.....	65
Fig 4.6: Fifth (5 th) Leaf chlorophyll content of maize as influenced by different rates of briquette and granule NPK fertilizer at Ejura during 2022 major season	66
Fig 4.7: Sixth (6 th) Leaf chlorophyll content of maize as influenced by different rates of briquette and granule NPK fertilizer at Bunuso during 2022 major season.....	67
Fig 4.8: Sixth (6 th) Leaf chlorophyll content of maize as influenced by different rates of briquette and granule NPK fertilizer at Ejura during 2022 major season	67

LIST OF ABBREVIATIONS

QPM	-	Quality protein maize
MoFA	-	Ministry of Food and Agriculture
WAP	-	Weeks after Planting
SARI	-	Savannah Agricultural Research Institute
AGRA	-	Alliance for Green Revolution in Africa
CRI	-	Crops Research Institute
OPV	-	Open pollinated variety
MAFAP	-	Monitoring Africa Food and Agriculture policies
NPK	-	Nitrogen, Phosphorus and Potassium
USA	-	United State of America
FAW	-	Fall Armyworm
FAO	-	Food and Agriculture Organization
IFDC	-	International Fertilizer Development Center
CEC	-	Cation exchange capacity
TEB	-	Total Exchangeable Base
CM	-	Centimeters
CV	-	Coefficient of Variation
ECEC	-	Exchangeable Cation Exchange Capacity
GMA	-	Ghana Meteorological Agency
Na	-	Sodium
NH ₃	-	Ammonia
°C	-	Degree Celsius
C	-	Carbon
Ca	-	Calcium

Org. C	-	Organic Carbon
Org. M	-	Organic Matter
P ₂ O ₅	-	Phosphorus pentoxide
ml	-	milliliters
mm	-	millimeters
KG	-	kilogram
WP	-	Wettable Powder
CGR	-	Crop Growth Rate
RGR	-	Relative Growth Rate

ABSTRACT

Two field experiments were conducted at Bunuso in Mampong - Ashanti Municipal and at Ejura Agricultural College crop farm in the Ejura- Sekyedumasi Municipality during the major rainy season from April 2022 to July 2022. The objective of the study was to determine the effects of different rates of granular and briquette NPK and urea fertilizers on growth and yield of maize. The experimental design used for the two studies was a Randomized Complete Block Design (RCBD), with seven treatments and each replicated four times. The treatments were: (1) Control (No fertilizer), (2) Granule (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha), (3) Briquette (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha), (4) Briquette (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha), (5) Briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha), (6) Briquette (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha) and (7) Briquette (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha). The results showed that the application of NPK and urea fertilizers granular and briquettes form to the soil at the two experimental sites improved soil organic matter, soil water holding capacity, nitrogen, pH, calcium, magnesium and potassium which resulted in the availability of nutrients in the soil needed for optimal plant yield. The results revealed that, application of granular (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha) to maize tasseled and silked earlier across both locations. At Bunuso maize plants that received briquette (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha) had significantly taller plant height from 5 to 7 WAP and briquette (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha) had the tallest plants from 9 to 11 WAP. The no fertilizer (control) treatment produced the shortest plant heights across the growing period at both locations. The briquette (31-32-31 kg/ha NPK) + Briq urea (33.2 kg/ha) fertilizer produced significantly higher total stover weight per plot than Granular (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha) at Bunuso. Maize plants that received different rates of NPK + briquette urea fertilizer had higher grain yield than plant

that received granular NPK + urea fertilizer and the control across both locations. The application of briquette fertilizer (94-65-62 kg/ha NPK) + BriqUrea (66 kg/ha) at Bunuso and Ejura had the highest crop growth rate from 0-8 WAP and 8-10 WAP and were significantly different from the control. However, the briquette fertilizer (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha) had the highest Relative growth rate from 0-8 WAP across both locations and significantly different from the control. Briquette NPK (124-40-38 kg/ha) + Briq urea (100 kg/ha) gave the highest yield at Bunuso, while Briquette (116-48-46 kg/ha) + Briq urea (100 kg/ha) and Briquette (31-32-31 kg/ha) + Briq urea (33.2 kg/ha) gave the highest yield at Ejura. It is recommended that for increased maize yield farmers are encouraged to apply briquette NPK (124-40-48 kg/ha) + Briq urea (100 kg/ha) in briquette form. Further research should be conducted at different agro ecological zones of Ghana with more appropriate fertilizer formulations to increase the efficiency of fertilizer for optimize maize yield.

CHAPTER ONE: INTRODUCTION

1.1 Background of study

Maize (*Zea mays* L) is an important cereal food crop of the world with highest production and productivity as compared to rice and wheat. It is the most versatile crop which is being grown in more than 166 countries across the globe including tropical, sub-tropical and temperate regions (Azam, 2019). Based on area and production, maize is ranked the third most important cereal crop after wheat and rice in the world (Kling *et al.*, 2016; FAO, 2015). Maize is an important food security crop; it serves as cash crop and recently replacing some crops, such as sorghum in the northern region of Ghana, as the most consumed cereal. Maize is one of the major cereal crops grown in the humid tropics and sub-Saharan Africa.

Maize crop is a key source of food and livelihood for millions of people in many countries of the world. It is produced extensively in Ghana, where it is consumed roasted, baked, fried and fermented (Agbato, 2019). In advanced countries, it is an important source of many industrial products such as corn sugar, corn oil, corn flour, starch, syrup, brewer's grit and alcohol (Dutt, 2020). Maize is a major component of livestock feed and it is palatable to poultry, cattle and pigs as it supplies them energy (Iken *et al.*, 2015). The stalk, leaves, grain and immature ears are cherished by different species of livestock (Dutt, 2020). In Ghana, maize is produced predominantly by smallholder resource farmers under rain-fed conditions (SARI, 2019). In spite of the increasing relevance and high demand for maize in Ghana, yield across the country continues to decrease with an average of about 2 t/ha which is the lowest African yield recorded (Mahapatra *et al.*, 2018). Maize production is worldwide and has been a staple food for most people in the different parts of the world. In Ghana, maize is the most important staple and food security crop and it accounts for

more than 50 % of total cereal production and the second important commodity crop the country after cocoa (Kaur *et al.*, 2020). It is cultivated in all agro-ecological zones of Ghana but grows best in deep and well-drained loamy soils (MoFA, 2019). Of all the major food crops grown in 2020 to 2022, maize occupied the largest proportion of 50- 60 % in terms of total area cultivated (MoFA, 2022). Smallholder farmers produce 90 % of maize in Ghana (AGRA, 2022). Maize has wider uses than any other cereal (Vashist, 2021). Maize is an important crop that is grown in all the major agro-ecologies, and farmers are advised to apply inorganic fertilizers (N, P and K) to increase yield.

Maize is a major source of calories provider in Ghana, and report indicated that it has nearly replaced sorghum and pearl millet as traditional staple crops in northern Ghana (Vashist, 2021). The average yearly maize production was reported to be 4.8 million MT in 2019 to 2021 (Darfour and Rosentrater, 2021) with an average yield of about 2.3 t/ha (Tagne *et al.*, 2021). In Ghana, maize is the most important staple food produced and consumed leading to an increase in production since 1965 (Wakene *et al.* 2016). According to Vann *et al.* (2015). The increased use of chemical fertilizer today is rapidly making the soil infertile, forcing many farmers to further increase their use of chemical fertilizers. Soils in Ghana are low in fertility, and it is important to apply external fertilizers to promote growth and yield of crops.

1.2 Problem statement and Justification

Maize production worldwide is around 75 million tons in 2022, representing 7.5% of world maize production (Badu-Apraku *et al.*, 2019). In Africa, maize accounts for roughly 24% of farmland, with an average production of 2 tons per hectare per year (Sang, 2021). The per capital consumption of maize in Ghana in 2022 was estimated at 42.5 kg (Savant *et*

al., 2022) and an estimated national consumption of 943000 Mt in 2022 (Smith *et al.* 2022). The production estimate of maize in Ghana for the past (4) years from 2019- 2023 is 13,486 metric tonnes (Chand, 2022). The increase in maize production is related to an increase in productivity, even considering the increase in cultivated area. Whilst in 2019 maize productivity was 2,588.3 kg ha⁻¹, in 2022 in Ghana it was 4,178 kg ha⁻¹ (an increase of 61.43 %) (Chand, 2022).

Although the average productivity in the last harvests in 2016 has been between 3,500 and 5,396 kg ha⁻¹ (Chand, 2022), these values are low compared with the average productivity in the USA (where maize productivity exceeds 8,500 kg ha⁻¹). Maize consumption has risen tremendously, in recent years and millions of people around the world rely on it as a staple food (FAO, 2022). Maize is a good source of carbohydrate, vitamin A and B, protein, iron, and minerals when eaten as grain or as a snack or cereal. According to FAOSTATS (2015), demand for maize, particularly white maize, is high due to population growth and rising per capita consumption in both Ghana and many other countries in sub-Saharan Africa. Maize demand is increasing day by day as food for human consumption, fodder for livestock and feed for poultry, fuel and raw materials for industry (Tajul *et al.*, 2013; Ahmed, 2019). Maize can be consumed directly as green cob, roasted or boiled cob or popped grain. Its grain can be used for human consumption in various ways, such as corn meal, fried grain and flour. Maize oil is used as the best quality edible oil.

Despite anthropogenic factors such as inappropriate land use systems, mono cropping, nutrient mining and inadequate supply of nutrients are considered to have aggravated the situation. These anthropogenic factors, especially those associated with the loss of major and minor soil nutrients require appropriate remedy to restore the fertility of the soil for

enhanced growth and yield of maize. However, poor and peasant farmers in sub-Saharan Africa may not be able to afford the cost of procuring separate inorganic fertilizers to apply to their fields. Besides, there is limited special minor nutrient formulation for farmers in sub-Saharan Africa. This calls for formulated granular fertilizer into a single fertilizer briquette by farmers for plant growth (Paliwal, 2011). Poor soil fertility has been cited as a major constraint affecting maize growth and yield. Inorganic fertilizer releases its nutrients rapidly which help in plant growth unlike in organic fertilizer which releases nutrients gradually (Ogunlade *et al.*, 2016). In Ghana and other tropical countries, research interest recently is shifted to utilization of inorganic fertilizer as nutrient source in crop production.

Most farmers use granular fertilizer haphazardly, since information available on the doses and timing of fertilizer application on maize are few. The surface applied granular has been observed to lose up to 35% of its nitrogen; whereas, buried briquettes only lose about 4% of their nitrogen, which is a significant gain in N use efficiency (IFDC, 2019). Fertilizer management is crucial for maize cultivation (Baral *et al.*, 2015). To eliminate the problem of low yield in maize, nutrient management is an option as it utilizes available inorganic nutrients to build ecologically sound and economically viable farming system (Arif *et al.*, 2017).

Inorganic fertilizer provides readily available nutrients for plant growth and subsequent yield. Inorganic fertilizers are used to provide soil nutrients in order to maintain optimum soil fertility and healthy growth of plants and high yield. Application of N, P and K fertilizer in acid soil and nutrient depleted soil resulted in change in pH from 6.2 to 5.8 (Alam *et al.* 2018). The NPK fertilizer briquettes can be used in a variety of ways, and can

be buried by hand using a hand-driven plough. However, an account by Adu-Gyamfi *et al.* (2019) indicated that, maize plants cultivated in Ghana's savanna agro-ecological zones recovered 77 % N of the applied fertilizer with the use of fertilizer briquettes, resulted in a 23 % increase in maize production over split use of granular fertilizer. Kanouo *et al.*, (2018) found that employing multi-nutrient fertilizer briquettes resulted in a nutrient utilization efficiency of N, compared to granular or prilled fertilizer sources in comparison to the typical farmer practice of applying granular fertilizer.

1.3 Objectives of the study

1.3.1 Main objective

The main objective of the study is to determine the growth and yield response of maize to different rates of NPK granular and briquettes fertilizer application.

1.3.2 Specific objectives

The specific objectives were to:

1. Determine the effect of different rates of granular and briquette NPK fertilizer on soil physical and chemical properties.
2. Assess the effect of different rates of granular and briquette NPK fertilizer on phenology, growth and yield of maize.
3. Evaluate, the effectiveness of granular and briquette NPK fertilizer on physiological growth parameters of maize.

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin and Distribution

Maize originated from the Mesoamerican region, which is now Mexico and Central America. Evidence from archaeology shows that for over 6000 years, maize was domesticated in the regions of southwestern United States, Mexico and Central America. The Portuguese also introduced maize to India and to China and later it was introduced to Philippines and the East Indies (Clerk, 2018). Maize is now widely grown in many countries including USA, China, Brazil, Argentina, Mexico, South Africa, Rumania, Yugoslavia and India. Maize was later introduced to Spain after the return of Columbus from America, and from Spain, it went to France, Italy and Turkey (Dowswell, 2019). Research in the early 21st century has modified this view, scholars now indicate the adjacent Balsas River Valley of south-central Mexico as the center of domestication (Piperno and Dolores, 2011).

Maize is a direct domestication of a Mexican wild annual grass strain of teosinate (*Zea mays parviglumis*) which is native to the Balsas River valley of Southern Mexico (Cruz-Cárdenas *et al.*, 2021). The 12% of maize genetic material is obtained from *Zea mays Mexicana* through introgression; it is derived from hybridization between a small domesticated maize (a slightly changed form of wild maize) and teosinate of section *Luxuriantes*, either *Z. luxurians* or *Z. diploperennis*. Recent genetic evidence suggests that maize production occurred 9000 years ago in Central Mexico (Shiferaw *et al.*, 2017). The crop is well adapted and grows in most of the ecological zones of Ghana including the northern savannah. It provides a major source of calories in many parts of Ghana. It has nearly replaced traditional staple crops such as sorghum and pearl millet in northern

Ghana. An average maize grain yield on farmers' fields is about 1.7 t/ha as against an estimated achievable yield of about 6.0 t/ha (MoFA, 2011).

2.2 Botany

The maize plant is often 3 m in height, though some natural strains can grow 13 m tall (Karl, 2018). A leaf, which grows from each node, is generally 9 cm in width and 120 cm in length. Ears develop above few of the leaves in the midsection of the plant, between the stem and leaf sheath, elongating around 3 millimeters per day, to a length of 18 cm with 60 cm being the maximum alleged in the subspecies (Karl, 2018). There are female inflorescences, tightly enveloped by several layers of ear leaves commonly called husks. Certain varieties of maize have been bred to produce many additional developed ears. This is the source of the "baby corn" used as a vegetable in Asian cuisine. The maize inflorescence consists of the tassel and the ear. The ear develops from lateral branches from auxiliary shoot buds on the stalk and produces silk receptive to pollens.

The male inflorescence (tassel) produces anthers from spikelets which emerge from the florets. The anther produces pollen grains. A tassel can produce roughly seven thousand anthers on average. Research suggests that each tassel can produce fourteen million pollen grains (DeHaan *et al.*, 2016). Environmental conditions such as cool temperatures and high humidity are suitable for pollen shed and pollen longevity. Pollen shed by tassel are captured by the fine sticky hair on the silk resulting into fertilization which eventually develop into cob (DeHaan *et al.*, 2016). The permanent maize root system consists of adventitious and prop roots. Adventitious roots develop in a crown of roots from nodes below the soil surface. Normally four to six adventitious roots are formed per band. After tasselling, prop roots develop into bands from the first two to three aerial nodes (Cassman,

2018). If root growth is not restricted, the root system of a mature plant extends approximately 1.5 m laterally and downwards to approximately 2.0 m or even deeper. The plant has a profusely branched, fine root system. Under optimal conditions, the total root length, excluding the root hairs, can reach 1500 m, numerous root hairs occur on young plants (Yawalkar *et al.*, 2015). The lateral shoot bearing the main ear develops more or less from the bud on the eighth node above the soil surface. The five or six buds directly below the bud give rise to rudimentary lateral shoots of which one or two develop to produce ears (Kellogg, 2015). The internodes directly below the first four leaves do not lengthen, whereas those below the sixth, seventh and eighth leaves lengthen to approximately 25-, 50- and 90-mm. Maize stem varies in height from less than 0.6 m in some genotypes to more than 5.0 m in extreme cases in others. The stem is cylindrical, solid and is clearly divided into nodes and internodes. It may have eight to 21 internodes (Onuk *et al.*, 2017).

2.2.1 Leaves

Stomata occur in rows along the entire leaf surface. More stomata occur on the underside of the leaf than on the upper surface. On the upper surface motor cells are present. The maize leaf is a typical grass leaf and consists of a sheath, ligules, auricles and a blade. The leaf blade is long, narrow, undulating and tapers towards the tip and is glabrous to hairy (Phutthai & Hughes, 2017). The leaf is supported by a prominent mid-rib along its entire length. During moist conditions, these cells rapidly absorb water, become turgid and unfold the leaf. During warm, dry weather, the cells quickly lose their turgor with the result that leaves curl inwards exposing a smaller leaf surface to evaporation. Leaves that may form, are arranged spirally on the stem, and they occur alternately in two opposite rows on the stem and about 8 to 20 leaves (Lebot, 2020).

Male and female flowers are borne on the same plant as separate inflorescences. Male flowers are borne in the tassel and female flowers on the ear. The maize ear (the female inflorescence) terminates one or more lateral branches, usually halfway up the stem. Bracts enclose the ear. The silk of the flowers at the bottom appears first and thereafter those on the upper part of the ear. It remains receptive to pollen for approximately three weeks but after the tenth day, receptivity decreases (Lithourgidis *et al.*, 2011). The maize kernel consists of an endosperm, embryo, a pericarp and tip cap. The endosperm contains the main carbohydrates. The embryo contains the parts that give rise to the next generation, while the pericarp and tip cap enclose the entire kernel. Kernels can be of the dent or flint (round) types. Dent kernels have a dented crown, which is formed during drying when the softer starch in the middle of the kernel shrinks faster than the outer more translucent sides. The dent kernel has two flat sides opposite each other and the one side contains the embryo (Price & Nguyen, 2016).

The maize inflorescence consists of the tassel and the ear. The ear develops from lateral branches from auxiliary shoot buds on the stalk and produces silk receptive to pollens. The male inflorescence (tassel) produces anthers from spikelets which emerge from the florets. The anther produces pollen grains. A tassel can produce roughly seven thousand anthers on average. Research suggests that each tassel can produce fourteen million pollen grains (DeHaan *et al.*, 2016). Environmental conditions such as cool temperatures and high humidity are suitable for pollen shed and pollen longevity. Pollen shed by tassel are captured by the fine sticky hair on the silk resulting into fertilization which eventually develop into cob (DeHaan *et al.*, 2016).

2.3 Varieties

Maize is classified as dent corn, flint corn, popcorn, flour corn, sweet corn and Indian corn. The dent corn is the most widely grown maize while sweet corn is mainly meant for human consumption. Maize can be classified on the basis of its protein content and hardness of the kernel. These include popcorn, flint, flour, Indian and sweet corn (Mauricio, 2017). Flint maize kernels are characterized by their high percentage of hard endosperm and small soft Centre. Flint maize is grown predominantly in Latin America and Europe for food. Dent maize is the most commonly grown for grain and silage, and is the predominant type grown in the USA. Hard endosperm is present on the sides and base of the kernel. The remainder of the kernel is filled with soft starch; when the grain starts drying the soft starch at the top of the kernel contracts, producing the depression for which it is named.

Varieties of maize grown in Ghana include; "*obatanpa*", "*aburotia*" "*dobidi*" "*mamaba*" "*dadaba*" and "*okomasa*". In addition, extra-early maturing and quality protein maize varieties tolerant of drought and resistant to weeds have been released to farmers. They are ; Golden Jubilee and "*Aziga*" (meaning big egg in Ewe). In 1992, the variety *Obatanpa* (literally means a good nursing mother) which is larger in yield and early maturing was researched into by the Crops Research Institute of Ghana (CRI) to combat the global famine which was fast spreading. It is a white dent, streak resistant quality protein maize.

The most peculiar attribute of this quality is that it has superior nutritional quality than normal maize grown in Ghana and elsewhere. Though it has 10% protein just like any other maize, its protein has higher level of lysine and tryptopan unlike others. *Obatanpa* is well adapted to the growing conditions in the low land tropics and has been adopted extensively in Northern Ghana and many other parts of the country as well as many other

African countries (Egyir *et al.*, 2015). In the major season of 2012, *Obatanpa* was by far the dominant variety of maize and was planted in 41 percent of maize producing areas in Ghana. It has become more popular over the years, from 16 percent adoption in 1997 to 40 percent in 2013. Varietal improvement and testing done by CRI and SARI focus on high yield, protein content (that is, quality protein maize [QPM]), tolerance to pests and disease (mainly blight, rust, streak, and stem borers), *Striga resistance*, kernel type, lodging resistance, and early maturity. Six general varieties of maize are differentiated by the characteristics of the kernel. Maize comes in a variety of cultivars, each with its own set of features based on the endosperm and grain component. These include the following; Flint maize seed, these are maize varieties with a high portion of hard endosperm and little soft starch. It has early maturing, robust cultivars with a nutritive value (protein) but poor producing yields. Southern Europe, Asia, and South and Central America are the primary producers.

It comes in a variety of colours, including white, yellow, red-blue, and their variations. Flint is primarily grown for human consumption (Loussaert *et al.* 2018). Sweet maize, the grains possess a recessive gene that prevents the conversion of translocated sugar into starch resulting in grains with a glossy sweetish endosperm in this group of maize cultivars. They are mostly grown for human use and harvested 18 to 20 days following pollination, when the moisture level is around 70 %. Vitamins C and A are abundant in it. The majority of cultivars are grown in the United States of America (Marschner & Dell 2018). In waxy maize, the starch is totally made up of amylopectin, rather than the customary 70 % amylopectin and 30 % amylose. As a result, they are employed for industrial uses (Ziegler, 2019). Dent corn is the leading type of corn grown on Ghanaian farms (Ghanbari *et al.*, 2019). The sides of the kernel consist of hard, so-called horny starch, and the crown

contains soft starch. As the grain matures, this soft starch shrinks, forming the characteristic dent. In flint corn, the horny starch extends over the top of the kernel, so there is no denting. Popcorn, a light, highly popular snack throughout the United States, is a variant of flint corn with small hard kernels. When heated, the moisture in the kernels expands, causing the kernels to pop open. Flour corn contains a preponderance of soft or less densely packed starch, and it is readily ground into meal. (Liu & Rosentrater, 2016). Four varieties were released in 2012 in Ghana: three of them were high-yield, QPM hybrids (Mamaba, Cida-ba, and Dada-ba), and the other was an extra-early-maturing open-pollinated variety (OPV) (Dodzi). Four varieties were again released in 2007; two were high-yield, QPM, open-pollinated yellow maize varieties (Aziga and Golden Jubilee); one was an extra-early maturing, QPM, drought-tolerant variety (Akposoe); and the other was a QPM, drought-tolerant hybrid variety (Etubi). In 2010, another set of four varieties was released: QPM hybrid (Enibi). In total, five hybrid varieties were developed and released by CRI and SARI, namely, Mamaba, Cida-ba, Dada-ba, Etubi, and Enibi. In 2012, six varieties were officially released: five hybrids and one OPV with pro-vitamin A. Private companies have also begun promoting hybrid maize varieties in Ghana (Ragasa *et al.*, 2017).

2.4 Uses and Nutritional value

Maize demand is increasing day by day as food for human consumption, fodder for livestock and feed for poultry, fuel and raw materials for industry (Tajul *et al.*, 2013). Maize can be consumed directly as green cob, roasted cob or popped grain. Its grain can be used for human consumption in various ways, such as corn meal, fried grain and flour. Maize oil is used for edible oil. Green parts of the plant and grain are used as livestock and poultry feed, respectively. Stover and dry leaves are used as good fuel (Ahmed, 2019). The

starch grain can be made into adhesives and syrup. The high-fructose maize syrup is used as a preservative, thickener and sweetener. The husk is used to wrap food whilst the cobs and stover are used as bio-fuels (Idoko *et al.*, 2018). Industrially, maize provides raw materials for food industry world over. Maize is used in manufacturing corn starch, glucose, corn syrup, dextrin, food sweeteners, alcoholic beverages and used in the preparation of lubricants, soaps, salad oil, and fuel (Rouf *et al.*, 2016). The bulk of maize produced in Ghana is consumed in every household and it is arguably the most important crop for cash and food security because every household in Ghana consumes it. It is estimated that 85% of all maize grown in Ghana is consumed by humans and the remaining 15 % is used for the animal feed preparation (mainly poultry) (Angelucci, 2020). It contributes about 20 % of calories to the Ghanaian diet (Brimoh & Vlek, 2018). In 2015, the per capital consumption of maize in Ghana was estimated at 42.5 kg (MoFA, 2019) and in 2016 at 43.8 kg/capita (MoFA, 2016) whilst the national consumption of maize was projected at 943,000 Mt in 2016 (SRID, 2017).

The maize grain contains calories and protein and is used to formulate food for babies (Miller & Welch, 2013). Whole grain of maize may contain up to 10% protein, 80-90% soluble starch, 1-2% crude fibre (Van Zyl *et al.*, 2021). Maize gives kwashiorkor to children when fed to them in a form of porridge without protein. *Obatanpa* rather nourishes children when they are fed to them as a result of the presence of the two amino acids which are low in cereals such as maize (Adu *et al.*, 2017). The maize seed endosperm contains approximately 80 % of the carbohydrates, 20 % of the fat and 25 % of the minerals, while the embryo contains about 80 % of the fat, 75 % of the minerals and 20 % of the protein found in the kernel (Ogindo *et al.*, 2018). In essence corn is used in three major areas, such as in human nutrition (21%) in animal feed (72%) and in the industrial sector (7%)

(Ardelean *et al.*, 2017). The grain starch can be made into adhesives and syrup. The high-fructose maize syrup is used as a preservative, thickener and sweetener. The husk is used to wrap food whilst the cobs and stovers are used as bio-fuels (Idoko *et al.*, 2018). Maize has a great utility in agro-industry for the production of corn syrup, soft drink, juice, beer, chewing gum, candy, chips, corn flakes and starch.

2.5 Production Estimate

Maize is widely cultivated throughout the world, and a greater weight of maize is produced each year than any other grain. In 2014, total world production was 1.04 billion tons, led by the United States with 35% of the total. China produced 21% of the global total. In 2016, maize production was forecast to be over 15 billion tons, an increase of 11 % over 2014 American production. Based on conditions as of August 2016, the expected yield would be the highest ever for the United States. The area of harvested maize was forecast to be 87 million, an increase of 7 % over 2015, Maize is especially popular in Midwestern states such as Indiana and Illinois, in the latter, it was named the state's official grain in 2017 (Janssen *et al.*, 2017).

Maize was introduced to Ghana by the Portuguese in the 16th century and ever since, the land area for maize production has been increasing every year. It is cultivated by majority of people in all the five agro-ecological zones in the country (Callo-Concha *et al.*, 2013). The increase in maize production is related to an increase in productivity, even considering the increase in cultivated area. In 2020 maize productivity was 2,588.3 kg ha⁻¹, in 2016 in Ghana it was 4,178 kg ha⁻¹ (decline of 61.43%) (Zheng *et al.*, 2020). Although the average productivity in the last harvests has been between 3,500 and 5,396 kg ha⁻¹ (Artuzo *et al.*, 2018), these values are low compared with the average productivity in the USA (where

maize productivity exceeds 9,000 kg ha⁻¹). In addition, maize productivity varies between the different Brazilian states, which may be explained by the technological level of production (Coelho *et al.*, 2013). Maize production is also concentrated in the Center-West and South Brazilian regions: in 2016, Mato Grosso, Parana, and Goias were respectively, the largest producers. Historically, these states are among those with the highest yields (Ribera *et al.*, 2020). Maize is the largest staple crop in Ghana and contributes significantly to consumer diets. It is the number one crop in terms of area planted (about 1,000,000 hectares) and accounts for 50-60% of total cereal production. Additionally, maize represents the second largest commodity crop in the country after cocoa.

Maize is one of the most important crops for Ghana's agricultural sector and for food security (Jensen *et al.*, 2020). With regard to the high production regions of maize, according to MoFA, (2011), maize is grown throughout Ghana. However, the leading producing areas are mainly in the middle southern part (Brong, Ahafo, Eastern and Ashanti Region where 84 % of the maize is grown, with the remaining 16 percent being grown in the northern regions of the country (Northern, Upper East and Upper West Regions). The total maize production in Ghana is about 70 % by small holder farmers. Maize average yield reported by Ministry of food and Agriculture in 2020 was 1.7 Mt/ha against an estimated achievable yield of around 6 Mt/ha (MoFA, 2020).

2.6 Climatic and Soil Requirements

2.6.1 Climatic Requirements

Maize has remarkable adaptability to a wide range of environmental conditions. It is adapted to different climatic conditions hence more extensively distributed over the earth than any other cereal crop. Maize crop is primarily a warm season crop and it is grown in

wide range of climatic conditions (Zeidan *et al.*, 2016). Maize grows best under sub-tropical conditions of 21 °C to 28 °C (Kankam-Boadu *et al.*, 2018). Maize is grown in tropical, sub-tropical and temperate climates and tolerates a wide range of temperatures (from 35 to 45 °C), However, highest production, occurs between 21 °C and 27 °C. Very low or high temperatures can have a detrimental impact on yield. Although the minimum temperature for germination is 10 °C, germination is faster and less variable at soil temperatures of 16 to 18 °C. At 20 °C with good soil moisture, maize emerges within five to six days (Merino-Martín *et al.*, 2017). Frost may also cause destruction to maize at all stages of growth and frost-free periods of 120 to 140 days prevent damage (Vitassem & Rebetez, 2018).

Morel *et al.* (2016) observed that maximum temperatures greater than 32 °C during the period of tasseling and pollination increased rapidly the differentiation process of the reproductive parts that resulted in higher rates of kernel abortion and yield. However, the crop is cold-intolerant, in the temperate zone's maize must be planted in the spring. Its system is generally shallow, so the plant is dependent on soil moisture. As a plant that uses C₄ carbon fixation, maize is a considerably more water-efficient crop than plants that use C₃ carbon fixation up to five weeks, but thereafter it is very susceptible. Maize is most sensitive to drought at the time of silk emergence, when the flowers are ready for pollination. The importance of sufficient soil moisture is shown in many parts of Africa, where periodic drought regularly causes maize crop failure and consequent famine. Although it is grown mainly in wet, hot climates, it has been said to thrive in cold, hot, dry or wet conditions, meaning that it is an extremely versatile crop (Fernandez *et al.*, 2011). In the tropics, the growth duration of adapted genotypes is commonly 90-110 days, and up to 140 days for the late maturing ones (Mahad, 2018). The relatively short growth duration

is primarily due to sensitivity to the day length. This affects the extent of vegetative growth, flower induction, production of viable pollen, length of tasseling, cob filling and maturity characteristics (Hatfield & Prueger, 2015).

2.6.2 Soil Requirement

The most suitable soil for maize is one with a good effective depth, favourable physical properties, good internal drainage and an optimal moisture regime, sufficient and balanced quantities of plant nutrients and chemical properties. Although large-scale maize production takes place on soils with a clay content of less than 10 % (sandy soils) or in excess of 30 % (clay and clay-loam soils), the texture classes between 10 and 30 % have air and moisture regimes that are optimal for healthy maize production. Maize needs a pH of 5.8 – 7.0. The field should be limed if the pH is 6.0 or lower. If the soil magnesium index is 0 or 1 the use of magnesium limestone should be considered (Sahu, 2016).

2.7 Crop Propagation

In most regions today, maize grown in residential gardens is still often planted manually with a hoe, whereas maize grown commercially is planted with a planter. Planting maize early is important for the crop to utilize the entire growing season and consequently maximize yield. It is always safe to plant after rains have established. Uniformity of seedling emergence depends on seed quality (viability, purity), seed treatment against soil-borne pathogens, proper planting methods (depth and spacing) and correct seedling rate (ARC-Grain crop, 2013). When planting maize varieties of different maturity groups, start with late to intermediate maturing varieties, and then plant early and extra-early ones late (Mann *et al.*, 2019). The optimum planting density of maize should be adjusted according to local conditions and types of varieties to be grown. During planting, rope or sighting

poles should be used to mark the beginning and end of rows to enable you plant in lines. Seeding rates depend on soil-fertility levels, plant spacing and expected germination rates. If early maturing varieties are to be planted, 75 cm should be left between every two rows and 40 cm between stands. For intermediate to late maturing varieties, 80 cm between every two rows and 40 cm between stands should be left. Use cutlass, hoe or a stick to make a hole, 5-7 cm deep. Plant 2-4 seeds per hole depending on the germination test. Cover the hole with soil and step as recommended in Production Practices for Maize in Ghana (Yasmin *et al.*, 2016).

2.8 Agronomic Practices

2.8.1 Fertilizer Application

Fertilizer nutrient application in Ghana is approximately 8 kg/ha (FAO, 2018) while depletion rates range from about 40 to 60 kg of nitrogen, phosphorus, and potassium (NPK) ha⁻¹ year⁻¹ (FAO, 2018). Maize responds well to the application of organic manure, which improves the physical conditions of the soil and its water retention capacity. Mineral fertilizers will allow a quick start of the vegetative growth and supply nutritional needs during the active plant growth. Maize production depends heavily on mineral fertilizer, which is sometimes supplemented by manure and by rotation with legumes. Maize has a high requirement for nutrients, especially nitrogen (N), phosphorus (P) and potassium (K). Among these major nutrients, N is the one that most often limits yield. It determines the number of leaves the plants produces and the number of seeds per cob, and therefore determines yield potential. The amount of mineral fertilizer to apply varies with the P and K content of the soil and its moisture content (CSIR/AGRA, 2016).

In addition, optimal fertilizer requirement for maize depends on the productive potential of the variety, the previous cropping history, cultural practices adopted and general fertility of the field. In general, rates of applications per hectare in Ghana average around 90 kg N, 60 kg P₂O₅ and 60 kg K₂O. However, fertilizer N level up to 120 kg/ha is recommended for cultivation in degraded soil (CSIR/AGRA, 2016). Beside the rate applied, application method and timing is also critical to ensuring maximum benefit from using these fertilizers. Nitrogen easily leaches through the soil; therefore, the total amount of nitrogen fertilizer required should be split between two in-crop applications to ensure nitrogen availability throughout the critical growth stages of the crop for improved yield. In most cases, all the P and K and about two-thirds of the N are applied basally, with the rest of the N top-dressed later.

The application of N-P-K compound fertilizer (60-60-60 kg/ha as N, P₂O₅ and K₂O) within 7-10 days after planting and top-dressed with 30 kg N/ha at 4-6 weeks after planting 4 weeks for early maturing varieties or 6 weeks for intermediate to late maturing varieties. The number of bags of each fertilizer needed per hectare depends on the amount of N, P and K contained in the grade of fertilizer purchased (Albrecht, 2020). Fertilizer application should be carried out after weeding so that weeds do not benefit from applied fertilizers. Integrated use of mineral and organic fertilizers should be employed to maximize economic yield and to improve the physical, chemical and biological properties of the soil. Crop rotation strategies as well as intercropping maize with legumes can be used to maintain soil fertility. Growing cowpea, groundnut and soya bean before maize will add residual nitrogen to the soil, which can then be utilized by maize (Titterton *et al.*, 2016).

The optimum utilization of nutrients such as potassium, phosphorus and other elements are facilitated by nitrogen. Therefore, nitrogen deficiency can result in reduced maize yield. There have been several figures by different authors on maize nitrogen requirements depending on environmental factors like irrigation, varieties, soil type, cropping history of the field and expected yield. For example, Singh *et al.* (2018) reported that N at 180 kg/ha and 200 kg/ha are optimum for maize yield. In another study conducted, an application of 50, 100 and 150 kg/ha N with 60 kg/ha P increased crop yield. Increased in maize grain yield with an increased in the rates of nitrogen application have been reported by (Aflakpui *et al.*, 2018). The best time to minimize the effect of weeds on maize yield is when maize is in the 2-9 leaf stage. Weeding twice or three time suppresses weed growth, increase yield of maize and maximizes profit in maize production (Dogan *et al.*, 2015)

2.8.2 Pest and disease control

Maize is most susceptible to damage by insects during the crop establishment phase when soil insects can cause up to 30 % losses and necessitate replanting of the crop, and from silking to harvest (Farrell & O'Keeffe, 2015). The most common insect pests of maize are stalk/stem borers, fall armyworms, grasshopper and termites. These pests are controlled by the application of insecticides such as Kilsect 2.5 EC, Karat, Batelic, Actelic and Endosulfan preferably at the hatching areas when the nymphs are young (Martin *et al.*, 2017). Cultural control measures such as early planting, the use of resistant varieties and the burning of stalks after harvest can also control the insect infestation by breaking their life cycle. Birds, cane rat, squirrels, rats, frogs and monkeys often cause various damages to the plant. The squirrels, frogs and crows remove seeds and seedlings sown from the soil, the cane rat chews the stovers and ears whilst the monkeys and birds destroy ears and grains. The birds, squirrels and frogs can be scared by erecting statues and noise making

structures on the farm immediately after sowing seeds. Moreover, strips of paper rolled into cups can be used to cover ears to prevent birds from having access to the ears to damage. The rodents can be controlled by scaring, poisoning or trapping. Diseases such as smut, rust, bacterial blight, and streak affect maize. These diseases can be controlled by the use of chemicals, seed selection and the removal of alternative host. To minimize yield reduction due to diseases, it is important to cultivate disease tolerant maize or practice crop rotation to control diseases (Brust and King, 2015).

2.8.3 Fall Armyworm

The fall armyworm (FAW) is a pest that cause extensive damage, especially to maize fields and to a lesser degree sorghum and other crops. Currently, over 30 countries have identified the pest within their borders including the island countries of Cape Verde, Madagascar, São Tomé and the Seychelles. FAW consumes many different crops. FAW is capable of feeding on over 80 different crop species, making it one of the most damaging crop pests. While FAW has a preference for maize, the main staple of SSA, it can also affect many other major cultivated crops, including sorghum, rice, sugarcane, cabbage, beet, groundnut, soybean, onion, cotton, pasture grasses, millets, tomato, potato, and cotton. (Zhang *et al.* 2020). FAW spreads quickly across large geographic areas. Like other moths in the genus *Spodoptera*, FAW moths have both a migratory habit and a more localized dispersal habit. In the migratory habit, moths can migrate over 500 km before oviposition. FAW can persist throughout the year. In most areas of North America, FAW arrives seasonally and then dies out in cold winter months, but in most of Africa, FAW generations will be continuous throughout the year wherever host plants are available, including off-season and irrigated crops, and when climatic conditions are favourable. Although the patterns of population persistence, dispersal, and migration in Africa are yet

to be determined, conditions in Africa, especially where there is a bimodal rainfall pattern, suggest that the pest can persist throughout much of the year. Due to the rapid spread of Fall Army worm and distinctive ability to inflict widespread damage across multiple crops, FAW poses a serious threat to the food and nutrition security and livelihoods of hundreds of millions of farming households in SSA particularly when layered upon other drivers of food insecurity.

2.8.4 Weed Control

The best time to minimize the effect of weeds on maize yield is when maize is in the 2-9 leaf stage. Weeding twice or three time suppresses weed growth, increase yield of maize and maximizes profit in maize production (Dogan *et al.*, 2020). The growth of weeds decreases significantly in the order of increasing frequency of weeding. Meanwhile the highest growth and yield of maize parameters occur in the weed-free plot indicating that it is necessary to protect the crop from weed competition throughout most of its growth to ensure maximum yield (Adenawoolan *et al.*, 2015). According to Sweet and Minotti (2014), moisture is implicated early during the first three weeks after emergence in weed-crop competition before other growth factors becoming limiting. Youdeowei (2015) indicated that weeds acted as hosts to pests and harbour many fungal, viral and bacterial diseases. Akobundu (2008) reported that all crops are sensitive to early weed interference and should be cleared within the first two to three weeks after planting.

2.9 Harvesting

Maize takes between 3- 4 months (Williams *et al.*, 2017) to mature depending on variety and weather condition. The leaves and husks start to dry out. The part of the kernel where it is attached to the cob starts to turn brownish or blackish in 90% of the kernels of the cob.

This is called black layer formation. The cobs are no longer appreciated for roasting. Upon breaking a kernel, the inside of it is no longer milky. At least a quarter of the cobs have started to droop. Moisture content is about 13 to 14 % (Zhou *et al.*, 2018).

2.10 Effect of Inorganic Fertilizer (NPK) on Chemical Properties

Inorganic fertilizers are used to provide soil nutrients in order to maintain optimum soil fertility and healthy growth of plants and quality yield. Application of N, P and K fertilizer in acid soil and nutrient depleted soil resulted in change in pH from 5.1 to 5.3 and from 6.2 to 5.8, respectively (Adeniyani *et al.*, 2016). Rahman and Akter (2018) reported that the use of phosphorus fertilizer in combination with N and K raised the soil P content in all the fractions such as colloid P, Al-P, Fe-P, Ca-P and total P in soil. The increase was more at higher rates of P addition along with higher doses of N and K compared to differential combinations of N, P and K. Chemical fertilizers help crops to withstand stress conditions and, in some cases, these were used to correct plant nutrients deficiencies (Rahman & Akter, 2018).

2.11 Effect of Nitrogen on growth and yield of maize

Maize has a high requirement for nutrients, especially nitrogen (N), phosphorus (P) and potassium (K). Among these major nutrients, N is the one that most often limits yield. It determines the number of leaves the plants produces and the number of seeds per cob, and therefore determines yield potential. Fertilizer N levels up to 120 kg/ha is recommended for cultivation in degraded soils (Vasconcellos & Cardoso, 2019). Maize responds well to the application of organic manure, which improves the physical conditions of the soil and its water retention capacity. Mineral fertilizers will allow a quick start of the vegetative growth and supply nutritional needs during the active plant growth. Maize production

depends heavily on mineral fertilizer, which is sometimes supplemented by manure and by rotation with legumes. Nitrogen is a vital plant nutrient and a major yield determining factor required for maize production (FAO, 2016). It is very essential for plant growth and makes up 1 to 4 percent of dry matter of the plants (Vasconcellos & Cardoso, 2019). Nitrogen is component of protein and nucleic acids and when Nitrogen is sub-optimal, growth is reduced (Haque *et al.*, 2017). Its availability in sufficient quantity throughout the growing season is essential for optimum maize growth. It is also a characteristic constituent element of proteins and also an integral component of many other compounds essential for plant growth processes including chlorophyll and many enzymes. It also mediates the utilization of phosphorus, potassium and other elements in plants (Brady, 2019). The optimal amounts of these elements in the soil cannot be utilized efficiently if nitrogen is deficient in plants.

Nitrogen deficiency or excess can result in reduced maize yields. Nitrogen is the structural element of protein and chlorophyll molecule, and its higher concentrations had proved to increase the chloroplast formation and leaf photosynthetic efficiency (Lin *et al.*, 2021). Hokmalipour & Darbandi (2011) reported that nitrogen fertilization activates the enzymes associated with chlorophyll formation thus results in higher concentration of chlorophyll than control plots. These results are in full accordance with that of Zhao *et al.* (2015). Nitrogen increases leaf area index (LAI) and also improves the physiological properties of the plant. Nitrogen is a component of many biological compounds that plays a major role in photosynthetic activity and crop yield capacity, and its deficiency constitutes one of the major yield limiting factors for production (Adhikari *et al.*, 2020). Nitrogen deficiency leads to loss of green colour in the leaves, decreased leaf area and intensity of photosynthesis, leading to reduced photosynthate production and thus lower

yields (Marković, *et al.*, 2019). Over application of nitrogen causes many environmental pollution problems (Lee *et al.*, 2020) and can lead to decreased yields due to luxury consumption (Alva *et al.*, 2016). Leaf area influences the interception and utilization of solar radiation of crop canopies (Hokmalipour & Darbandi, 2021), but it also plays an important role in water use (Liu & Stützel, 2018). LAI is a significant feature for the determination of plant photosynthetic activity and is a crucial structural characteristic of plants due to the role of green leaves in controlling many biological and physical processes in plant canopies (Jangir *et al.*, 2015)

2.12 Effect of phosphorus

The Phosphorus in NPK provides plants with a means of storing energy of their metabolic processes. According to Len *et al.* (2019), much of the energy required for metabolism is stored chemically in the form of complex organic phosphates and is released, as required to chemical processes involved in growth. The significance of phosphorus is pronounced during the early and mature periods of a plant's production cycle. Nurung *et al.* (2016) stated that phosphorus helps roots and flowers grow and develop. This is corroborated by Clerk (2018), who argues that phosphorus is essential for seed germination and root development. It is needed particularly by young plants forming their root system and fruits. The consequence of deficiency of phosphorus also underscores the necessity of the element in the productivity of plants. John *et al.* (2019) indicated that without ample phosphorus you will see stunted growth probably a purple tinge to leaves and low fruit yields. Confirming this, Parray *et al.* (2017) noted that plants deficient in phosphorus become dwarfed and spindly. Increases in P₂O₅ application rate from 0 to 60 kg P₂O₅/ha resulted in a decrease in yield from 65 to 52 kg/ha; further application resulting in an increase in yield to 63 kg/ha.

2.13 Effect of potassium

The Potassium in the NPK is among the macronutrients. It makes no direct contribution to the cellular structure of plants (Hedge, 2015). Its main function appears to be that of a regulator for many of the metabolic processes in the cells; including protein synthesis (Bukhsh *et al.*, 2019). Potassium (potash) is important for the overall plant health. Potassium promotes flower and fruit production and is vital for maintaining growth and helping plants resist diseases (Hedge, 2016). Potassium is used in the process of building starches and sugars, so it is needed in vegetables and fruits. Bukhsh *et al.* (2019) stated that potassium deficiency somewhat restricts growth and causes yellowing of the margins of the upper and middle leaves. The fruits ripen uneventfully and tend to be irregularly shaped susceptible to hollowness and softer than normal. Research conducted in Pakistan by Wasaya *et al.* (2017) on the yield and quality of tomato showed that, the yield of tomato increased significantly with Potassium application. Maximum yield of maize 24.9 t/ha was obtained with application of 100 kg/ha Potassium (K) and it was significantly higher than the control (12.6 t/ha). The orthogonal contrast analysis clearly indicated that tomato yield harvested from control plot significantly differed from the other treatment.

2.14 Effect of inorganic fertilizer briquette on maize yield

The fertilizer briquettes have a smaller surface area than conventional fertilizer grades and hence dissolve slowly, releasing nutrients in a more gradual manner over a longer period of time, reducing soil nutrient losses, notably N (Bindraban *et al.*, 2020). As a result, briquetting granular fertilizers have the potential to improve the agronomic performance of applied fertilizer while also contributing significantly to environmental sustainability. The use of a buried inorganic fertilizer briquette has been demonstrated to dramatically reduce nitrogen losses due volatilization (Fugice *et al.*, 2018). For example, surface

applied granular has been observed to lose up to 35% of its nitrogen; whereas, buried briquettes only lose about 4% of their nitrogen, which is a significant gain in N use efficiency (IFDC, 2019). The fertilizer briquettes can be used in a variety of ways, and can be buried by hand using a hand-driven plough. However, an account by Adu-Gyamfi *et al.* (2019) indicated that, maize plants cultivated in Ghana's savanna agro-ecological zones recovered 77 % N of the applied fertilizer with the use of fertilizer briquettes, resulted in a 30 % increase in maize production over split use of granular fertilizer sources. Agyin-Birikorang *et al.* (2018) found that employing multi-nutrient fertilizer briquettes resulted in a nutrient utilization efficiency of 66% N, compared to 35% for granular or prilled fertilizer sources in comparison to the typical farmer practice of applying granular fertilizer. Islam *et al.* (2011) used fertilizer briquettes on maize grown in tidal flood conditions and found significant increases in fertilizer recovery and usage efficiency. Furthermore, according to IFDC report (2015), fertilizer briquettes increased maize yield by 18% on average while reducing fertilizer use by 33%. They also found that using fertilizer briquettes increased maize yields while using less fertilizer. Few studies have looked at the impact of multi-nutrient fertilizer briquettes on upland crop productivity, notably maize (Adu-Gyamfi *et al.*, 2019).

According to Agyin-Birikorang *et al.* (2018), the performance of multi-nutrient fertilizer briquettes is strongly reliant on environmental variables, notably soil moisture, and is reduced in dry conditions. Adu-Gyamfi *et al.* (2019) found that multi-nutrient fertilizer briquettes were agronomically beneficial even in Ghana's savanna agro-ecological zones, where the weather conditions are relatively dry. NPK fertilizer briquettes are an alternative N source that provides N as well as P and K with the purpose of boosting N, P, and K use efficiency (Miah *et al.*, 2016). It's all mineral, and provides N, P, and K nutrients in the

right proportions for the crop and soil (Abebe and Feyisa, 2017). Due to its single application relative to the 2 - 3 split applications of typically used prilled and granular fertilizers, NPK fertilizer briquette enables for nutrient-balanced site-specific fertilization, reducing nutrient, notably N, losses and saving labour. Since NPK fertilizer briquettes have a smaller surface area, they dissolve more slowly, releasing nutrients at a slower rate for a longer period of time, thereby reducing nutrient losses, notably N, and consequently protects water and air quality compared with the prilled and granular fertilizers (Huda *et al.*, 2016). Under typical meteorological circumstances, Alam *et al.* (2020) found that NPK fertilizer briquette boosted maize production by 16 % (P and K) and by 23 % to 34 % compared to granular, as well as higher N, P, and K utilization efficiencies.

In Vietnam and Cambodia, studies done by the IFDC (2015), found that using the NPK fertilizer briquettes instead of conventional granular fertilizer enhanced maize yields from 25% to 50%. When the NPK fertilizer briquette was employed in Ghana, maize yield increased by 25–35 % while commercial fertilizer costs reduced by 24–32 % (Huda *et al.*, 2016; Gaihre *et al.*, 2017). The NPK briquette's higher N-use efficiency means less N is lost to water bodies and the atmosphere through leaching and volatilization (Gaihre *et al.*, 2017). Nitrogen volatilization losses can account for up to 40% of total nitrogen sprayed globally, especially in places with high temperatures and soil pH (Wang *et al.*, 2016). Studies have demonstrated that when fertilizers are applied by subsurface integration in briquette form rather than surface broadcast application, fertilizer efficiency and, as a result, crop yields improve (Nkebiwe *et al.*, 2016).

According to IFDC (2015), converting traditional granular to briquettes and placing the briquettes deep into the soil towards the plant's root zone is one effective technique to

boost nitrogen efficiency in maize cropping systems. In maize, Kadam (2015) discovered that NPK briquette fertilizer was superior to surface applied increasing yield ranging from 5 to 83 % in maize grain. Briquettes were a better fertilizer alternative than granular surface applied to reduce N losses in either case. Kadam (2015) further reported that it is possible to mechanically put granular and attain the same agronomic efficiency as hand-placed briquettes. Akhtar *et al.* (2019) discovered that deeply placed phosphate briquettes with weights of 114 kg N and 25.4 kg P easily outperformed the recommended dose fertilizer, 150 kg N and 75 kg P in all rice-related criteria, including more panicles per hill, greater panicle lengths and weights, greater grain weights per panicle, more filled grain per panicle, greater grain weight and yield.

Granular and prilled NPK dissolves in water at a higher pace than urea briquettes, according to studies (IFDC, 2015). Apart from the reduced surface area, the high ammonium concentration around the urea briquette during the early phases of dissolving also affects the nitrification rate by blocking or lowering Nitrosomonas activity (IFDC, 2015). Thus, urea briquettes have the potential to improve the agronomic effectiveness of applied fertilizer and, as a result, to contribute significantly to environmental sustainability. Urea briquettes have been found to be an effective way of delivering nitrogen to rice plants (Huda *et al.*, 2016). When compared to surface broadcast of granular urea, urea briquettes use at least 15% less urea yet result in up to a 50% increase in grain production (Yao *et al.*, 2018).

Briquettes are a proven method in Bangladesh, Sub-Saharan Africa, and, most recently, Myanmar, that can boost the yield of transplanted lowland rice by 15-20% while using up to 40% less urea than broadcast urea application according to IFDC, (2016). Several

researches have shown that new fertilizers and application technologies (briquettes) are successful, and they outperform granular or prilled NPK, as well as the traditional broadcast application approach. Higher agronomic nitrogen use efficiency of maize at 90-135 kg N/ha (25.8- 47.31 kg grain per kg applied N) was observed from urea briquette compared to the conventional broadcast application at 90-135 kg N/ha (Agyin-Birikorang *et al.*, 2018). Likewise, higher efficiency and effectiveness of NPK briquette in reducing nitrogen loss and yield increment was also reported by researchers from China and the USA (Jiang *et al.*, 2019).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Experimental sites and Location

Two field experiments were conducted at different sites. The first experiment was carried out at Bunuso in Mampong - Ashanti Municipal during the major rainy season, from April to July 2022. The second field experiment was also carried out at Ejura Agricultural College crop farm in the Ejura- Sekyedumasi Municipality during the same period with one-week interval between them.

3.1.1 Bunuso Experimental Site

Bunuso lies in the forest-Savannah transition Zone of Ghana. Bunuso lies at an altitude of 315 meters above sea level and within latitude $7^{\circ} 3' 11.2932''$ N of equator and longitude $1^{\circ} 23' 59.9892''$ W of the Greenwich Meridian. Bunuso has a bimodal rainfall pattern with annual rainfall between 1094.4 mm and 1200 mm and monthly mean rainfall of about 91.2 mm (Ghana Meteorological Department, 2005). The major rainy season occurs from March to July while minor rainy season occurs from September to November. The dry harmattan season occurs from December to March. Bunuso has a mean daily temperature of about 30.5°C .

3.1.2 Ejura Sekyedumase Experimental Site

The second field experiment which was conducted at the Ejura Agricultural College crop farm is located in the Ejura Sekyedumase Municipality of Ashanti Region. Ejura lies on longitudes $1^{\circ}5' \text{ W}$ and $1^{\circ}39' \text{ W}$ and latitudes $7^{\circ}9' \text{ N}$ and $7^{\circ}36' \text{ N}$. The flat and undulating topography allows for mechanized agriculture. The area lies in the forest-Savannah transition Zone of Ghana. High temperature with a mean monthly of $21\text{-}30^{\circ} \text{C}$ is generally experienced. The area experience bimodal rainfall. The major rainy season occurs is April

to July and minor rainy season occurs from September to November (Ghana Meteorological Department, 2008). The annual rainfall for the area varies between 1200-1500 mm.

3.2 Soil type and vegetation

3.2.2 Soil type and vegetation at Bunuso experimental site

The soil at the Bunuso experimental site was derived from the Voltaian sandstone of Afram plains. It belongs to the Chromic Luvisol class and is characterized by deep sandy loam; free from pebbles. It is well drained and contains moderate organic matter. The soil has a good water holding capacity. It has been classified by FAO/UNESCO (2008) legend as Chromic Luvisol and locally as Bediesi series. It is good for tuber, cereal, and legume crops production. The pH ranges from 6.0 to 6.5. The experimental site had been used for the cultivation of various crops such as maize, cassava and cowpea.

3.2.1 Soil type and vegetation at the experimental site of Ejura

The soil at the Ejura experimental site has been classified by FAO/UNESCO (2008) legend as Haplic Lixisol. The soil is deep, light in colour, well aerated and drained with moderate supply of organic matter and plant nutrients. The soil has good water-holding capacity, very easy to work with and is well adapted to mechanized cultivation. The soil ranges from sandy, loam or clay. The pH ranges from 5.3 to 6.5. The soils are suitable for growing maize, millet, groundnuts, cowpea, guinea corn, yam, cassava and vegetables. The South-Eastern part of Ejura has semi-deciduous forest vegetation, while the northern part has derived or open savannah vegetation (Guinea Savannah). The Guinea Savanna vegetation consists of tall grasses interspersed with short fire-resistant tree species.

3.3 Experimental Design and Treatment

The experimental design used for the two experiments was a Randomized Complete Block Design (RCBD), with four (4) replications. There were seven treatments. Each treatment was replicated four times. The details of the treatments used are shown below and in (Table 3.1).

3.4 Treatments

1. Control (No fertilizer)
2. Granule (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)
3. Briquette (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha)
4. Briquette (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha)
5. Briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)
6. Briquette (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)
7. Briquette (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)

A total field size of 40.0 m × 26.0 m (1040 m²) was demarcated, ploughed, harrowed, lined and pegged. Each experimental plot measured 5 m x 5 m and 2.0 m was left between blocks and 1m between plots.

Table 3.1: Treatment details of granule and Briquette NPK and urea fertilizers

TREATMENT	N (g)	P₂O₅	K₂O	NPK (10:20:20)	Urea		*briq/hill	*briq/hill
1- Control	0	0	0	0	0		NPK (10:20:20)	Urea
2- Granule	120	40	38	500	543	Gram granules/plot	--	--
3 - Briquette	124	64.5	62	333	250	* briq/plot	4	3
4 - Briquette	116	48	46	250	250	* briq/plot	3	2
5 - Briquette	94	65	62	333	167	* briq/plot	4	2
6 - Briquette	77	32	31	167	167	* briq/plot	2	2
7 - Briquette	31	32	31	167	83	* briq/plot	2	1

3.5 Planting material

Maize seed used as planting material for the experiment was *Sanzal Sima* and was obtained from International Fertilizer Development Center on FERARI project. The *Sanzal Sima* maize variety is white dent maize seed with maturity period between 105-110 days.

3.6 Land Preparation and Planting

The experimental site was ploughed, harrowed, lined and pegged and leveled to obtain the desire germination and growth of crop. The *Sanzal Sima* maize seed was planted on a flat land after the plots have been prepared. Maize seeds were sown on 13th April, 2022 at Bunuso and on the 20th April, 2022 at Ejura Agricultural college crop farm at a depth of 4 cm to 6 cm. Three (3) seeds were sown per hill and at a spacing of 75 cm x 40 cm. Each experimental plot had six (6) rows with twenty-four (24) plants per row. The total number of plants per experimental plot was one hundred and forty-four (144) plants. Maize seedling emerged by six (6) days after sowing and eight (8) days later vacant holes were refilled, seedlings were thinned to two (2) plant per hole ten (10) days after emergence.

3.7 Soil Sampling

Soil samples from the experimental sites were collected from 5 randomly chosen spots on each experimental plot from a depth of 0 – 20 cm. Soil samples from each plot were bulked and thoroughly mixed in a container, air dried and was passed through a 2.0 mm sieve mesh to get a fine texture after which sub – samples were put in labelled plastic bags. The labelled soil samples were then sent to CSIR-Soil Research Institute (SRI) laboratory in Kumasi to estimate the amount of nutrient content present in the soil as well the soil physical properties. This was done for each experimental site before planting. Soil

chemical analyses were also done after the application of granular and briquette NPK fertilizer after harvest.

3.8 Protocol for soil physical and chemical properties

3.8.1 Soil physical properties

The following soil physical characteristics were analyzed: Bulk density, total porosity and volumetric moisture.

3.8.1.1 Bulk Density

A core sampler with a measured height, radius and weight was used to collect soil from all the plots. The soil was weighed and then oven dried at a temperature of 105 °C for 24 hours after which it was computed for its bulk density.

$$BD = \left(\frac{W_2 - W_1}{V_s} \right)$$

W_1 is the oven dry soil weight, W_2 is wet soil weight and V_s is the volume (Hillel, 1982).

3.8.1.2 Total Porosity

The porosity was also calculated using computed figures from the bulk density with a constant particle density of 2.6g cm³

$$F = \left(1 - \frac{BD}{PD} \right) * 100$$

Where BD is the bulk density and PD is the particle density (Baver *et al.*, 1987).

3.8.1.3 Volumetric Moisture

The volumetric moisture of the soil was determined based on the computed bulk density and the gravimetric moisture.

$$\theta V = (\theta_g * BD) * 100$$

Where θV is the soil volumetric moisture, BD is the bulk density (Baver *et al.*, 1987).

3.8.2 Soil chemical Analyses

3.8.2.1 Measured parameters

In order to assess the improving effect of inorganic fertilizer briquette on soil properties, the following parameters were measured and analysis done;

3.8.2.2 Determination of pH

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

3.8.2.3 Determination of available phosphorus

Available phosphorus was determined using the Bray P1 method (Athokpam *et al.*, 2016). The method is based on the production of a blue complex of molybdate and orthophosphate in an acid solution. A 10 μg P/mL standard sub-stock solution was diluted to produce standard series of 0, 0.8, 1.6, 2.4, 3.2, and 4.0 μg P/mL. These were subjected to colour development and their respective absorbance values read on a spectrophotometer at a wavelength of 660 nm. A standard line graph was constructed using the readings. A 2.0 g of soil sample was then weighed into a 50 ml shaking bottle and 20 ml of Bray-1 extracting solution (0.03 N NH_4F + 0.025 N HCl) added. The sample was shaken for one minute and then filtered through No. 42 Whatman filter paper. Ten millilitres of the filtrate was

pipetted into a 25 ml volumetric flask and 1 ml each of molybdate reagent and reducing agent added for colour development. The absorbance was measured at 660 nm wavelength on a spectrophotometer. The concentration of P in the extract was obtained by comparing the results with the standard curve.

3.8.2.4 Determination of total nitrogen

Kjeldahl (1883) digestion method was used to determine Total N. Ten grams (10 g) of distilled water was added to 10 g of soil in a Kjeldahl flask and allowed to stand for 10 minutes to moisten it. One spatula of Kjeldahl catalyst (1 part selenium + 10 parts CuSO_4 + 100 parts Na_2SO_4) and 20 ml conc. H_2SO_4 was then added to the mixture. The solution was then digested until it was clear and colorless. The flask was allowed to cool and the solution transferred into a 100 ml volumetric flask and make up to the mark with distilled water.

Twenty millilitres (20 ml) of 40 % NaOH was then added and distilled over 10 ml of 4 % Boric acid and three drops of indicator for 4 minutes. This changed the solution to light blue colour. The distillate was then titrated with 0.1 N HCl until the light blue colour changed to grey and then back to pink. Weight of soil sample used, considering the dilution and the aliquot taken for distillation was expressed as:

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

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

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

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

B = volume of standard HCl used in the blank titration

N = Normality of standard HCl

3.8.2.5 Determination of ammonium by Indophenol blue method

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

3.8.2.6 Exchangeable Cations

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

3.8.2.6.1 Calcium and Magnesium

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

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

3.8.2.6.2 Potassium and Sodium

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

$Y =$ Therefore K and Na C mol/kg =

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

$X =$ K and Na Cmol/kg

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

$B =$ constant value from the curve

39.1 = atomic weight of K and Na

3.9 Cultural Practices

3.9.1 Weed control

Weed control was done three (3) times. The first weeding was done manually using a hoe, two weeks after seedling emergence. The second and third weedings were done using a hoe just before tasseling and before harvesting, respectively. This was to ensure that weeds do not compete with the maize crop for soil nutrients and water. Hand pulling of weeds

was additionally done two weeks after planting and continued at two weeks interval for the rest of the period of experiment.

3.9.2 Fertilizer Application

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

3.9.3 Pest and Disease control

Incidence of pests and diseases were monitored periodically by frequent visit to the experimental site to check for pests such as rodents, birds, stem borers and fall army worm. The insecticide Rain top-M (70 WP) at the rate of 80- 150 g/ 16 L and Bypel 1 *Basilus thuringensis* (16000/N/mg at the rate apply (180-170 product per acre 15-20 g) per 15L knapsack was applied four weeks after planting using CP 15 knapsack sprayer on the maize plants. This was expected to control pest and protect the plants from any disease attack. Fall Army worm infestation occurred six weeks after planting (6WAP) and it was controlled with Pirimiphos methyl and Permethrin at a rate of 30 ml per 15 litres at 6 weeks after planting and every other week, until the 9th week after planting.

3.10 Data Collected

3.910.1 Phenological data

3.9.1.1 Percentage Plant Establishment

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

3.10.1.2 Days to 50% Tasseling

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

3.10.1.3 Days to 50 % Silking

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

3.10.1.4 Days to 50 % maturity

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

3.11.2 Physiological Growth Parameters

3.11.2.1 Crop Growth Rate (CGR)

The crop growth rate (CGR) was determined from the formula below as described by Baumann *et al.* (2002).

$$\text{CGR} = \left(\frac{1}{\text{GA}}\right) \times \left(\frac{\text{W}_2 - \text{W}_1}{\text{T}_2 - \text{T}_1}\right) \text{ g m}^{-2} \text{ day}^{-1}$$

Where CGR= Crop growth rate; GA= Ground Area; W1=Initial Dry Weight of plant or plant part; W2= Final Dry Weight of plant or plant part; T1=Initial time (in terms of days after planting); T2= Final time (in terms of days after planting)

3.11.2.2 Relative Growth Rate (RGR)

The classical approach by Anten & Ackerly (2001) was used to determine the relative growth rate (RGR).

$$\text{RGR} = \left(\frac{\ln \text{W}_2 - \ln \text{W}_1}{\text{T}_2 - \text{T}_1}\right) \text{ g m}^{-2} \text{ days}^{-1}$$

Where RGR = Relative growth rate; W1= Initial dry weight of plant; W2= Final dry weight of plant; T1= Initial time (in terms of days after planting); T2= Final time (in terms of days after planting).

3.11.3 Vegetative Growth Data

3.11.3.1 Plant height

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

3.11.3.2 Number of leaves per plant

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

3.11.3.4 Dry Matter Accumulation

Six (6) plants were randomly selected and uprooted from the fifth row and were separated into root and shoot. The dry root and shoot weights were determined using electronic weighing scale and then oven drying at 70°C to constant weight. This was done two weeks before and after tasseling.

3.11.3.5 Leaf chlorophyll content

The leaf chlorophyll content was measured on the fifth and sixth leaf of each plant at five (5) weeks after planting and at two (2) weeks interval until eleven weeks after planting. This was estimated on five (5) randomly selected tagged plants from the 3 m x 3 m area within the four (4) central rows per plot using the calibrated SPAD meter and the mean was computed.

3.11.4 Yield and Yield Components

3.11.4.1 Number of plants harvested

The total number of plants harvested per plot from the 3 m x 3 m area within the four (4) central rows per plot was counted and the mean estimated.

3.11.4.2 Number of cobs per plot

The total number of cobs from the 3 m x 3 m area within the four central rows per plot was harvested and counted and the mean was recorded.

3.11.4.3 Number of damaged cobs per plot

The number of damage cobs per plot from the 3 m x 3 m area within the four central rows per plot was harvested and counted and the mean was recorded.

3.11.4.4 Number of seeds per cob

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

3.11.4.5 Cob length

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

3.11.4.6 Cob diameter

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

3.11.4.7 Undehusked cob weight per plot

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

3.11.4.8 Dehusked cob weight per plot

The total number of undehusked cob from the 3 m x 3 m area within the four central rows per plot was dehusked and weighed using electronic weighing scale and the mean was recorded.

3.11.4.9 Stover weight per plant

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

3.11.4.10 Total stover weight per plot

The total number of plants from the 3 m x 3 m area within the four central rows per plot was harvested and tied together. The entire bundle was weighed using an electronic weighing scale and the mean was estimated.

3.11.4.11 100-Seed weight

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

3.11.4.12 Total grain weight per plot

The fresh grain of the remaining harvest (excluding those from the 5 plants) was weighed using an electronic weighing scale at harvest and the mean computed.

3.11.4.13 Grain Yield

Grain yield was determined from sixty-four (64) plants from the 3 m x 3 m area within the four central rows per plot. Grains from cobs after harvest were removed with a manually grain remover and sun dried to a constant moisture. The dried grains were weighed with an electronic weighing scale and their grain yield per plot was estimated in kg/ha.

$$\text{Grain yield (kg) per hectare} = \frac{10000\text{m}^2 \times Q \text{ grain (kg)}}{\text{Harvest area (m}^2\text{)}} \text{ (Makarova et al., 2020).}$$

3.12 Statistical Analysis

The data collected was subjected to statistical analysis. The analysis of variance (ANOVA) was carried out using GenStat Statistical Package (2008) Version 11.1. (VSN International Ltd). Where there are significant differences between treatment means, separation was

done by using the Tukey Honestly Significance Difference (HSD) test criterion at 5% probability level.

CHAPTER FOUR: RESULTS

4.1 Initial soil chemical properties

Table 4.1 indicates the initial soil condition at Bunuso and Ejura experimental sites. The soils at Bunuso and Ejura were moderately acidic. The organic matter content of the soil at Bunuso and Ejura were low. Total nitrogen content was low, the exchangeable cations Ca, Mg and K were low. Effective cation exchange capacity was also moderate and the available P and K for both experimental sites were also low. The initial soil chemical properties provided valuable insights into the nutrient status and characteristics of the soil at the two locations, Bunuso and Ejura as shown in (Table 4.2). The available phosphorus (P) levels were within the range of 0-10 ppm, and the exchangeable potassium (K) levels varied between 0.11-0.18 e/100g soil at Bunuso and below 0.15m.e/100g soil at Ejura. Calcium, magnesium and sodium levels were generally low, highlighting potential deficiencies in these micronutrients.

4.2 Final soil chemical properties of the soil during 2021 minor and 2022 major cropping seasons

Table 4.3 and 4.4 shows the final soil condition at Bunuso and Ejura experimental sites after harvest, the amended plots briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha) and briquette (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha) showed increases in some nutrient levels at Bunuso and decrease in some nutrient levels at Ejura, respectively (Table 4.3 and 4.4). The Available P levels remained within the initial range of 0-10 ppm across all treatments and locations exchangeable K levels varied but did not show consistent patterns across treatments. However, it was observed that granule NPK and briquette NPK treatments generally resulted in slightly higher exchangeable K levels compared to the control. Calcium and magnesium levels did not show substantial changes after the

application of fertilizer treatments. The cation exchange capacity (ECEC) values were relatively consistent across treatments and locations, with slight increases observed in the fertilized treatments compared to the control.

Table 4.1: Initial Soil Chemical Properties at Bunuso and Ejura Experimental Sites

Property	Exchangeable Cations (meq/100g)										Available Nutrients (ppm)	
	pH (1:1H ₂ O)	Org C (%)	Total N (%)	Org Matt (%)	Ca ²⁺	Mg ²⁺	K ⁺	Na ⁺	TEB	ECEC (meq/100g)	Base Sat (%)	P
Bunuso 5.78	1.02	0.11	1.10	0.28	0.04	0.20	0.01	0.50	0.97	57.21	9.41	0.20
Ejura 5.63	0.82	0.2	1.14	0.3	0.03	0.09	0.01	0.34	0.59	92.83	8.44	13.00

4.2 Initial Soil Physical Properties

Initial soil physical properties for both experimental sites is shown in (Table 4.2). The results showed that the soil at Bunuso was sandy loam and that of Ejura was clayey loam. The bulk density at Bunuso was higher (1.6 g/cm³) than Ejura at (1.3 g/cm³). The total porosity, volumetric moisture content and air-filled porosity for Bunuso were higher than at Ejura. Total porosity was greater in sandy loam than in clayey loam soils. The infiltration rate for Bunuso site was greater than at Ejura site as well as for soil available water content (Table 4.2).

Table 4.2: Initial Soil physical properties at Bunuso and Ejura Experimental Sites

Variable	Bunuso	Ejura
Bulk density (g/cm ³)	1.6	1.3
Volumetric moisture content (cm ³)	19.1	17.5
Total porosity (%)	67.3	36.2
Air filled porosity (%)	25.4	19.1
Clay	13	60
Silt	10	5
Sand	77	35
Degree of saturation (%)	41.0	48
Infiltration (mm)	10.1	5.4
Available water content (%)	11.7	7.4

Table 4.3: Soil Chemical Properties after harvest at Bunuso experimental site after application of NPK briquette and granular and urea fertilizers during 2022 major season

BUNUSO	pH	% TN	% OC	% OM	P ppm	Ca+2 cmol/kg	Mg+2 cmol/kg	K cmol/kg	Na+ cmol/kg	TEB cmol/kg	Ex. Acid (H + Al)	ECEC	% B.S
Control (No fertilizer)	5.01	0.12	1.1	1.50	6.39	1.71	1.28	0.18	0.02	3.19	0.10	3.29	96.96
Gr (120-40-40 kg/ha NPK + Briq Urea (217.2 kg/ha)	5.08	0.12	2.1	1.80	5.02	1.50	1.28	0.14	0.01	2.94	0.10	3.04	96.71
Briq (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha)	5.66	0.15	2.2	1.82	9.09	1.50	1.39	0.11	0.05	3.05	0.20	3.25	93.84
Briq (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha)	6.33	0.16	1.3	1.92	9.62	1.71	2.03	0.16	0.03	3.93	0.08	4.01	98.01
Briq (94-65-62 kg/ha NPK) + Briq urea (66 kg/ha)	5.62	0.18	2.1	1.71	7.42	1.71	1.50	0.19	0.02	3.42	0.20	3.62	94.47
Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)	5.92	0.12	1.0	1.90	9.02	1.50	1.18	0.14	0.03	2.84	0.11	2.95	96.27
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	5.77	0.16	2.0	1.83	9.02	1.82	1.28	0.14	0.04	3.28	0.13	3.41	96.18

OM – Organic matter, OC- Organic Carbon, TN- Total Nitrogen, ECE-Exchangeable Cation Exchange, BS- Base Sat, Briq-Briquette.

Table 4.4: Soil Chemical Properties after harvest at Ejura experimental sites after application of NPK briquette and granular and urea fertilizers during 2022 major season

Ejura	pH	% TN	% OC	% OM	P ppm	Ca ²⁺ cmol/kg	Mg ²⁺ cmol/kg	K cmol/kg	Na ⁺ cmol/kg	TEB cmol/kg	Ex. Acid (H + Al)	ECEC	% B.S
Control (No fertilizer)	5.13	0.11	2.1	1.36	39.26	1.07	0.64	0.04	0.07	1.82	0.50	2.32	78.49
Gr (120-40-40 kg/ha NPK) Briq Urea (217.2 kg/ha)	5.04	0.14	1.2	1.55	3.85	0.86	0.43	0.03	0.05	1.37	0.50	1.87	73.22
Briq (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha)	5.17	0.15	2.1	1.83	7.85	1.07	0.43	0.04	0.07	1.60	0.50	2.10	76.25
Briq (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha)	5.03	0.15	1.0	1.64	4.58	1.28	0.64	0.04	0.05	2.02	0.50	2.52	80.15
Briq (94-65-62 kg/ha NPK)	5.18	0.14	1.1	1.69	28.07	0.86	0.86	0.04	0.07	1.82	0.55	2.37	76.82
Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)	5.42	0.2	1.1	1.57	6.04	0.86	0.64	0.04	0.04	1.58	0.60	2.18	72.45
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	5.72	0.15	2.0	1.59	4.51	0.86	0.64	0.05	0.07	1.62	0.50	2.12	76.40

OM – Organic matter, OC- Organic Carbon, TN- Total Nitrogen, ECE-Exchangeable Cation Exchange, BS- Base Sat, Briq-Briquette

4.4 Climatic Conditions during the experimental period

Differences in climatic factors such as; temperature, rainfall and relative humidity were observed at Bunuso and Ejura (Table 4.5 and Table 4.6). At Bunuso, the mean monthly temperature for the area ranged between 23.0 °C to 31.3 °C with the highest daily temperature of 33.4 °C occurring in May 2022. The total rainfall during the growing season from April to August 2022 at Bunuso was 912.5 mm with the highest recorded in June (254.8 mm). The average relative humidity for Bunuso ranged from 50 to 81 % with the highest occurring between June and August (Table 4.5). In Ejura, the total rainfall during the growing season from April to August 2022 was 680.8 mm with the highest recorded in July (203.6 mm). The mean monthly temperature for the area ranged between 22.0 °C to 32.7 °C, with the highest daily of 32.7 °C occurring in May. The mean monthly relative humidity ranged from 41 to 80 % with the highest recorded in August (Table 4.6).

Table 4.5: Climatic Data for Bunuso Site during 2022 major season

Month	Total Rainfall (mm)	Mean Relative Humidity (%)		Mean Temperature (°C)	
		06.00hrs	15.00hrs	Min.	Max.
April, 2022	210.3	81	50	23.4	33.4
May	177.6	79	56	23.3	33.4
June	254.8	80	62	22.4	31.4
July	160.2	79	64	22.4	30.9
August	109.6	81	61	20.5	29.8
Total	912.5 mm				

Table 4.6: Climatic Data for Ejura during 2022 major season

Month	Total	Mean Relative		Mean Temperature	
	Rainfall (mm)	Humidity (%) 06.00hrs	15.00hrs	(° C) Min.	Max.
April, 2022	79.6	78	41	23.5	33.1
May	147.8	77	53	23.8	32.7
June	149.0	79	60	23.3	31.0
July	203.6	79	59	22.7	30.0
August	100.8	80	52	22.0	29.7
680.8 mm					

Source: Ghana Meteorological Agency- Kumasi, 2022.

4.5 Phenology of maize

4.5.1 Percentage plant establishment

Table 4.7 shows results on percentage plant establishment as influenced by different rates of briquette and granular inorganic fertilizers at Bunuso and Ejura. There were no significant ($P \geq 0.05$) differences among treatments in percentage plant establishment at both locations. There were a significant differences between location and location \times treatment interaction in percent plant establishment (Table 4.7). Percentage plant establishment was slightly higher at Bunuso than at Ejura.

Table 4.7 Percentage plant establishment as influenced by different rates of briquette and granule NPK and urea fertilizers at Bunuso and Ejura during 2022 major season

Treatment	Percentage plant establishment		Mean
	Bunuso	Ejura	
Briq (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha)	60.7	58.7	59.7
Briq (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha)	61.5	61.7	61.6
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha /ha)	60.7	55.5	58.1
Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)	61.2	59.2	60.2
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	62.7	56.7	59.7
Gr (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)	62.0	55.2	58.6
Control (No fertilizer)	62.0	56.7	59.3
Mean	61.5	57.7	
Tukey ($P \leq 0.05$)	NS	NS	
CV (%)	1.8	6.3	
Location = 1.24** Treatment = NS Location x Treatment = 5.79* Overall CV (%) = 3.2			

* Briq----- Briquette

* Gr-----Granular

4.5.2 Days to 50% tasseling

The days to 50% tasseling as influenced by different rates of NPK fertilizer briquette and granule for the two experimental locations (Table 4.8). The results showed a significant difference ($P \leq 0.05$) between treatments and location in days to 50% tasseling at Bunuso and Ejura (Table 4.8). No fertilizer (Control) plot used significantly ($P \leq 0.05$) greater number of days to tasseling than amended plots. The granular (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha) tasseled five days earlier than the control plot at Bunuso.

At Ejura, maize planted on No fertilizer (Control plot) tasseled three days later (62.7 days) than maize planted on granular (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha) (59.7

days) in days to 50 % tasseling and differed significantly ($P < 0.05$) from other treatments (Table 4.5). Maize planted on briquette (31-32-31 kg/ha NPK) + Briq Urea (33.2 kg/ha) and briquette (77-32-31 kg/ha NPK) + Briq Urea (66 kg/ha) tasseled the same day (61 days). There was a significant ($P \leq 0.05$) difference between maize planted at Bunuso and Ejura in days to 50 % tasseling (Table 4.8).

4.5.4 Days to 50% silking

The results on days to 50% silking as influenced by different rates of fertilizer briquettes and granule are presented in Table 4.8. At Bunuso maize plants that received granule (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha) silked four days earlier than maize plants that received briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha) and the control and was significantly ($P \geq 0.05$) different. There were however, no significant ($P \geq 0.05$) differences among the other briquettes amended plots in days to 50% silking (Table 4.8). In Ejura, non-significant difference occurred between treatment and location \times treatment interaction in days to 50% silking. There was a significant difference between maize planted at Bunuso and Ejura in days to 50% silking (Table 4.8).

Table 4.8 Days to 50% tasseling and days to 50% silking as influenced by different rates of briquette and granule NPK and urea fertilizers at Bunuso and Ejura during 2022 major season

Treatment	Days to 50% tasseling			Days to 50% silking		
	Bunuso	Ejura	Mean	Bunuso	Ejura	Mean
Briq (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha)	61.5	60.7	61.1	71.0	76.7	73.8
Briq (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha)	63.2	60.2	61.7	71.0	78.0	74.5
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	63.0	61.0	62.0	72.5	75.5	74.0
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	60.7	61.0	60.8	71.0	78.0	74.5
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	62.2	60.7	61.5	73.2	76.7	75.0
Gr (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)	59.5	59.7	59.6	69.2	76.2	72.7
Control (No fertilizer)	65.0	62.7	63.8	73.0	77.2	75.1
Mean	62.1	60.8		71.5	76.9	
Tukey ($P \leq 0.05$)	5.40	2.11		3.32	NS	
CV (%)	4.2	2.7		2.6	2.3	
Tukey ($P \leq 0.05$):	Location = 1.120*					0.897*
	Treatment = 3.216*					NS
	Location x Treatment = NS					NS
	Overall CV (%) = 3.7					4.4

* Briq----- Briquette

* Gr-----Granular

4.5.5 Days to 50 % maturity

Table 4.9 shows the effect of different rates of briquette and granule inorganic fertilizers on days to 50 % maturity. There were no significant ($P \geq 0.05$) differences among treatments and location x treatment interaction in days to 50 % across both locations. There

was however, a highly significant ($P \leq 0.05$) difference between locations in days to 50 % maturity with maize in Ejura having longer days to 50 % maturity than Bunuso (Table 4.9).

Table 4.9: Effect of different rates of briquette and granular NPK and urea fertilizers on days to 50 % maturity of maize at Bunuso and Ejura during 2022 major season

Treatment	Days to 50% maturity		Mean
	Bunuso	Ejura	
Briq (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha)	98.5	102.2	100.3
Briq (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha)	98.0	101.7	99.8
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	100.2	101.5	100.8
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	99.7	102.7	101.2
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	100.5	101.7	101.1
Gr (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)	98.7	100.5	99.6
Control (No fertilizer)	101.0	103.0	102.0
Mean	99.5	101.9	
Tukey ($P \leq 0.05$)	NS	NS	
CV (%)	2.1	1.5	
Tukey ($P \leq 0.05$):			
Location = 0.968*			
Treatment = NS			
Location x Treatment = NS			
Overall CV (%) = 2.2			

* Briq----- Briquette

* Gr-----Granular

4.6 Growth Analysis

4.6.1 Crop growth rate (CGR)

Table 4.10 shows Crop growth rate (CGR) ($\text{g m}^{-2} \text{ day}^{-1}$) as influenced by briquette and granular NPK fertilizer from 4 – 8 weeks after planting (WAP) and 8 to 10 WAP at Bunuso

and Ejura. During the initial growth period (4-8 WAP), the application of NPK briquette and granular fertilizers generally led to higher crop growth rate compared with the control across both locations. However, from 8 – 10 WAP, the crop growth rate decreased sharply in all treatments at both locations. From 4-8 WAP, maize plants that received both briquette and granular fertilizers and without NPK fertilizer at Bunuso recorded significantly higher crop growth rate mean values than maize plants at Ejura. However, maize plants with or without granular and briquette fertilizer at Ejura recorded significantly higher crop growth rate than maize planted at Bunuso from 8- 10 WAP. There were no significant differences between treatment and treatment \times location interaction.

Table 4.10 Crop growth rate as influenced by different rates of briquette and granule NPK and urea fertilizers at Bunuso and Ejura from 0-8 WAP and 8-10 WAP during 2022 major season

Treatment	Crop growth rate (g m ⁻² day ⁻¹)					
	4 - 8 Weeks after planting		Mean	8 - 10 Weeks after planting		Mean
	Bunuso	Ejura		Bunuso	Ejura	
Briq (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha)	24.26	24.71	24.49	12.63	12.75	12.69
Briq (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha)	32.08	21.91	26.901	11.63	14.41	13.02
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	29.34	20.68	25.01	12.19	14.19	13.19
Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)	20.74	22.64	21.69	12.86	12.56	12.71
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	23.48	25.72	24.61	12.97	18.17	15.57
Gr (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)	25.83	21.13	23.48	11.96	12.72	12.34
Control (No fertilizer)	20.74	19.45	20.01	10.06	13.54	11.82
Mean	25.21	22.32		12.04	14.05	
Tukey (P < 0.05)	NS	4.72		2.81	NS	
CV (%)	28.87	9.05		9.99	30.34	
Tukey (P ≤ 0.05)	Location = 2.83*			1.70*		
	Treatment = NS			NS		
	Treatment x Location = NS			NS		

* Briq----- Briquette

* Gr-----Granular

4.6.2 Relative Growth Rate

Table 4.11 shows the relative growth rate (RGR) (g g⁻¹m⁻²/day⁻¹) of maize plants as influenced by different rates of briquette and granular NPK fertilizer and no fertilizer at 0-8 weeks after planting and 8-10 WAP at Bunuso and Ejura. The briquette NPK fertilizers generally resulted in higher relative growth rates compared to the granular and the control (no fertilizer) from (4-8 WAP). The Relative growth rate declined sharply from 8-10 WAP across both locations. Maize plants planted at Bunuso produced significantly higher

relative growth rate than maize plants planted at Ejura from 8-10 WAP. Maize plants that received briquette fertilizer Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha) at Bunuso and at Ejura had the highest relative growth rate from 0-8 WAP. The lowest relative growth rate was recorded in the control across both locations at the same growing season (Table 4.11). There were no significant ($P \geq 0.05$) differences between treatment and treatments \times location interaction in Relative growth rate from 8 to 10 WAP across both locations.

Table 4.11 Relative growth rate as influenced by different rates of briquette and granule NPK and urea fertilizers at Bunuso and Ejura from 0-8 WAP and 8-10 WAP during major season

Treatment	Relative growth rate ($\text{g g}^{-1}\text{m}^{-2}\text{ day}^{-1}$)					
	4 - 8 Weeks after planting		Mean	8 - 10 Weeks after planting		Mean
	Bunuso	Ejura		Bunuso	Ejura	
Briq (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha)	0.79	0.86	0.83	0.56	0.31	0.44
Briq (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha)	0.78	0.83	0.81	0.60	0.37	0.49
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	0.77	0.84	0.81	0.57	0.31	0.44
Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)	0.81	0.87	0.84	0.56	0.23	0.39
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	0.78	0.84	0.81	0.61	0.29	0.45
Gr (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)	0.77	0.84	0.81	0.56	0.24	0.44
Control (No fertilizer)	0.75	0.79	0.77	0.43	0.34	0.39
Mean	0.68	0.73		0.49	0.26	
Tukey ($P < 0.05$)	0.04	0.06		NS	NS	
CV (%)	3.66	3.22		25.10	31.04	
Tukey ($P \leq 0.05$)		Location = 0.11*		0.07 *		
		Treatment = 0.03*		NS		
		Treatment x Location = NS		NS		

* Briq----- Briquette

* Gr-----Granular

4.7 Vegetative Growth Parameters

4.7.1 Plant height

The results of plant height as influenced by different rates of briquette and granule NPK fertilizers at Bunuso and Ejura are presented in Figures 4.1a and 4.1b respectively. At Bunuso and Ejura, there was increase in maize plant height throughout their growing period (Fig 4.1a and Fig 4.1b). There were no significant ($P \geq 0.05$) differences among different rates of briquette and granule NPK fertilizers in plant height across both locations (Fig 4.1a and Fig 4.1b). Generally, the control had the least height at both locations while

the Briquette (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha) had the highest plant height at Bunuso and Briquette (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha) at Ejura.

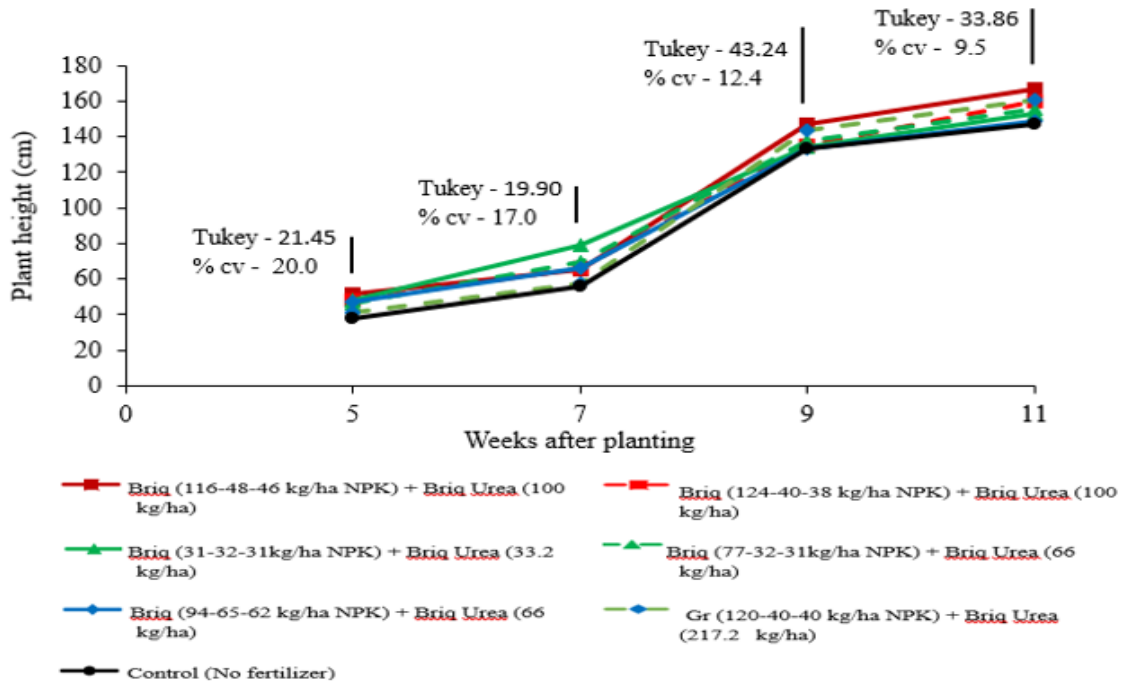


Fig 4.1a: Plant height of maize as influenced by different rates of briquette and granule NPK fertilizer at Bunuso during 2022 major season

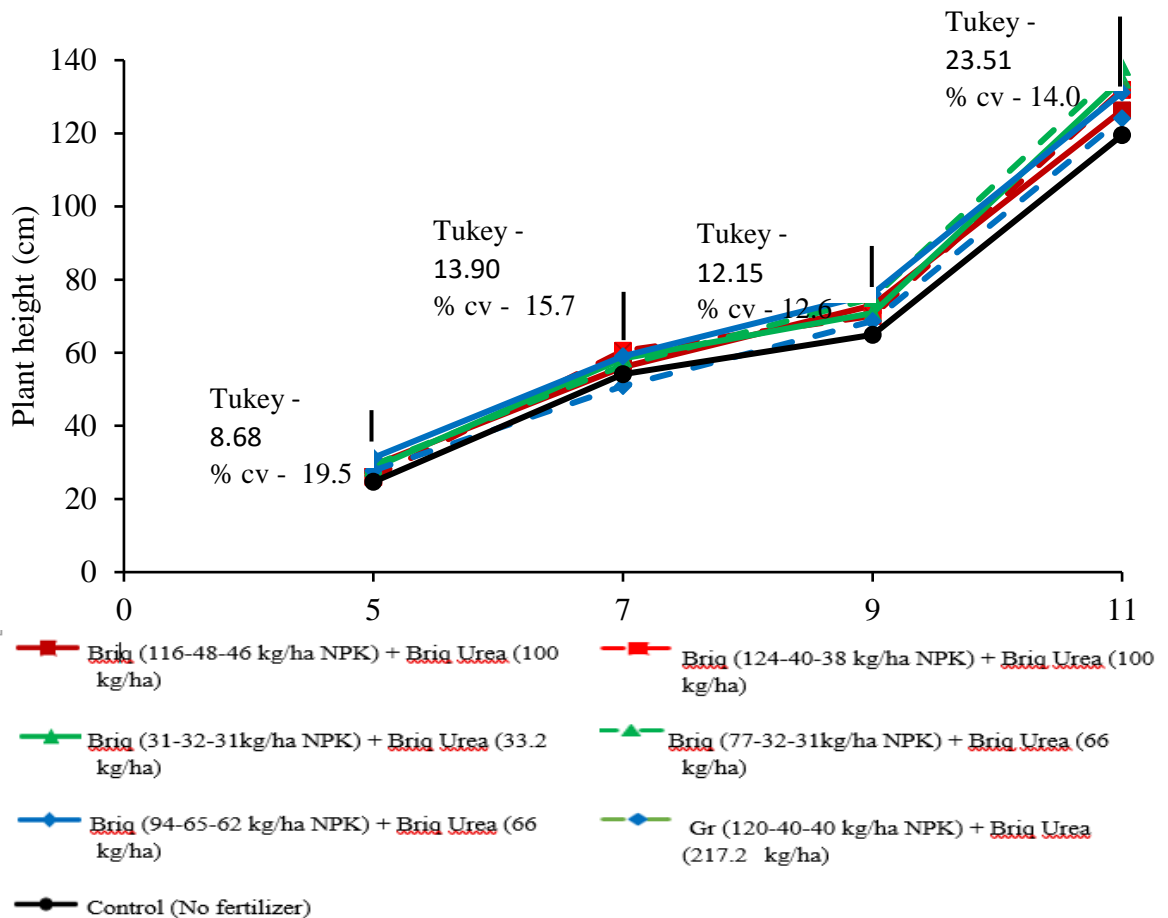


Fig 1b: Plant height of maize as influenced by different rates of briquette and granules NPK fertilizer at Ejura during 2022 major season

4.7.2 Number of leaves per plant

The results in Figures 4.2a and 4.2b, show the number of leaves per plant produced by maize plants at Bunuso and Ejura, respectively. The results show that at Bunuso, the number of leaves per plant from 9 WAP to 11 WAP (Figure 4.3) did not differ significantly among the fertilizer treatments. At Ejura, the number of leaves per plant with different rates of fertilizer treatments were not significantly ($P \geq 0.05$) different from each other from 5 WAP to 11 WAP although the greatest number of leaves per plant was recorded in maize that received briquette (31-32-31 kg/ha NPK) + Briq Urea (33.2 kg/ha) at 5 WAP and 11 WAP (Figure 4.2b). The leaf numbers recorded for the Ejura site were generally fewer in number compared to the Bunuso experimental site during the cropping period.

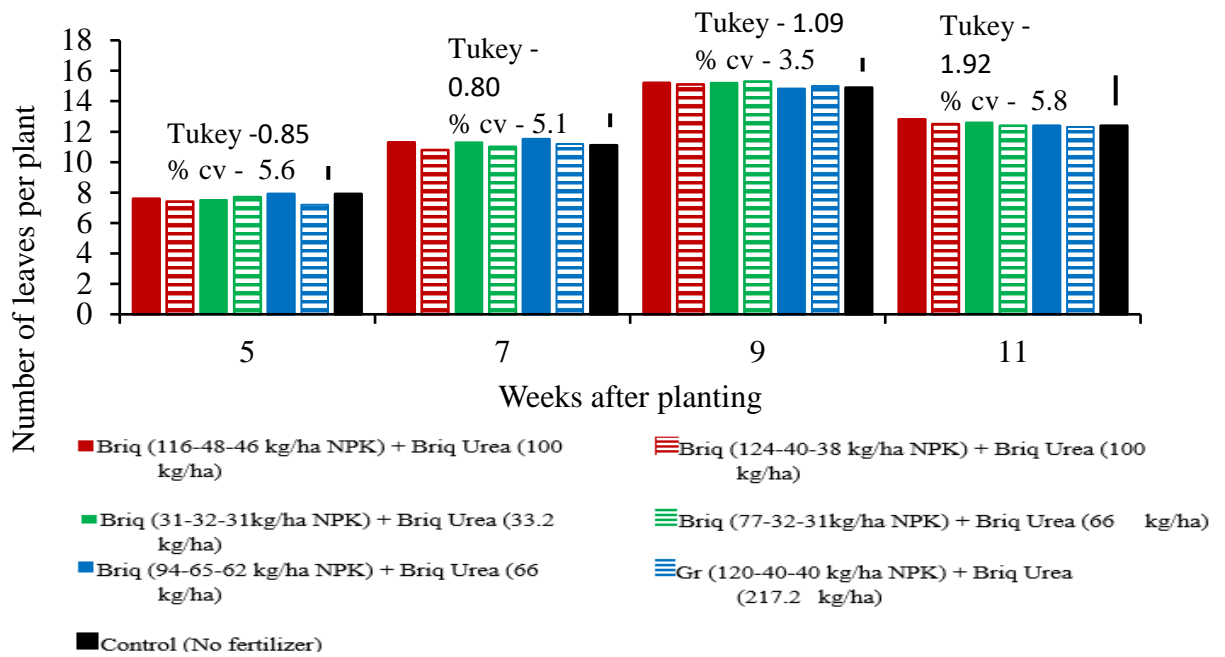


Fig 4.2a: Number of leaves per maize plant as influenced by different rates of briquette and granule NPK fertilizer at Bunuso during 2022 major season

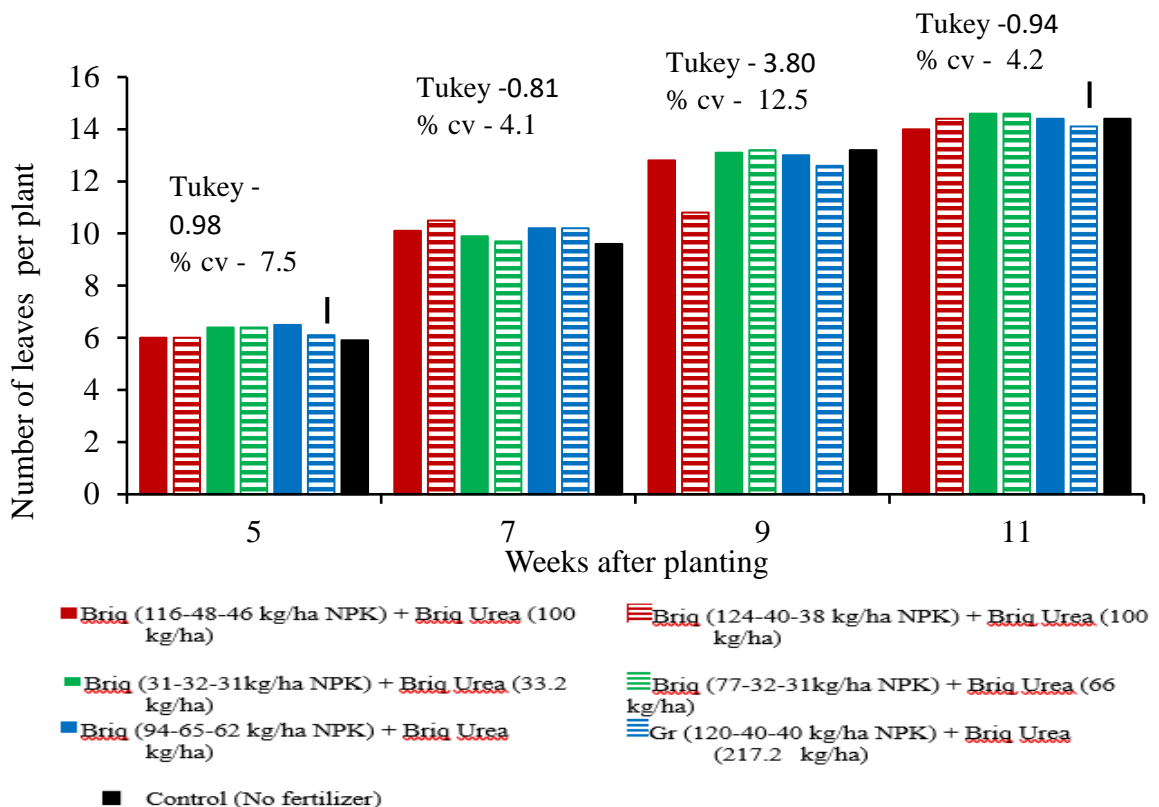


Fig 4.2b: Number of leaves per maize plant as influenced by different rates of briquette and granule NPK fertilizers at Ejura during 2022 major season

4.7.3 Fifth (5th) Leaf chlorophyll content

The results of 5th leaf chlorophyll content at Bunuso and Ejura are presented in Figs 4.3a and 4.3b. At Bunuso, the 5th leaf chlorophyll content did not differ ($P \geq 0.05$) significantly among the treatments, and at Ejura from 5 WAP to 11 WAP (Fig. 4.3a). At Ejura, maize plant that received briquette (31-32-31 kg/ha NPK) + Briq Urea (33.2 kg/ha) treatment recorded the greatest 5th leaf chlorophyll content from 5 WAP to 9 WAP, while the control recorded the least. The briquette (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha) treatment had similar mean values as the briquette (77-32-31 kg/ha NPK) + Briq Urea (66 kg/ha) treatment at 11 WAP. At Ejura at 9 WAP, the control treatment produced the least 5th leaf chlorophyll content from 5 to 9 WAP (Figure 4.3b).

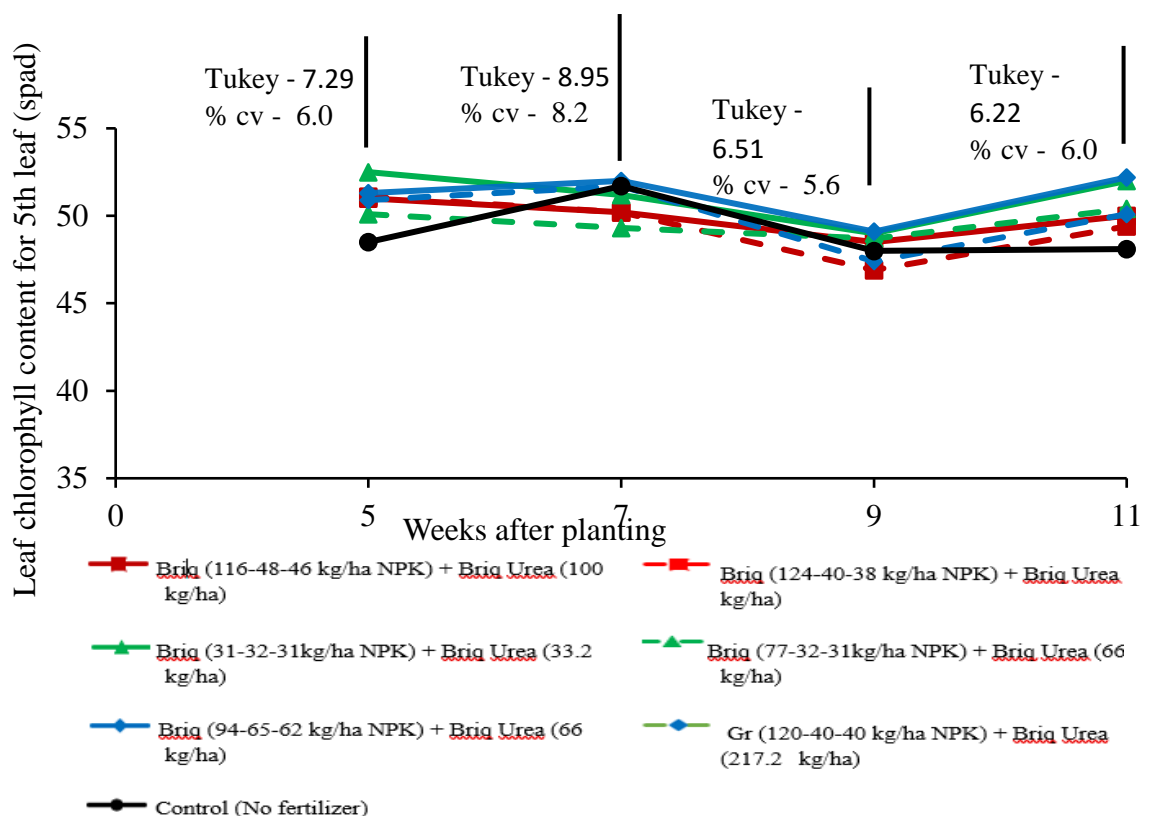


Fig 4.3a: Fifth (5th) Leaf chlorophyll content of maize as influenced by different rates of briquette and granule NPK fertilizer at Bunuso during 2022 major season

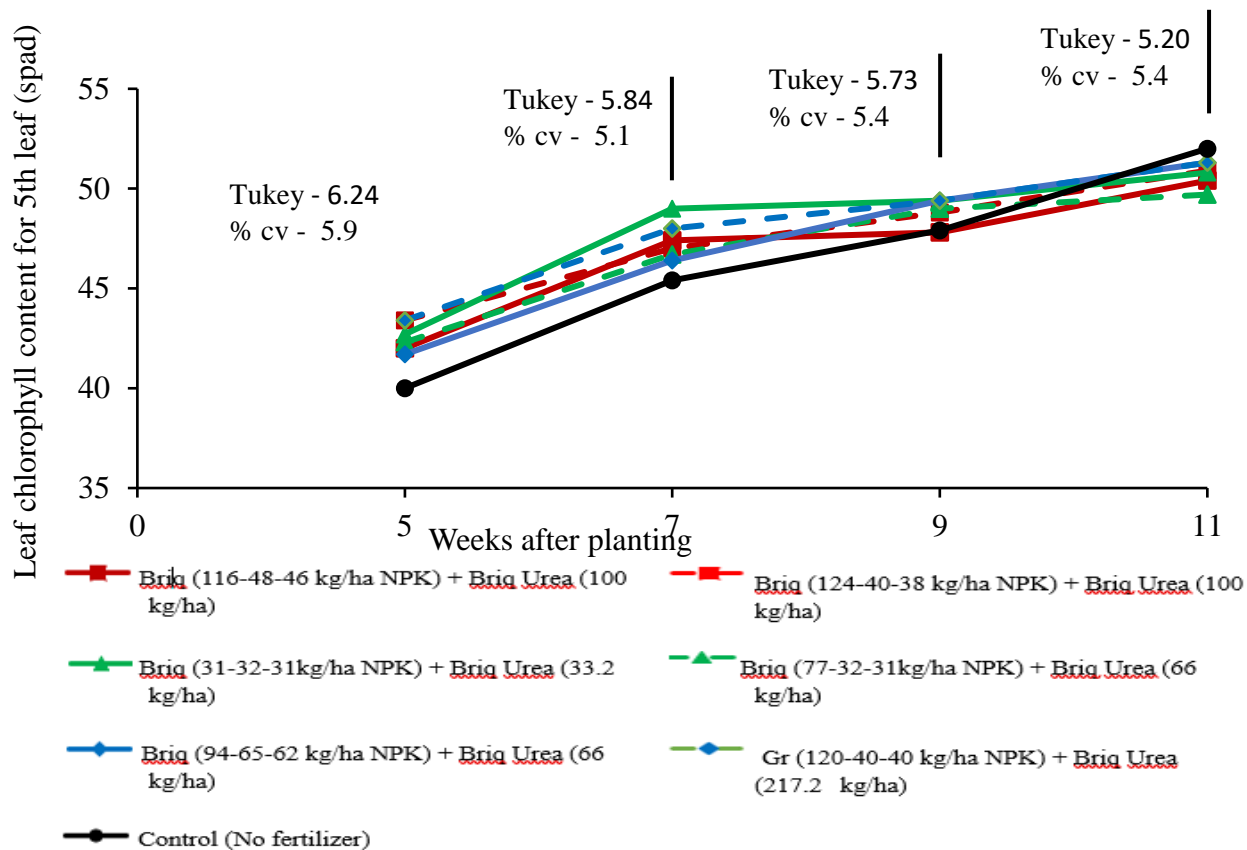


Fig 4.3b: Fifth (5th) Leaf chlorophyll content of maize as influenced by different rates of briquette and granule NPK fertilizer at Ejura during 2022 major season

4.7.4 Sixth (6th) Leaf chlorophyll content

The results on chlorophyll content of the 6th leaf of maize are presented in Figures 4.4a and 4.4b. The 6th leaf chlorophyll content for maize plants at Bunuso was not significantly different among the treatments from 5 to 11 WAP. At Ejura, the 6th leaf of maize chlorophyll content did not differ ($P \leq 0.05$) significantly between treatments from 5 WAP to 11WAP (Fig. 4.4b). There was an increase in maize 6th leaf chlorophyll content from 5 to 9 WAP and decreased sharply at 11 WAP at both locations (Fig 4.4b).

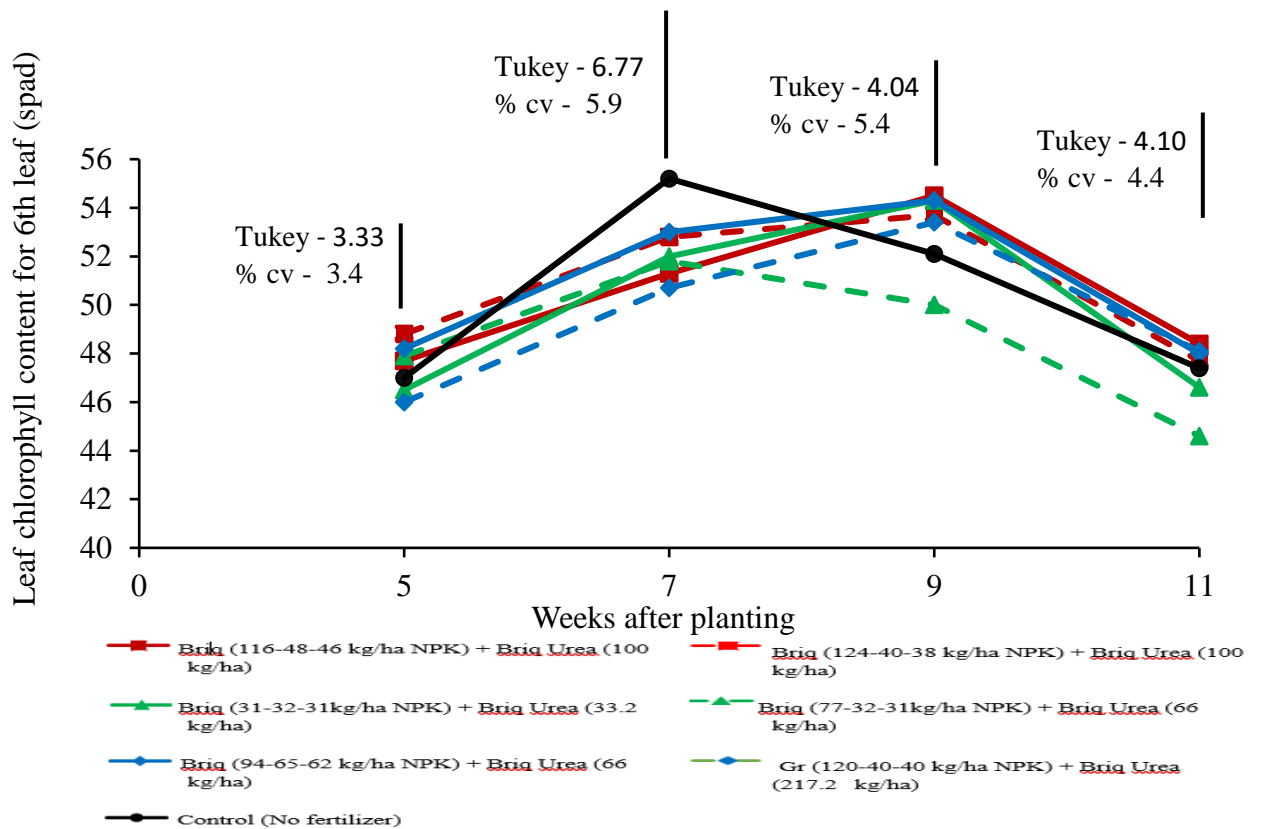


Fig 4.4a: Sixth (6th) Leaf chlorophyll content of maize as influenced by different rates of briquette and granule NPK fertilizer at Bunuso during 2022 major season

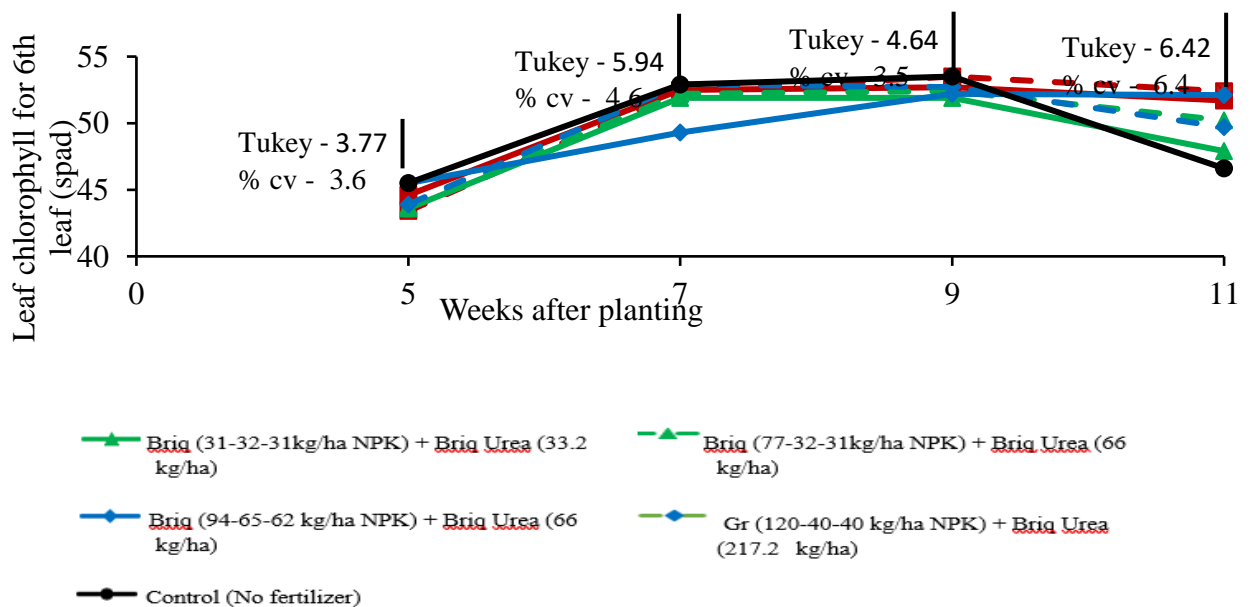


Fig 4.4b: Sixth (6th) Leaf chlorophyll content of maize as influenced by different rates of briquette and granule NPK fertilizer at Ejura during 2022 major season

4.7.5 Shoot dry weight two weeks before and after tasseling of maize

Table 4.12 shows results of shoot dry weight two weeks before and after tasseling of maize as influenced by briquette and granule NPK fertilizers at Bunuso and Ejura. There were significant ($P \geq 0.05$) differences between treatments at both locations. At Bunuso maize plants that received briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha) was significantly different from the control in shoot dry weight two weeks before tasseling maize.

Shoot dry weight at Ejura 2 weeks before tasseling was significantly higher than at Bunuso (Table 4.12).

At Ejura, briquette (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha) produced significantly higher shoot dry weight than all treatments, except briquette (77-32-31 kg/ha NPK) + Briq Urea (66 kg/ha) and briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha) at two weeks before tasseling. Maize that received briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha) produced significantly greater shoot dry weight 2 weeks after tasseling at Ejura. There were no significant ($P \leq 0.05$) differences between location \times treatment interactions in shoot dry weight across both locations (Table 4.12).

Table 4.12 Shoot dry weight two weeks before and after tasseling of maize as influenced by different rates of briquette and granule NPK and urea fertilizers at Bunuso and Ejura during 2022 major season

Treatment	Shoot dry weight (g) 2 weeks before tasseling of maize		Mean	Shoot dry weight (g) 2 weeks after tasseling of maize		Mean
	Bunuso	Ejura		Bunuso	Ejura	
	Briq (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha)	28.25	55.75	42.00	43.75	60.25
Briq (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha)	26.00	49.75	37.88	46.50	59.25	52.88
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	27.25	46.25	36.75	46.00	56.50	51.25
Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)	28.75	50.25	39.50	42.00	57.75	49.88
Briq (94-65-62 kg/ha NPK) + BriqUrea (66 kg/ha)	31.00	50.00	40.50	44.00	64.00	54.00
Gr (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)	26.75	48.75	37.75	43.25	54.25	48.75
Control (No fertilizer)	22.50	45.00	33.75	35.75	51.50	43.62
Mean	27.21	49.39		43.04	57.64	
Tukey ($P \leq 0.05$)	7.280	8.553		8.961	5.802	
CV (%)	13.5	9.3		11.0	8.5	
Tukey ($P \leq 0.05$):	Location =	1.84**			1.98**	
	Treatment =	5.28**			5.69**	
	Location x Treatment =	NS			NS	
	Overall CV (%) =	11.1			17.4	

* Briq----- Briquette

* Gr-----Granular

4.7.6 Root dry weight two weeks before and after tasseling of maize

Root dry weight two weeks before and after tasseling of maize are presented in Table 4.13.

At Ejura before tasseling, maize plants that received briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha) produced significantly higher root dry weight than the No fertilizer (control) plot which recorded the lowest in root dry weight (Table 4.13). However, there were no significant differences between treatments at Bunuso, Location and location \times

treatment interaction root dry weight two weeks before and after tasseling of maize (Table 4.13).

Maize plants that received briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha at Ejura produced significantly higher root dry weight 2 weeks after tasseling than the control which produced the least. There were no significant ($P \geq 0.05$) differences among treatments at Bunuso, location and location \times treatment interaction in root dry weight, 2 weeks after tasseling (Table 4.13). The performance of NPK briquette fertilizer was better in root dry weight, 2 weeks before tasseling across both location and root dry weight, 2 weeks after tasseling at Ejura compared to NPK granular fertilizer and the control (Table 4.13).

Table 4.13 Root dry weight two weeks before and after tasseling of maize as influenced by different rates of briquette and granular NPK and urea fertilizers at Bunuso and Ejura during 2022 major season

Treatment	Root dry weight (g) 2 weeks before tasseling of maize			Root dry weight (g) 2 weeks after tasseling of maize		
			Mean			Mean
	Bunuso	Ejura		Bunuso	Ejura	
Briq (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha)	98.2	98.2	98.2	162.8	139.5	151.1
Briq (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha)	82.8	95.2	89.0	148.0	141.3	144.6
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	87.5	95.2	91.4	123.3	126.3	124.8
Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)	89.5	98.5	94.0	127.2	138.8	133.0
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	81.2	103.8	92.5	137.5	153.5	145.5
Gr (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)	94.0	91.8	92.9	141.5	126.2	133.9
Control (No fertilizer)	76.5	66.0	71.2	111.5	106.8	109.1
Mean	87.1	92.7		136.0	133.2	
Tukey ($P \leq 0.05$)	NS	13.85		NS	38.78	
CV (%)	10.2	11.5		12.4	18.2	
Tukey ($P \leq 0.05$):	Location =	NS		NS		
	Treatment =	21.84*		41.27*		
	Location x Treatment =	NS		NS		
	Overall CV (%) =	17.5		10.3		

* Briq----- Briquette

* Gr-----Granular

4.8 Yield and yield components of maize

4.8.1 Number of plants harvested per plot

Results in Table 4.14 indicate that there was a significant ($P \leq 0.05$) difference between locations (Bunuso and Ejura) in number of plants harvested per plot. Bunuso had significantly greater number of plants harvested per plot than Ejura (Table 4.14). There were no significant ($P \geq 0.05$) differences among treatments across both locations and location \times treatment interaction in number of plants harvested per plot.

4.8.2 Number of cobs per plot

Results on number of cobs per plot as affected by briquette and granule NPK fertilizer are shown in Table 4.14. There were no significant ($P \geq 0.05$) differences among treatments across both location and treatment \times location interaction in number of cobs per plot. There was, however, a significant ($P \leq 0.05$) difference between maize planted at Bunuso and those at Ejura in number of cobs per plot (Table 4.14). Generally, most maize plants that received briquette NPK fertilizer + urea produced a greater number of cobs per plot than maize plants that received granular fertilizer at both locations (Table 4.14).

Table 4.14 Number of plants harvested per plot and number of cobs per plot as influenced by different rates of briquette and granule NPK and urea fertilizers at Bunuso and Ejura during 2022 major season

Treatment	Number of plants harvested per plot		Mean	Number of cobs per plot		Mean
	Bunuso	Ejura		Bunuso	Ejura	
Briq (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha)	59	56	58	55	54	54
Briq (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha)	61	60	60	59	58	59
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	57	50	54	56	49	53
Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)	61	56	59	59	55	55
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	60	54	57	58	52	55
Gr (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)	59	51	55	57	51	54
Control (No fertilizer)						
Mean	59	54		57.0	53	
Tukey ($P \leq 0.05$)	NS	NS		NS	NS	
CV (%)	4.0	12.6		4.9	12.6	
Tukey ($P \leq 0.05$):	Location = 2.49*			2.50*		
	Treatment = NS			NS		
	Location x Treatment = NS			NS		
	Overall CV (%) = 10.0			10.1		

* Briq----- Briquette

* Gr-----Granular

4.8.3 Number of damaged cobs per plot

Table 4.15 shows number of damaged cobs per plot as influenced by different briquette and granule fertilizer at Bunuso and Ejura. There were no significant ($P \geq 0.05$) differences between location, treatment and location \times treatment interaction in number of damaged cobs per plot.

4.8.4 Number of seeds per cob

Table 4.15 shows number of seeds per cob as influenced by different NPK fertilizer briquette and granule at Bunuso and Ejura. There were no significant ($P \geq 0.05$) differences among treatments and location \times treatment interaction in number of seeds per cob, but difference existed between treatment (Table 4.15). There was a significant ($P \leq 0.05$) difference between locations in number of seeds per cob. Maize planted at Bunuso and received both briquette and granule NPK fertilizer produced higher number of seeds per cob than those planted at Ejura (Table 4.15). Generally, the NPK briquette fertilizer recorded higher number of seeds per cob compared to the NPK granular fertilizer (Table 4.15).

Table 4.15 Number of damaged cobs per plot and number of seeds per cob as influenced by different rates of briquette and granular NPK and urea fertilizers at Bunuso and Ejura during 2022 major season

Treatment	Number of damaged cobs per plot			Number of seeds per cob		
	Bunuso	Ejura	Mean	Bunuso	Ejura	Mean
Briq (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha)	2.25	2.50	2.38	485.9	392.9	439.4
Briq (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha)	2.25	2.50	2.38	452.2	396.1	424.2
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	3.00	3.00	3.00	458.8	449.0	453.9
Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)	3.00	2.00	2.50	467.8	378.0	422.9
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	3.75	3.25	3.50	463.8	409.7	436.8
Gr (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)	4.00	3.00	3.50	434.3	389.6	412.0
Control (No fertilizer)	2.25	2.00	2.12	439.7	353.3	396.5
Mean	2.93	2.61		457.5	395.5	
Tukey ($P \leq 0.05$)	NS	NS		NS	NS	
CV (%)	4.4	7.0		8.1	7.5	
Tukey ($P \leq 0.05$):	Location = NS			25.30*		
	Treatment = NS			NS		
	Location x Treatment = NS			NS		
	Overall % CV = 11.5			14.0		

* Briq----- Briquette

* Gr-----Granular

4.8.5 Cob length

The results of cob length as affected by briquette and granule NPK fertilizer at Bunuso and Ejura are presented in Table 4.16. There were no significant ($P \geq 0.05$) differences among treatments and location \times treatment interaction in cob length although maize plants that received briquette (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha) produced longer cob length (15.56 cm) compared to maize without fertilizer which produced shorter cob length (14.04 cm) at Bunuso (Table 4.16). Cob length of maize planted at Bunuso ranged from 14.04 – 15.56 cm, while that of Ejura ranged from 12.69 – 14.19 cm (Table 4.16).

4.8.6 Cob diameter

Table 4.16 shows cob diameter as influenced by different rates of NPK briquette and granular fertilizer at Bunuso and Ejura. There was a significant difference ($P \leq 0.05$) between location in cob diameter (Table 4.16). Maize planted at Bunuso produced the widest cob diameter with mean value of 4.60 cm while maize planted at Ejura recorded the least cob diameter with mean value of 4.35 cm (Table 4.16). There were no significant ($P \geq 0.05$) differences among treatments and location \times treatment interaction in cob diameter although maize that received Briquette (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha) and Briquette (31-32-31 kg/ha NPK) + Briq Urea (33.2 kg/ha) and then briquette (77-32-31 kg/ha NPK) + Briq Urea (66 kg/ha) and granule (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha) recorded the same mean value (4.37 and 4.31 cm) respectively at Ejura (Table 4.16). The NPK briquette fertilizer produced wider cob diameter compared to NPK granular fertilizer at both location (Table 4.16).

Table 4.16 Cob length and cob diameter as influenced by different rates of granular and briquette NPK and urea fertilizers at Bunuso and Ejura during 2022 major season

Treatment	Cob length (cm)			Cob diameter (cm)		
	Bunuso	Ejura	Mean	Bunuso	Ejura	Mean
Briq (116-48-46 kg/ha NPK) +Briq Urea (100 kg/ha)	15.56	13.74	14.65	4.60	4.37	4.48
Briq (124-40-38 kg/ha NPK) +Briq Urea (100 kg/ha)	14.78	14.13	14.45	4.64	4.42	4.53
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	15.42	13.81	14.62	4.76	4.37	4.57
Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)	15.14	13.53	14.34	4.67	4.31	4.49
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	15.54	14.19	14.87	4.57	4.34	4.45
Gr (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)	15.08	14.08	14.58	4.48	4.31	4.39
Control (No fertilizer)	14.04	12.69	13.37	4.49	4.30	4.39
Mean	15.08			4.60	4.34	
Tukey ($P \leq 0.05$)	NS	13.74		NS	NS	
CV (%)	5.8	NS		4.7	6.3	
		9.3				
Tukey ($P \leq 0.05$):	Location = 0.571*				0.121*	
	Treatment = NS				NS	
	Location x Treatment = NS				NS	
	Overall CV (%) = 8.9				6.1	

* Briq----- Briquette

* Gr-----Granular

4.8.7 Undehusked cob weight per plot

Table 4.17 shows undehusked cob weight per plot at Bunuso and Ejura as influenced by different rates of granular and NPK fertilizer briquette. At Bunuso, and Ejura maize plants that received briquette and granular NPK fertilizer were not significantly different in undehusked

cob weight per plot. The unhusked cob weight for Bunuso was, however, a significantly higher than those from Ejura. There was no significant ($P \geq 0.05$) difference between location \times treatment interaction in unhusked cob weight per plot (Table 4.17).

4.8.8 Dehusked Cob weight per plot

Table 4.15 shows the dehusked cob weight per plot for Bunuso and Ejura as influenced by granular and briquette NPK fertilizer applied at different rates. The results indicates that treatment and location \times treatment interaction were not significantly different in dehusked cob weight per plot. Maize planted at Bunuso had significantly higher dehusked cob weight per plot than those planted at Ejura. The NPK briquette fertilizer applied at Bunuso did better in dehusked cob weight per plot compared to NPK granular fertilizer and control treatment at Ejura. Maize plants that received different rates of briquette NPK fertilizer produced higher dehusked cob weight per plot compared to NPK fertilizer granule at Bunuso (Table 4.17).

Table 4.17 Undehusked cob weight per plot and dehusked cob weight per plot as influenced by different rates of granular and briquette NPK and urea fertilizers at Bunuso and Ejura during 2022 major season

Treatment	Undehusked cob weight per plot (kg)		Mean	Dehusked cob weight per plot (kg)		Mean
	Bunuso	Ejura		Bunuso	Ejura	
Briq (116-48-46 kg/ha NPK) +Briq Urea (100 kg/ha)	8.50	6.50	6.50	7.25	5.25	6.25
Briq (124-40-38 kg/ha NPK) +Briq Urea (100 kg/ha)	9.50	6.75	6.75	8.00	4.75	6.38
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	9.75	6.25	6.25	7.75	4.80	6.27
Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)	9.25	6.00	6.00	7.75	4.75	6.25
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	9.25	5.00	5.00	8.00	4.00	6.00
Gr (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)	7.00	6.00	6.00	5.75	4.50	5.12
Control (No fertilizer)	7.50	4.50	4.50	6.00	3.50	4.75
Mean	8.68	5.86		7.21	4.51	
Tukey ($P \leq 0.05$)	NS	NS		NS	NS	
CV (%)	17.1	35.9		20.4	37.3	
Tukey ($P \leq 0.05$):	Location = 0.864*				0.780*	
	Treatment = NS				NS	
	Location x Treatment = NS				NS	
	Overall CV (%) = 11.6				15.4	

* Briq----- Briquette

* Gr-----Granular

4.8.9 Stover weight per plant at harvest

Table 4.18 shows stover weight per plant as influenced by different NPK fertilizer briquette and granule at Ejura and Bunuso. There were no significant differences among treatments and location x treatment interaction in stover weight per plant at harvest across both locations. There was a significant difference between locations with maize planted at Bunuso producing significantly higher stover weight per plant than that of the Ejura site (Table 4.18).

4.7.10 Total stover weight per plot at harvest

Table 4.18 shows total stover weight per plot at harvest for Ejura and Bunuso sites as influenced by different rates of granular and briquette NPK fertilizer. At Bunuso, maize plants that received briquette (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha) differed significantly from plants that received granule (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha) fertilizer in total stover weight per plot at harvest. Maize plants that received different rates of briquette NPK and fertilizer produced higher total stover weight per plot at harvest than the control at Bunuso. At Ejura, there were significant differences between briquette (124-40-38 kg/ha NPK + Briq Urea (100 kg/ha), briquette (77-32-31 kg/ha NPK) + Briq Urea (66 kg/ha) and briquette (94-65-62 kg/ha NPK) + BriqUrea (66 kg/ha) and control in total stover weight per plot at harvest. There were no significant differences between location x treatments interaction in total stover weight per plot at harvest (Table 4.18). Generally, briquette NPK fertilizer recorded higher mean total stover weight per plot at harvest compared to NPK granular fertilizer (Table 4.18).

Table 4.18 Stover weight per plant and total stover weight per plot as influenced by different rates of briquette and granular NPK and urea fertilizers at Bunuso and Ejura during 2022 major season

Treatment	Stover weight per plant (kg)			Total stover weight per plot at harvest (kg)		
	Bunuso	Ejura	Mean	Bunuso	Ejura	Mean
Briq (116-48-46 kg/ha NPK) +Briq Urea (100 kg/ha)	0.35	0.15	0.25	8.75	5.75	7.25
Briq (124-40-38 kg/ha NPK) +Briq Urea (100 kg/ha)	0.25	0.15	0.20	10.2	8.00	9.12
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	0.12	0.12	0.12	10.5	6.50	8.50
Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)	0.25	0.17	0.21	9.7	7.00	8.38
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	0.27	0.17	0.22	10.0	7.00	8.50
Gr (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)	0.25	0.17	0.21	6.7	6.25	6.50
Control (No fertilizer)	0.17	0.12	0.15	7.0	5.25	6.13
Mean	0.23	0.15		9.0	6.54	
Tukey (P ≤ 0.05)	NS	NS		3.63	1.49	
CV (%)	54.9	37.5		22.8	29.2	
Tukey (P ≤ 0.05):	Location = 0.051*					0.96**
	Treatment = NS					2.76*
	Location x Treatment = NS					NS
	Overall CV (%) = 15.7					29.9

* Briq----- Briquette

* Gr-----Granular

4.8.11 100-seed weight

Table 4.19 shows that there was significant ($P \leq 0.05$) differences between the 100-seed weight of maize planted at Bunuso and those planted at Ejura. The 100-seed weight of maize at Bunuso was significantly higher (29.57 g) than that at Ejura with the least mean

value of (26.64g). At Bunuso there were no significant differences among the treatments although briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha).

and Briquette (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha) applied to maize plants recorded the same 100-seed weight (29.75g). At Ejura, maize plants that received briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha) produced significantly higher 100-seed weight (29.25 g) than the control (23g). There were no significant ($p \geq 0.05$) differences among maize plants that received different rates of briquette NPK and those that receive granule NPK as well as location \times treatment interaction in 100-seed weight (Table 4.19). Generally, maize planted at Bunuso with briquette NPK briquette produced heavier 100-seed weight than maize planted at Ejura on the same treatment and with NPK fertilizer granular (Table 4.19).

4.8.12 Total grain weight per plot

There were no significant ($P \geq 0.05$) differences among treatments across both locations and location \times treatment interaction in total grain weight per plot although maize plants that received Briquette (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha) and Briquette (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha) produced the same mean value and heaviest (3.67 kg) total grain weight per plot (Table 4.19). There was a significant ($P \leq 0.05$) difference between maize planted at Bunuso (4.44 kg) in total grain weight per plot from maize planted at Ejura (2.36 kg) (Table 4.19). The briquette NPK fertilizer recorded higher total grain weight per plot than NPK granular fertilizer and the control across location (Table 4.19).

Table 4.19 100-seed weight and total grain weight per plot as influenced by different rates of granular and briquette NPK and urea fertilizers at Bunuso and Ejura during 2022 major season

Treatment	100-seed weight (g)			Total grain weight per plot (kg)		
	Bunuso	Ejura	Mean	Bunuso	Ejura	Mean
Briq (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha)	29.75	27.50	28.62	4.65	2.70	3.67
Briq (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha)	30.25	26.00	28.12	4.80	2.55	3.67
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	31.00	27.25	29.12	4.40	2.70	3.55
Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)	31.00	26.75	28.88	4.65	2.65	3.65
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	29.75	29.25	28.50	4.72	2.20	3.46
Gr (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)	27.75	26.75	27.25	3.80	2.00	2.90
Control (No fertilizer)	27.50	23.00	25.25	4.05	1.70	2.87
Mean	29.57	26.64		4.44	2.36	
Tukey ($P \leq 0.05$)	NS	4.665		NS	NS	
CV (%)	8.0	9.7		15.6	44.4	
Tukey ($P \leq 0.05$):	Location =	1.196**		0.437*		
	Treatment =	3.432**		NS		
	Location x Treatment =	NS		NS		
	Overall CV (%) =	10.2		13.3		

* Briq----- Briquette

* Gr-----Granular

4.8.13 Grain Yield

The result of grain yield for Bunuso and Ejura as influenced by briquette and granular is presented in Table 4.20. The maize grain yield ranged between 1.52 to 1.92 t/ha at Bunuso and 0.68 to 1.08 t/ha at Ejura. Averaged across treatments maize planted at Bunuso yield about 88% more than maize planted at Ejura. There were no significant ($P \geq 0.05$) differences among treatment and location \times treatment interaction in grain yield (t/ha). However, on the averaged across locations, maize that received briquette fertilizers

recorded (1.38-1.47t t/ha) yielded which is about 18-27% and 19-28% higher than the grain yield produced under granular application and no control treatments, respectively. Briquette (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha) gave the highest yield at Bunuso, while Briquette (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha) and Briquette (31-32-31 kg/ha NPK) + Briq Urea (33.2 kg/ha) gave the highest yield at Ejura. Maize grain yield was significantly higher at Bunuso than those obtained from Ejura. Maize plants that received NPK fertilizer briquette produced higher grain yield than plants that received granular NPK fertilizer across both locations (Table 4.20).

Table 4.20 Grain yield (t ha⁻¹) as influenced by different rates of briquette and granular NPK and urea fertilizers at Bunuso and Ejura

Treatment	Grain Yield (t ha ⁻¹)		Mean
	Bunuso	Ejura	
Briq (116-48-46 kg/ha NPK) + Briq Urea (100 kg/ha)	1.86	1.08	1.47
Briq (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha)	1.92	1.02	1.47
Briq (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha)	1.76	1.08	1.42
Briq (77-32-31kg/ha NPK) + Briq Urea (66 kg/ha)	1.86	1.06	1.46
Briq (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha)	1.89	0.88	1.38
Gr (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha)	1.52	0.80	1.16
Control (No fertilizer)	1.62	0.68	1.15
Mean	1.77	0.94	
Tukey (P ≤ 0.05)	NS	NS	
CV (%)	11.6	14.4	
Tukey (P ≤ 0.05):	Location = 0.1749*		
	Treatment = NS		
	Location x Treatment = NS		
	Overall CV (%) = 14.3		

* Briq----- Briquette

* Gr-----Granular

CHAPTER FIVE: DISCUSSION

5.1 Effect of different rates of granular briquette NPK and Urea fertilizers on Soil Conditions at both Experimental Sites

The study determined the effect of different rates of NPK and urea briquette and granular fertilizers application on the improvement, particularly the chemical properties of the soil. The results showed that the soil fertility was improved following the application of briquette and granular NPK fertilizer at Bunuso and Ejura. The findings indicate that the soil at Bunuso produced higher amounts of Mg^{2+} , K^+ and organic carbon content (Table 4.1) compared to Ejura. This indicates that, the amendment to Bunuso soil might have increased the exchangeable cations and organic carbon content in the top soil which were essential to improve the soil fertility. This finding agrees with the results of Butterly *et al.* (2013) who reported that the application of NPK briquette tended to increase the fertility of the soil by providing supplemental cations such as Ca, Mg and organic matter in the soil.

Similarly, this present study supports findings from Goldberg *et al.* (2020) who concluded that, applying inorganic fertilizer to amend the soil possibly increase the cation exchange capacity (CEC) which is a measure of the retention of positively charged ions in the top soil. The NPK fertilizer briquettes have high prospects to support the growth and development of crops. The application of NPK fertilizer briquette enhanced the soil pH as shown in Table 4.2. The results indicate that the pH of Bunuso background soil was 5.78. After NPK fertilizer briquette application the pH values for Bunuso soil had a higher pH 6.33 compared to Ejura's pH of 5.97. This implies that, the soil at Bunuso experimental site showed more improvement in the pH which enhanced growth and development of the maize crop. To improve the growth and development of a crop, the soil pH plays a key

role hence, the results suggest that, applying the NPK fertilizer briquette has a greater potential to improve the soil fertility. The results further showed that, the soils across both locations recorded higher levels of organic carbon, total nitrogen and organic matter content than the control soil (without any amendment) (Table 4.2). The results confirm that all the amended soils with NPK fertilizer briquette and granular improved the soil nutrient levels and hence enhanced plants growth, development and subsequently yield. The findings agree that of with Guo *et al.* (2017). Again, the results of the current study are in line with a study by Biratu *et al.* (2019) who found high soil organic carbon, N and organic matter in the soil with NPK briquette application. This might have supported the growth and crop yield of maize and has an advantage over the application of the granule inorganic fertilizer.

5.2 Phenology of maize as influenced by different rates of granular and briquette NPK and Urea fertilizers

There were significant differences across both locations in days to 50 % tasseling, silking and maturity. The non-significant differences between treatments x location interaction in all phenological traits on maize except in percentage plant establishment might be that location had no effect on treatment and were similar in conditions. The non-significant difference between treatment in percentage plant establishment meant that the treatments did not affect plant establishment. The significantly higher percentage plant establishment at Bunuso compared to Ejura could be attributed to the high rainfall recorded at Bunuso during the early growth period, high soil available water content and high pH and soil organic matter. This is an indication that at Bunuso experimental site, there were better conducive environmental factors such as soil pH, required soil moisture and nutrient available which assisted better crop growth.

Generally, days to 50% tasseling is an important parameter in maize plant development because from exponential plant growth stage towards grain formation, plants need much nutrient for growth and grain filling (Dauda *et al.*, 2019). In both locations there were significant differences between treatments and location with maize that received granule (120-40-40 kg/ha NPK) fertilizer + Briq Urea (217.2 kg/ha) tasseling five and three days earlier than the control at Bunuso and Ejura respectively. This probably implies that a high level of nitrogen in the NPK promoted reproductive growth than potassium (K) in the fertilizer formulation. This probably justifies the fact that the treatment has a pronounced effect on some important processes of maize plants like photosynthesis, nitrogen metabolism, carbonic anhydrase activity, chlorophyll synthesis and resistance to biotic and abiotic activity (Nandwa, 2019; Sanchez *et al.*, 2011).

The late tasseling of maize at Bunuso compared to Ejura could be attributed to the fact that the performance of briquettes NPK and urea fertilizers is strongly reliant on environmental variables, notably soil moisture, as a result, variations in the moisture levels in the soil made nutrient absorption difficult for plant roots which resulted in decreased nutrient availability, especially nitrogen (N) to improve plant growth and therefore delayed tasseling. The significant difference between Ejura and Bunuso in days to 50 % silking might be that fertilizer application improved soil fertility coupled with well distributed rainfall pattern at Bunuso fields during the experiment. Days to 50% silking are relevant to maize plant because from exponential plant growth stage towards grain production, plants need more nutrients to enhance physiological processes, vegetative growth and subsequent grain production (Bandaogo, *et al.* 2019). According to Agyeman *et al.* (2017)

inorganic fertilizer application improves vegetative growth that pave way for commencement of reproductive growth such as silking in maize.

The non-significant differences between treatment and location \times treatment interaction in days to 50 % silking is an indication that the treatments were similar and that location had no influence on days to 50% silking. The earlier days to 50 % maturity in NPK fertilizer briquette (124-40-38 kg/ha NPK) + Urea (100 kg/ha) than other formulated NPK fertilizers and the control at Bunuso implies that, the impact of the high N level in the NPK fertilizer briquette improved soil fertility at Bunuso and hence early maturity of maize. NPK fertilizer briquettes is strongly reliant on environmental variables such as well distributed rainfall pattern as a result, variations in the moisture levels in the soil made nutrient absorption easy for plant roots which resulted in increased nutrient availability, especially nitrogen (N) to improve plant growth and therefore early in maturity (Nandwa, 2019).

5.3 Physiological growth parameters as influenced by granular and briquette NPK and Urea fertilizers

The variation between Bunuso and Ejura in relative growth rate (RGR) and crop growth rate (CGR) might be due to variations in soil moisture content and nutrient availability during the initial growth of plants. This agrees with Makokha *et al.* (2016) that conducive environmental factor such as precipitation that leads to high soil moisture is required for nutrients availability for plant growth and development on crop growth rate (CGR) and relative growth rate (RGR). The CGR and RGR increased from 0-8 weeks after planting and declined sharply from 8-10 WAP at both locations. This might be due to the allocation of assimilates to the maize grains during grain-filling thereby resulting in sharp decrease in CGR and RGR at 8-10 weeks after planting at both locations (Essilfie *et al.*, 2023).

Kihara and Njoroge (2013) proposed that the decrease in crop growth rate from 8 to 10 weeks after planting may be related to the end of vegetative growth. Pandey *et al.* (2017) asserted that the decline in growth rate as plant aged could be due to the cessation of vegetative growth. Tajul *et al.* (2013) further claimed that the trend towards decline was partly due to the fact that the increase in metabolically active tissue had less of an impact on the overall growth of the plant. The results pertaining to CGR and RGR align with report by Fernandez & Ciampitti (2019). The higher CGR values recorded by maize plants that received briquette (124-40-38 kg/ha NPK + Briq Urea (100 kg/ha) and 94-48-46 kg/ha NPK) + Briq Urea (66 kg/ha) at Bunuso and Ejura and higher RGR in briquette (77-32-31 kg/ha NPK) + Briq Urea (66 kg/ha) across both locations at 4-8 WAP could be due to the higher nitrogen content and briquette fertilizer. Azarpour *et al.* (2014) reported that the nitrogen-enriched amendments may have improved photosynthetic tissues and showed raised CGR and RGR. Crops with longer growth periods might have benefited from the sustained nutrient release of briquettes, thereby promoting steady growth rates. This is in line with Essilfie *et al.* (2023) who reported highest CGR and RGR with maize plants that received amendment with high nitrogen content.

5.4 Effect of different rates of granular and briquette NPK and Urea fertilizers on vegetative growth of maize

Plant height at Bunuso and Ejura were not significantly affected by treatments from 5 WAP to 11 WAP although differences exist between locations. The differences in plant height between the two locations could be attributed to several factors including; soil type and climatic condition. Similar results were observed by Knaofmone *et al.* (2021) and Sucipto (2020) where they reported sorghum plants reacting differently due to

environment, climate and genetic characteristics of variety. The non-significant difference between treatments at Bunuso and Ejura in number of leaves per plant could be due to the fact that the granular and briquette NPK fertilizers applied did not have an effect on maize plant leaves and were similar. The highest chlorophyll content of the sixth leaf in the control plot (No fertilizer) at 7 WAP at both locations during the cropping season but the least at 11 WAP at Ejura is in line with the result of Poku *et al.* (2014) who reported that chlorophyll content of leaves of the no fertilizer treatment was high at some point during the plant growth period. The increase in shoot and root dry weight at two weeks before and after tasseling in briquette NPK fertilizer than in granular NPK fertilizer treated plot and the control could be due to the application of the briquette fertilizer. This is in line with Alam *et al.* (2020) that application of NPK fertilizer briquette boosted maize production compared to granular NPK fertilizer treated plants.

5.5 Effect of different rates of granular and briquette NPK and Urea fertilizers on yield and yield components of maize

There were no significant ($P \geq 0.05$) differences among treatments in number of plants harvested per plot but significant differences occurred between plants harvested per plot at Bunuso and Ejura. This could be due to high seed viability, differential uptake of nutrients and differences in climatic conditions such as rainfall, temperature, relative humidity at different locations which might have resulted in an increased number of plants harvested per plot at Bunuso than at Ejura (Habib *et al.* 2019). Amdahl *et al.* (2017) reported that varying rainfall and nutrient content of soil were conducive for well-established plants. The non-significant differences between treatments and location \times treatment interaction in most of the yield and yield components such as number of cobs per plot, unhusked and husked cob weight per plot, number of damaged cobs per plot and number of seeds per cob at harvest

could be that location had no effect on the treatments which also had no effect on the variables measured and therefore similar. The significant differences between maize planted at Bunuso and Ejura in cob length, cob diameter, dehusk and undehusked cob weight per plot and yield could be due to variations in rainfall pattern and less soil moisture content at Ejura experimental site. This agrees with Agyin-Birikorang *et al.* (2018) who reported that, the performance of inorganic fertilizer briquettes is strongly reliant on environmental variables, notably soil moisture. Total stover weight is an important indicator of the effectiveness of fertilizer. Maize plants that received both granular and briquette NPK fertilizer did not, however, differ significantly in stover weight per plant in both Bunuso and Ejura. Meanwhile, maize planted at Bunuso had significantly higher stover weight per plant than those planted at Ejura. The greatest stover weight per plant recorded at Bunuso could be due to differences in climatic conditions such as rainfall, and this supports the importance of the availability of nutrients to plants due to high soil moisture.

The higher 100-seed weight of maize plants that received briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha) fertilizer than granular (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha) and the control at Ejura could be due to the fact that nitrogen losses due to volatilization was minimal (Fugice *et al.*, 2018) due to NPK fertilizer briquette application which was buried compared to the granular which was exposed. This might have increased the chloroplast formation and leaf photosynthetic efficiency which might have been transformed into formation of cobs and also increased seed weight of maize (Lin *et al.*, 2021). This corroborates with Singh *et al.* (2015). The significantly higher total grain weight per plot produced at Bunuso than at Ejura could probably be due to better distributed rains, favorable temperature and good soil condition such as pH, soil water and

organic carbon content at Bunuso than Ejura. This might have resulted into heavier grain weight. The presence of ample amount of fertilizer with required soil moisture content is important because it enables maize plants to build vigour better. The increase level of N in maize plants that received briquette (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha) increased maize grain yield at Bunuso although not significant from other treatments but significantly different from those planted at Ejura. This may be due to the enriched nutrient availability and difference in location. This result corroborates the findings of Yeboah *et al.* (2016) who reported that maize yield increased significantly due to growing conditions at the experimental site. Although briquette (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha) had the highest yield of 1.92 t/ha at Bunuso the value is low compared with the average maize yield of Ghana in 2022 (5.75 kg/ha) (FAOSTAT, 2022).

The variation in yield at both locations could also be differences in environmental factors such as water, temperature, nutrients and soil conditions. The low maize yield produced in this current study could be due to low initial rainfall experienced during the growing period coupled with slow release of nutrients from both briquette and granular NPK fertilizer for effective plant growth at initial stage.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

Based on the results presented on different rates of granular and briquette NPK and urea fertilizer the following conclusions are drawn:

Objective 1:

- The effect of granular and briquette NPK and urea fertilizers improved the nutrient and chemical characteristics of soils compared to the control.
- Bunuso soil recorded higher levels of organic matter, organic carbon, Mg^{2+} , K^+ , and available P than Ejura soil

Objective 2:

- The application of granular (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha) to maize resulted in the earliest days to 50 % tasseling across both locations
- Maize plants that received granular (120-40-40 kg/ha NPK) + Briq Urea (217.2 kg/ha) exhibited the earliest days to 50% silking at Bunuso, and silked 4 days earlier than briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha) and the control
- The application of NPK briquette (116-48-46 kg/ha NPK) fertilizer + Briq Urea (100 kg/ha) exhibited significantly greater number of leaves per plant than other treatments from 9 to 11 WAP at Bunuso
- The application of NPK fertilizers briquette (31-32-31 kg/ha NPK) + Briq Urea (33.2 kg/ha) to maize across both locations improved the 5th leaf chlorophyll content from 5 to 9 WAP whereas at Ejura, on chlorophyll content on 6th leaf, no fertilizer (control) gave highest mean value from 5 to 9 WAP.

- Maize plants that received briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha) produced significantly higher shoot dry weight, 2 weeks before tasseling at Bunuso as well as shoot dry weight, 2 weeks after tasseling at Ejura than no fertilizer (control).
- Maize plants that received briquette NPK and urea fertilizers at Bunuso produced significantly greater number of plants harvested than at Ejura.
- Maize plants that received briquette (31-32-31kg/ha NPK) + Briq Urea (33.2 kg/ha) demonstrated significantly greater total stover weight per plot than granular (120-40-kg/ha NPK) + Briq Urea (217.2 kg/ha) fertilizer at Bunuso
- The application of briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha) to maize plants at Ejura produced significantly higher 100- seed weight than the control.
- Maize yield ranged between 1.52 to 1.92 t/ha at Bunuso and 0.68 to 1.08 t/h at Ejura although no significant differences exist among treatment.
- With the exception of number of damaged cobs per plot, all yield and yield components variables measured showed a significantly higher mean value at Bunuso than Ejura.

Objective 3

- The application of granular and briquette NPK and urea fertilizers and without fertilizer at Bunuso recorded significantly higher crop growth rate values (0-8 WAP and 8-10 WAP) than those planted at Ejura.
- Maize plants that received granular and briquette NPK and urea fertilizers did not differ significantly in CGR from 0-8 WAP and 8-10 WAP at Bunuso and Ejura.

- The application of briquette fertilizer (77-32-31 kg/ha NPK) + Briq Urea (66 kg/ha) to maize plants at Bunuso and at Ejura gave significantly higher relative growth rate from 0-8 WAP than the control
- Maize plants that received granular and briquette NPK and urea fertilizers and with no fertilizer produced significantly higher relative growth rate from 8 to 10 WAP than those planted at Ejura.

6.2 Recommendations

The findings of this study necessitate the following recommendations based on the study:

- ❖ Farmers are encouraged to adopt the use of NPK fertilizer briquettes to their farms to improve the long-term fertility of the soil that may increase crop yield rather than using granular NPK fertilizer
- ❖ For earliest days to tasseling and silking of maize, farmers are to apply granular (120-40-40kg/ha NPK) + Briq Urea (217.2 kg/ha) fertilizer to the plots.
- ❖ For higher vegetative growth maize farmers are to apply briquette NPK fertilizer than the granular NPK fertilizer to their maize which may serve as livestock feed.
- ❖ For improved maize grain quality in terms of seed weight and cob diameter farmers are encouraged to apply briquette (31-32-31 kg/ha NPK) + Briq Urea (33.2 kg/ha).
- ❖ Farmers are encouraged to apply briquette (94-65-62 kg/ha NPK) + Briq Urea (66 kg/ha) and briquette (124-40-38 kg/ha NPK) + Briq Urea (100 kg/ha) for longer cob length and higher grain yield respectively.
- ❖ Farmers are to apply briquette NPK and urea fertilizers to their maize to promote early vigorous crop growth rate (CGR) and relative growth rate (RGR) to optimized grain yield.

- ❖ Further research should be conducted at different agroecological zones of Ghana to ascertain the overall effectiveness of the different NPK fertilizer briquettes.

REFERENCES

- Abdullah A. A. (2018). Effect of vermicompost and vermiwash on the productivity of spinach (*Spinacia oleracea*), Onion (*Allium cepa*) and Potato (*Solanum tuberosum*). *World Journal of Agricultural Sciences*. 4 (5): 554-557
- Abebe, A and Feyisa, H.K. (2017). Yield related traits and yield of quality protein maize (*Zea mays* L.) affected by nitrogen levels to achieve maximum yield in the central Rift Valley of Ethiopia. *J. Biol. Agric. Health*. 5, 2224–3208.
- Adenawoolan, B. (2015). Short term effect of biohar and compost on soil fertility and water status in NE Germany under field condition. *J. Plant Nutri Soil SCI* 57(1-2): 369-80
- Adeniyani O. N., Ojo A. O., Akinbode, O. A and Adediran J. A. (2016). Comparative study of different organic manures and NPK fertilizer for improvement of soil chemical properties and dry matter yield of maize in two different soils. *Journal of Soil Science and Environmental Management*. 2(1): 9-13
- Adhikari, F., Meelu, O.P., Yadoinder-Singh and Bijah-Singh (2016). Effect of NPK fertilizer for soil productivity improvement. *World Soil Resources Reports*, 76, FAO, Rome. Mexico, D.F.: CIMMYT and KARI, 2016
- Adhikary, M.T., Sanwal, S.K., Laxminarayana, K., Yadav, R.K., Rai, N., Yadav, D.S. & Bhuyan, M. (2020). Effect of inorganic fertilizer on soil fertility, growth, physiology, yield and quality of turmeric. *Indian Journal of Horticulture* 64(4): 444–449.
- Adu, G. B., Abdulai, M. S., Alidu, H., Nustugah, S. K., Buah, S. S., Kombiok, J. M., & Etwire, P. M. (2017). Recommended production practices for maize in Ghana. *CSIR-AGRA Maize production guide*, 1-18.

- Adu-Gyamfi G., K., Amanullah, P. Shah and K.B. Marwat. (2019). Nitrogen levels and its time of application influence leaf area, height and biomass of maize planted at low and high density. *Pakistan Journal of Botany* 41: 761-768
- Aflakpui, G. K. S., Anchirinah V. M. and Asumadu H. (2018). Response of a quality protein maize hybrid to N supply and plant density in the forest zone of Ghana. *Tropical and Science*. 45: 3–7.
- Agbato, J. C. (2019). Parallels between artificial selection in temperate maize and natural selection in the cold-adapted crop-wild relative *Tripsacum*. *bioRxiv*, 187575.
- AGRA (2022). Recommended Production practices for maize in Ghana Dol. *Research Journal of Agriculture and Environmental Management*, 3(3): 162-174.
- Agyeman, H., S.P. Singh, J.K. Singh, R.N. Singh, M.A. Ansari, R.L. Meena, and B. Yadav. (2017). Productivity, nitrogen balance and economics of winter maize (*Zea mays*) as influenced by QPM cultivars and nitrogen levels. *Indian J. Agric. Sci.* 84:306–308.
- Agyin-Birikorang, S.; Winings, J.H.; Yin, X.H.; Singh, U & Sanabria, J. (2018). Field evaluation of agronomic effectiveness of balanced-nutrient fertilizer briquettes for upland crop production. *Nutr. Cycl. Agroecosyst.* 110, 395–406.
- Ahmed, K. A. (2019). Maize in Ghana: an overview of cultivation to processing. In *2016 ASABE Annual International Meeting* (p. 1). American Society of Agricultural and Biological Engineer

- Akhtar, P., F. Goletti, Niknam, F and M. Yudelman. (2019). Integrated Nutrient Management, Soil Fertility, and Sustainable Agriculture: Current Issues and Future Challenges. Food, Agriculture, and the Environment Discussion Paper 32, International Food Policy Research Institute, Washington D.C., U.S.A. pp 38
- Akobundu. L. D. (2008). Weed management in groundnut. (In) Groundnut Research in India, pp. 248-259, Basu, M.S. and Singh, N.B. (Eds). CABI, Wallingford, UK.
- Alam, M. M., Hossain, S. M. M., Naher, K., Rafii, M. Y., & Latif, M. A (2018). Influence of plant population and nitrogen-fertilizer at various levels on growth and growth efficiency of maize. *Scientific World Journal*. 376(1-2): 1-29.
- Alam, I., Coares, K., Lee, S., Lovegrove, M., Robalino, M., Sakata, T., Santella, D., Surendran, S. & Urry, K., (2020). Energy in, energy out. Columbia University, USA.
- Albrecht, F. (2020). Hormonal and metabolic regulation of source–sink relations under salinity and drought: from plant survival to crop yield stability. *Biotechnology Advances*, 32(1): 12-30.
- Alva, M., Gruhn, P., F. Goletti, and M. Yudelman. (2016). Integrated Nutrient Management, Soil Fertility, and Sustainable Agriculture: Current Issues and Future Challenges. Food, Agriculture, and the Environment Discussion Paper 32, International Food Policy Research Institute, Washington D.C., U.S.A. pp 38
- Amdahl, E., Potarzycki, J. and Grzebisz, W. (2017) Effect of NPK Application on Grain Yield of Maize and Its Yielding Components. *Plant Soil and Environment*, 55, 519-527.

- Angelucci, K. D. (2020). A review on *Zea mays* (L.) (Maize). *World Journal of Pharmacy and Pharmaceutical Sciences*, 5(1), 356-371.
- Anten N.P.R, Ackerly D.D. (2001) A new method of growth analysis for plants that experience periodic losses of leaf mass. *Functional Ecology*;15(6):804–811. Available: <https://doi.org/10.1046/j.0269-8463.2001.00582.x> 13
- ARC-Grain Crop (2013). Impact of Companion cropping on incidence and severity of maize ear rots and mycotoxins in western Kenya. Directorate of Agricultural Information Service. vol. 13 Pp. 2224-2231
<https://www.arc.agric.za.arc>
- Ardelean R. D.N Achina, T., & Quain & P. T. M. D. (2017). Use of Morphological and Molecular Profiling for the Establishment of Relatedness between Commercially Available and Elite Soybean Genotypes. *European Journal of Biotechnology and Genetic and Biological Science*, 6(9): 50-57.
Engineering Vol, 6(1)
- Arif M, Ilyas M, Riaz M, Ali K, Shah K, Haq IU, Fahad S. (2017). Improves phosphorus use efficiency of organic-inorganic fertilizers, maize- wheat productivity and soil quality in a low fertility alkaline soil. *Field Crop. Res.*;214, 25–37.
- Artuzo, F. D., Foguesatto, C. R., de Souza, Â. R. L., & da Silva, L. X. (2018). Costs management in maize and soybean production. *Revista Brasileira de Gestão de Negócios*, 20(2).
- Athokpam, H., Ghosh, G. K., Wani, S. H., Akoijam, S., & Ningthoujam, R. (2016). Evaluation of some soil test methods in acid soils for available phosphorus for pea of Senapati district of Manipur (India). *International Journal of Agriculture, Environment and Biotechnology*, 9(1), 63-68

- Azam, R.T (2019). Global maize production, utilization, and consumption. *Annals of the New York Academy of Sciences*, 1312(1), 105-112.
- Azarpour E, Moraditochae M & Bozorgi H.R. (2014). Effect of nitrogen fertilizer management on growth analysis of rice cultivars. *International Journal of Bioscanes*. 4(5):35–47.
- Bandaogo, A., F. Bidjokazo, S. Youl, E. Safo, R. Abaidoo, and A. Opoku. (2019). Effect of fertilizer deep placement with urea supergranule on nitrogen use efficiency of irrigated rice in Sourou Valley (Burkina Faso). *Nutr. Cycling Agroecosyst*. 102:79–89. doi:10.1007/ s10705-014-9653-6
- Baral, P., Nehra, A. S., Hooda, I. S., & Singh, K. P. (2015). Effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum L.*). *Indian Journal of Agronomy*, 45, 112-17.
- Baumann D.T, Bastiaans L & Goudriaan J. (2002). Analysing crop yield and plant quality in an intercropping system using an ecophysiological model for interplant competition. *Agricultural Systems*.;73 (11):173–203.
- Badu-Apraku, Jensen, E. S., Carlsson, G., & Hauggaard-Nielsen, H. (2006). Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global-scale analysis. *Agronomy for Sustainable Development*, 40(1): 1-9.
- Baver, K., Peck, R. B., & Mesri, G. (1987). *Soil Mechanics in Engineering Practice*. 3rd Edition. *John Wiley and Sons, Inc.*
- Bindraban, G., Piperno, Dolore, R., Anthony, J., Ranere, I., Hoist, I. and Dickau, R. (2020). Challenging the evidence for prehistoric wetland maize agriculture at fort center Florida-jstor. <https://www.jstor.org>

- Biratu, G., Aghaie, R.T., Herath, H. M. S. K., Camps-Arbestain, M., & Hedley, M. (2019). Effect Of NPK fertilizer on soil physical properties in two contrasting soils: an Alfisol and an Andisol. *Geoderma*, 209: 188-197.
- Brady, E.E. (2019). Response of some maize hybrids (*Zea mays* L.) to different levels of nitrogenous fertilization. *J. Appl. Sci. Res.* 9:1902–1908.
- Butterly, R., Agyin-Birikorang, S., Tindjina, I., Ahmed, S., Twumasi, A., Avornyo, V., & Singh, U. (2013). One-Time Fertilizer Briquettes Application for Maize Production in Savanna Agroecologies of Ghana. *Agronomy Journal*, 111(6), 3339–3350.
- Braimoh, J., & Vlek, F. K. (2018). Nitrogen use efficiency and maize productivity in the Guinea Savanna Agro-ecological Zone of Ghana. *Journal of Experimental Agriculture International*, 1-15
- Brust, A. M., and King, R. (2015). Drought stress in maize (*Zea mays* L.) effects, resistance mechanisms, global achievements and biological strategies for improvement (pp.179).
- Bukhsh, H.S., Hokmalipour, S. & Darbandi, M. H. (2019). Effects of nitrogen fertilizer on chlorophyll content and other leaf indicators in three cultivars of maize (*Zea mays* L.). *World Applied Sciences Journal*, 15(12): 1780-1785.
- Callo-Concha, E.D., Kankam-Boadu, I., Sarkodie-Addo, J., & Amagloh, F. K. (2013). Profitability of maize production in the northern region of Ghana. *International Journal of Development Research*, 8(09), 22861-22869.
- Cárdenas, C. I., Cortés-Cruz, M., Gardner, C. A., & Costich, D. E. (2019). Wild relatives of maize. In *North American Crop Wild Relatives, Volume 2*, Springer. pp. 3-39.

- Cruz- Cárdenas, C. I., - M., Gardner, C. A., & Costich, D. E. (2021). Wild relatives of maize. In *North American Crop Wild Relatives, Volume 2*, Springer. pp. 3-39.
- Cassman, H. F., (2018). Field manual of maize breeding procedures, FAO, Rome. Ulger, A.C., The effect of different rows and intra-row spacing on grain yield and some agronomic characteristics of maize. *Journal of Agriculture*, 13:95-104.
- Chand, S. (2022). Maize production: production and distribution of maize around the world. Available at: <http://www.yourarticlelibrary.com/essay>
- Clerk, M.K. (2018). Effect of integrated nutrient management on yield and yield attributing characters in okra and residual effect on succeeding crop radish. *Indian Journal of Arid Horticulture*, 1(1): 25-27. *Sci. Plant Nutr.* 13:895–904.
- Coelho, B.G., Chauhan, B. S., & Johnson, D. E. (2013). Row spacing and weed control timing affect yield of aerobic rice. *Field Crops Research*, 121(2), 226
- CSIR/AGRA (2016). Recommended Production practices for Maize in Ghana. <https://www.researchgate.net> Dol: 10.3140b.1437
- Darfour, B., & Rosentrater, K. A. (2021). Maize in Ghana: an overview of cultivation to processing. In *2016 ASABE Annual International Meeting* (p. 1). American Society of Agricultural and Biological Engineers.
- Dauda S.N., Ajayi F.A. and Ndor E. (2019). Growth and yield of watermelon (*Citrullus lanatus*) as affected by poultry manure application. *Journal of Agriculture and Social Sciences* 4 121–124

- DeHaan, L. R., Van Tassel, D. L., Anderson, J. A., Asselin, S. R., Barnes, R., Baute, G. J., & Kantar, M. (2016). A pipeline strategy for grain crop domestication. *Crop Science*, 56(3): 917-930.
- Dogan, D. T., Lin, M. T., Occhialini, A., Andralojc, P. J., Parry, M. A., & Hanson, M. R. (2020). A faster Rubisco with potential to increase photosynthesis in crops. *Nature*, 513(7519): 547-550.
- Dogan, R., D'Andrea, H., Zingore, S., Murwira, H.K. & Delve R.J, (2015). Influence of nutrient management strategies on variability of soil fertility, crop yields and nutrients balances on smallholder farms in Zimbabwe. *Agric Ecosystem Environment* 119: 112-126.
- Dowswell, K. M. (2019). Potential role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farming systems of Sub-Saharan Africa. *Research Journal of Agriculture and Environmental Management*, 3(3): 162-174.
- Dutt, S. P. (2020). Wild relatives of maize, rice, cotton, treasure troves for tolerance to biotic and abiotic stresses. *Frontiers in plant science*, 9, 886
- Egyir, I. S., Ofori, K., Antwi, G., & Ntiamoa-Baidu, Y. (2015). Adaptive capacity and coping strategies in the face of climate change: a comparative study of communities around two protected areas in the coastal savanna and transitional zones of Ghana. *Plant and Soil*, 376(1-2): 1-29.
- Essilfie, E. M., Appiah, E., Asiedu E. K, and Owusu, S.E (2023). Growth and Yield Response of Maize (*Zea mays* L.) to Integrated Nutrient Management of Biochar, Organic and Inorganic Fertilizers. (Volume 23) Issue 4, Page 69-91, 2023; Article no. AJAAR.111277 ISSN: 2456-8864

- FAO (2015). Agriculture in Ghana: facts and figures. Produced by the Statistics, Research and Information Directorate. Accra.
- FAO (2016). Food Security in the Context of Economic and Trade Policy Reforms: *Insights from Country Experiences*. Ccp 05/11 Rome.
- FAO (2018). Agriculture in Ghana: facts and figures. Statistics, Research and Information Directorate. Accra.
- FAO, (2018). Performance of bread wheat (*Triticum aestivum* L.) in response to supplemental irrigation and rate of nitrogen application in Enderta, Tigray, Northern Ethiopia. *Int. J. of Life Sciences*, 2017, Vol. 5 (3): 345-361
- FAO/UNESCO. (2008). *FAO/UNESCO System of Soil Classification*.
- FAOSTAT. (2022). *Food and agriculture data of the Food and Agriculture Organization of the United Nations*. [Accessed 2018 May 12]. www.fao.org/faostat. [Google Scholar].
- FAO (2022). *Food and agriculture data of the Food and Agriculture Organization of the United Nations*. [Accessed 2022 May 12]. www.fao.org/faostat. [Google Scholar].
- FAOSTATS (2015). Food and Agriculture Organization of the United Nations Statistical Databases. (Available from <http://faostat.fao.org/default.aspx>; last accessed 1st June, 2021)
- Farrell, R. and O'Keeffe, B. (2015). Effect of growth Stage on the mineral concentrations in alfalfa leaf, stem and the whole plant. *Biotechnology in Animal husbandry*, 25:1225-1231.
- Fernandez, J.A, Ciampitti I.A. (2019). Effect of late nitrogen fertilization on grain yield and grain filling in corn. Kansas Agricultural Experiment Station Research Reports.;5(6):4.

- Fernandez, R. A., Anderson, J. B., Wellner, J. S., Minzoni, R. L & Hallet, B. (2011). Latitudinal variation in glacial erosion rates from Patagonia and the Antarctic Peninsula (46 S–65 S). *Bulletin*, 128(5-6): 1000-1023.
- Fugice, J. D Rajkouch, S., Enders, A., Hanley, K., Hyland, C., Zimmerman, A. R. and Lehmann, J. (2018). Corn growth and nitrogen nutrition after additions of biochars with varying properties to a temperate soil. *Bio fertile soils* 48(3): 271-841
- Gaihre, Y.K.; Singh, U.; Islam, S.M.; Huda, A.; Satter, M.A.; Sanabria, J.; Islam, R & Shah, A. (2017). Impacts of urea deep placement on nitrous oxide and nitric oxide emissions from rice fields in Bangladesh. *Geoderma* , 6, 370–379.
- Ghana Meteorological Department, (2008). Mampong Ashanti
- Ghana Meteorological Department, (2005). Mampong Ashanti
- Ghanbari, A., Dahmardeh, M., Syahsar, B. A., & Ramrodi, M. (2019). The role of soil chemical properties. *African Journal of Agricultural Research*, 5(8): 631-636.
- Goldberg, T., Agegnehu, G., Bass, A., Nelson, P., & Bird, M. (2020). Benefits of biochar, compost and biochar-compost for soil quality, maize yield and greenhouse gas emissions in a tropical agricultural soil. *Sci. Total Environ.*, 543, 295–306.
- Guo, E., Yan, C., Mei, X., He, W., Bing, S. H., & Ding, L. (2017). Long-term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest China. *Geoderma*, 158, 173–180.
- Habib, C., Abbasi, M.K.; Tahir, M.M & Rahim, N. (2019) Effect of N fertilizer source and timing on yield and N use efficiency of rainfed maize (*Zea mays* L.) in Kashmir–Pakistan. *Geoderma*, 195, 87–93.

- Hailemariam, A. G. (2017). Chemical characterization and estimation of Cheka: A traditional food and drink. *American Journal of Applied Chemistry*, 5(5): 73-83.
- Haque, M. M., Hamid, A. and Bhuiyan, N. I. (2017). Nutrient uptake and productivity as affected nitrogen and potassium application levels maize/sweet potato intercropping system". *Korean J. Crop Sci.*, 46(1): 1
- Hatfield, J. L., & Prueger, J. H. (2015). Temperature extremes: Effect on plant growth and development. *Weather and climate extremes*, 10, 4-10
- Hedge, M. F. (2016). NPK fertilizer amendments impact soil nutrients and microbial enzymatic activities in a semiarid irrigated maize cropping system. *Genetic modification. Regulatory Toxicology and Pharmacology 12*: p. 196.
- Hedge Y. (2015). Integrated Nutrient Management, Soil Fertility, and Sustainable Agriculture: Current Issues and Future Challenges. Food, Agriculture, and the Environment Discussion Paper 32, International Food Policy Research Institute, Washington D.C., U.S.A. pp 38
- Hillel, T. (1982). Methods of soil analysis. Part 1: Physical and mineralogical methods. *American Society of Agronomy and Soil Science Society of America*.
- Hokmalipour, S. & Darbandi, M. H. (2011). Effects of NPK fertilizer on chlorophyll content and other leaf area indicate in cultivars of maize (*Zea mays L.*). *World Applied Sciences Journal*, 18(15): 1942-1947.
- Huda, A.; Gaihre, Y.K.; Islam, M.R.; Singh, U.; Islam, R.; Sanabria, J.; Satter, M.A.; Afroz, H.; Halder, A & Jahiruddin, M. (2016). Floodwater ammonium, nitrogen use efficiency and rice yields with fertilizer deep placement and alternate wetting and drying under triple rice cropping systems. *Nutr. Cycl. Agroecosyst.* 104, 53–66.

- Idoko, J. A., Akaazua, B. W., & Oga, J. I. (2018). Evaluation of five improved maize varieties for intercropping with sweet potato in Makurdi, southern guinea savanna ecology of Nigeria. *Asian Research Journal of Agriculture*, 1-11.
- IFDC (2019) (International Fertilizer Development Center) Fertilizer Deep Placement. Mitigating Poverty and Environmental Degradation through Nutrient Management in South Asia; IFDC: Muscle Shoals, AL, USA, March (2019)
- IFDC (2019) (International Fertilizer Development Center) Fertilizer Deep Placement. Mitigating Poverty and Environmental Degradation through Nutrient Management in South Asia; IFDC: Muscle Shoals, AL, USA, March (2019)
- IFDC International Fertilizer Development Center (2015). Quarterly Magazine 40(4). <http://ifdc.org/ifdc-magazine>
- Iken, Y.U Htet, M. N. S., Ya-Qin, P., Ya-Dong, X., Soomro, R. N., & Jiang-Bo, H. (2015). Effect of plant spacing maize (*Zea mays* L.) on green forage yield, and quality evaluation. *IOSR Journal of Agriculture and Veterinary Science*, 9(12), 59-63.
- International Fertilizer Development Center (IFDC) (2016). Mitigating poverty and environmental degradation through nutrient management in South Asia. IFDCReport32(1).https://issuu.com/ifdcinfo/docs/march_2016_english_newsletter
- Islam, M.S., Rahman, F., & Hossain, A.T.M.S. (2011). Effects of NPK briquette on rice (*Oryza sativa*) in tidal flooded ecosystem. *Agriculturists* 9:37–43. doi:10.3329/argic 9i1-2.9477

- Jangir, D'Andrea, H., Zingore, S., Murwira, H.K. & Delve R.J, (2015). Influence of nutrient management strategies on variability of soil fertility, crop yields and nutrients balances on smallholder farms in Zimbabwe. *Agric Ecosystem Environment* 119: 112-126.
- Janssen, F., Pauly, A., Rombouts, J., Koen, J. A., Deleu, Jan, A, and Delcour, D. A. (2017). Proteins of Amaranth Buckwheat and Quinoa. A food Science and Technology perspective. <https://www.doi.org/10.1111/1541-4337.12240>
- Jensen, E. S., Carlsson, G., & Hauggaard-Nielsen, H. (2020). Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global-scale analysis. *Agronomy for Sustainable Development*, 40(1): 1-9.
- Jiang, E., L. Haby, M.L. Prieto-Linde, & Svensson, S.E. (2019). Influence of fertilizer placement on yield and protein composition in spring malting barley. *J. Soil*
- John, S.E., Lauren, J.G., Welch, R.M. & Duxbury, J.M. (2019) A comparison of the effects of micronutrient seed priming and soil fertilization on the mineral nutrition of chickpea (*Cicer arietinum*), Lentil (*Lens culinaris*), Rice (*Oryza sativa*) and Wheat (*Triticum aestivum*) in Nepal. *Experimental Agriculture*, 41, 427-448.
- Kadam, S. (2015). Nitrogen transformation, ammonia volatilization loss, and nitrate leaching in organically enhanced nitrogen fertilizers relative to urea. *Soil Sci. Soc. Am. J.* 76, 1842–1854. [Cross Ref]
- Kankam-Boadu, I., Sarkodie-Addo, J., & Amagloh, F. K. (2018). Nitrogen use efficiency and maize productivity in the Guinea Savanna Agro-ecological Zone of Ghana. *Journal of Experimental Agriculture International*, 1-15

- Kanouo, S., K.A., T.A. & Adiku, S. G.K. (2018). Evaluation of suitability of some soils in the Forest- Savanna Transition and the Guinea Savannah zones of Ghana for maize production, *West African Journal of Applied Ecology*. 26 (1).
- Karl, D. M. (2018). Seasonal and Inter Annual variability in sources of Nitrogen supporting export in the oligotrophic subtropical North Pacific Ocean. Department of oceanography
- Kaur, K., Kapoor, K. T. and Gupta, A. P. (2020). Impact of inorganic fertilizers on soil chemical and biological properties under tropical conditions. *J. Plant Nutr. Soil Sci.*, 168:117-122.
- Kellogg, E. (2015). Exploring global changes in nitrogen and phosphorus cycles in agriculture induced by livestock production over the 1900–2050 period. *Proceedings of the National Academy of Sciences*, 110(52), 20882-20887
- Kihara J. and Njoroge S. (2013) Phosphorus agronomic efficiency in maize-based cropping systems: a focus on western Kenya. *Field Crops Research*, 150, 1-8
- Kjeldahl, J. (1883) “Neue method ezur Bestimmung des stick stoffs in organize chem Korpem. (New method for the determination of nitrogen in organic substances). *Zeitschrift fur analytische chemie* 22(1): 366-383.
- Kling, B.N. Jie, F. U., Yang, X. Y., Cheng, M. J., Lü, G. H., Pei, W. A, Wu, Y. Q. & Tang, Q. L. (2016). Perennial aneuploidy as a potential material for gene introgression between maize and *Zea perennis*. *Journal of Integrative Agriculture*, 14(5), 839-846

- Knaofmone, T.K., Satybhan Singh, G., Virendra; A., and Mishra, T., Parmanand W.F., (2021). Effect of NPK, boron and zinc on productivity and profitability of late sown kharifmaize (*Zea mays* L.) in western Uttar Pradesh, India. *Ann. Agric. Res. New Series*, 38(3): 310-313.
- Lebot, A. F. (2020). Agricultural production in sub-Saharan Africa remains low compared to the rest of the world—a historical perspective. *International Journal of Water Resources Development*, 5(5): 73-83
- Lee, S., H. He, Y., Piper, D. M., Gu, M., Travis, J. J., George, S. M., & Zhang, J. G. (2020). In situ transmission electron microscopy probing of native oxide and artificial layers on silicon nanoparticles for lithium-ion batteries. *Acs Nano*, 8(11): 11816-11823
- Len, Aghaie, R.T., Herath, H. M. S. K., Camps-Arbestain, M., & Hedley, M. (2019). Effect of phosphorus on soil physical properties in two contrasting soils: an Alfisol and an Andisol. *Geoderma*, 209: 188-197.
- Lin, M. T., Occhialini, A., Andralojc, P. J., Parry, M. A., & Hanson, M. R. (2021). A faster Rubisco with potential to increase photosynthesis in crops. *Nature*, 513(7519): 547-550.
- Lithourgidis, S. U., A. Ghani, G. W. Yeates, G. Burch, and N. R. Cox. (2011). Effect of nitrogen and phosphate fertilizers on microbial and nematode diversity in pasture soils. *Soil Biology and Biochemistry* 33:953–964.
- Liu, K., & Rosentrater, J. P. (2016). Potassium-solubilizing microorganism in evergreen agriculture: an overview. In *Potassium solubilizing microorganisms for sustainable agriculture*. New Delhi: Springer. pp. 1-20.
- Liu, M., & Stutzel N.T. (2018). Fertilizer requirements for wheat and maize in China: The QUEFTS approach. *Nutr. Cycling Agro ecosystem.*, 74: 245-258.

- Loussaert, R. Ghanbari, A., Dahmardeh, M., Syahsar, B. A., & Ramrodi, M. (2018). The role of intercropping maize (*Zea mays* L.) on yield and soil chemical properties. *African Journal of Agricultural Research*, 5(8): 631-636
- Mahad, M. (2018). Potential role of cereal-legume systems in integrated soil fertility management in smallholder farming systems of Sub-Saharan Africa. *Research Journal of Agriculture and Environmental Management*, 3(3), 162-174.
- Mahapatra, M., Mojid, M. A., Tabriz, S. S., Acharjee, T. K., & Adham, A. K. M. (2018). Growth and yield of three hybrid maize varieties under different (*Daucus carota* L.) as influenced by farm yard manure. *African Journal of Agricultural Economics and Rural Development* ISSN: 2375-0693 Vol. 4 (3), pp.322-327,
- Makarova, O., Makarov, V., Gasparyan, S., Napris, Z., & Shemyakin, A. (2020). *Methodological approach to grain yield planning. In E3S Web of Conferences (Vol. 175, p. 01003). EDP Sciences.*
- Makokha S., Kimani S., Mwangi W., Verkuijl H. & F. Musembi (2016). Determinants of Fertilizer and Manure Use in Maize Production in Kiambu District, Kenya. Mexico, D.F.: CIMMYT and KARI, 2016
- Mann, D., Anderson, J. M. and Ingram, J. S. I. (2019). Tropical Soil Biology and Fertility: *A Handbook of Methods*. CAB International, Wallingford, UK. Pp 95-99
- Markovic, J., Strbanovic, R., Cuetkovic, M., Anelkovic, B. and Zukovic, B. (2019). Effect of growth Stage on the mineral concentrations in alfalfa leaf, stem and the whole plant. *Biotechnology in Animal husbandry*, 25:1225-1231.
- Marschner, H. & Dell, D. (2018). Nutrient uptake in mycorrhizal symbiosis. *Plant and soil* 159:89–102.

- Martin, G., Clouaire, R., Magne, M. A., Justes, E., & Sarthou, J. P. (2017). How to implement biodiversity-based agriculture to enhance ecosystem services: a review. *Agronomy for sustainable development*, 35(4): 1259-1281.
- Mauricio R. (2017). Diversity studies on maize accessions from three countries. *Biocatalysis and Agricultural Biotechnology*, 3(2), 198-206.
- McLean, E. O. (1982). Soil pH and lime requirement. *Methods of soil analysis: Part 2 Chemical and microbiological properties*, 9, 199-224.
- Moss, G. W. (1961). *Exchangeable cations*, In: *Methods of soil analysis*. 159–165.
- Merino-Martín, H Edmeades, T. R, Sam, S. M., Esenowo, G. J., & Udosen, I. R. (2017). Biochemical Characterization of Cassava Processing Waste Water and its Effect on the Growth of Maize Seedlings. *Nigerian Journal of Basic and Applied Sciences*, 25(2), 12-20.
- Miah, M.A.M., Y.K. Gaihre, G. Hunter, U. Singh, and S.A. Hossain. (2016). Fertilizer deep placement increases rice production: Evidence from farmers' fields in southern Bangladesh. *Agron. J.* 108:1–8.
- Miller, D. D., & Welch, R. M. (2013). Food system strategies for preventing micronutrient malnutrition. *Food policy*, 42, 115-128.
- MoFA (2011). Ghana's Economic and Agricultural Transformation past performance. <https://www.books.google.com.gh.books>
- MoFA (2011). Ghana's Economic and Agricultural Transformation past performance. <https://www.books.google.com.gh.books>
- MoFA (2016). Ghana's Economic and Agricultural Transformation past performance. <https://www.books.google.com.gh.books>

- MoFA (2019). Ghana's Economic and Agricultural Transformation past performance.
<https://www.books.google.com.gh/books>
- MoFA (2020). Statistics Research and Information Directorate (SRID), "Agriculture in Ghana: Facts and Figures", May 2020.
- MoFA (2022). Ghana's Economic and Agricultural Transformation past performance.
- MoFA Statistics, Research and Information Directorate (SRID)" (2019). Agriculture in Ghana: Facts and Figures (2019)". May 2019.
- Morel, A., Friedman, R., Tulloch, D. J., & Caldecott, B. (2016). Stranded assets in maize production: A case study of Indonesia. *Sustainable Finance*
- Nandwa, M.J. (2019). The effect of micronutrients in ensuring efficient use of macronutrients. *Turkish Journal of Agriculture and Forestry*, 32, 215-
- Nkebiwe, P. M., Weinmann, M., Bar-Tal, A., & Müller, T. (2016). Fertilizer placement to improve crop nutrient acquisition and yield: A review and meta-analysis. *Field crops research*, 196, 389-401
- Nurung, P. M., Weinmann, M., Bar-Tal, A., & Müller, T. (2016). Fertilizer placement to improve crop nutrient acquisition and yield: A review and meta-analysis. *Field crops research*, 196, 389-401.
- Ogindo, H., Capurso, A., Crepaldi, G. & Capurso, C. (2018). Legumes and Pulses. In *Benefits of the Mediterranean Diet in the Elderly Patient*. Springer, Cham. pp. 285-324.
- Ogunlade, D. P., Rana, N. S. and Singh, R.P. (2016). Growth and yield of winter maize (*Zea mays* L.) as influenced by intercrops and nitrogen application. *Indian Journal of Agronomy of Agriculture*, 1-11.

- Onuk, L., Kenchanmane Raju, S. K., Lai, X., Zhang, Y., Dai, X., Rodriguez, O., & Schnable, J. C. (2017). Parallels between natural selection in the cold-adapted crop-wild relative *Tripsacum dactyloides* and artificial selection in temperate adapted maize. *The Plant Journal*, 99(5): 965-977
- Paliwal, R. R. L. (2011). Tropical maize improvement and production. Plant production and protection division. FAO Rome (Italy).
- Pandey, Y., Winings, X. Yin, U. Singh, and J. Sanabria. (2017). Impact of excessive nitrogen fertilizers on the environment and associated mitigation strategies. *Asian Journal of Microbiology and International Sciences*, 15(2), 213-221.
- Parray, R.K., J.W. Maranville and A. Admou. (2017). Nitrogen effects on maize in a Sahelian environment. I. Grain yield and yield components. *Agriculture Water Management* 46: 1-13.
- Phutthai, T., & Hughes, M. (2017). Four new species of Begonia (*Begoniaceae*) from Thailand. *Edinburgh Journal of Botany*, 74(2): 149.
- Piperno, M.F., & Dolores, L. (2011). Yield response of maize (*Zea mays* L.) to conservation agriculture cropping system in Southern Africa. *Soil and Tillage Research*, 146
- Poku, P. A., Agyarko, K., Dapaah, H. K. K., & Hanley M. M. (2014). Influence of *Inorganic fertilizer* NPK on Soil Physico – Chemical Properties and Growth and Yield of Carrot (*Daucus carota* L) The productivity of soils under long-term crop production in Ghana has been declining, *Journal of Agriculture and Sustainability* 5(1), 26–44.
- Price, T., & Nguyen M. (2016). Effect of late nitrogen fertilization on grain yield and grain filling in corn. Kansas Agricultural Experiment Station Research Reports. 2019;5(6):4.

- Ragasa, B. & Farnham, K. L (2018). Forage yield and nitrogen nutrition dynamics of warm-season native forage genotypes under two shading levels and in full sunlight. *Revista Brasileira de Zootecnia*, 45(9), 1889-1997.
- Ragasa, T.E., Pietraszko, T & De-Clereq M.K., (2017). Organic source of nutrients in Engeisted, O, Pled fertilizer Technology and use. (3rd ed), SSSA Madison Wisscorisin. Pp. 503.
- Rahman, M. and Akter, F. (2018). Effect of NPK fertilizers on growth, yield and yield attributes of okra (*Abelmoschus esculentus* (L.) Moench.). *Bangladesh*
- Ribera, F., Nesticò, A., Cucco, P., & Maselli, G. (2020). A multicriteria approach to identify the Highest and Best Use for historical buildings. *Journal of cultural heritage*, 41: 166-177.
- Rouf, J. K., Yarish, C., Hwang, E. K., Park, M., Kim, Y., Kim, J. K., & Kim, Y. (2016). Seaweed aquaculture: cultivation technologies, challenges and its ecosystem services. *Algae*, 32(1), 1-13.
- Sahu, A. (2016). *Physiological and Biochemical Response of Maize to Low Grade Rock Phosphate Under Acidic Soils Of Odisha* (Doctoral Dissertation, Orissa University Of Agriculture And Technology):
- Sanchez W., Wrońska, M., Diatta, J.B. & Dullin, P. (2011) Effect of zinc foliar application at early stages of maize growth on patterns of nutrients and dry matter accumulation by the canopy. Part I. Zinc uptake patterns and its redistribution among maize organs. *Journal of Elementology*, 13, 17
- Sang, V. K. (2021). *Modelling food security in Africa using panel data analysis*.
- SARI, (2019). Biosynthesis, elicitation and roles of monocot terpenoid phytoalexins. *The Plant Journal*, 79(4), 659-678.

- Savant K.T., Pingali, H.S., Gul, S., & Whalen, J. K. (2022) Urea briquettes containing diammonium phosphate: a potential new NP fertilizer for transplanted rice. *Nutrient Cycling in Agro-ecosystems* 51:85–94.
- Shiferaw, E.T., Schnable, J. C., Yan, L., Kenchanmane Raju, S. K., Lai, X., Zhang, Y., Dai, X., & Rodriguez, O (2017). Parallels between natural selection in the cold-adapted crop-wild relative *Tripsacum dactyloides* and artificial selection in temperate adapted maize. *The Plant Journal*, 99(5): 965-977
- Singh, B. P., Cowie, A. L. & Chan, K. Y. (Eds.). (2018). *Soil health and climate change* (Vol. 29). Springer Science & Business Media
- Singh, U., Patil, S.K., Magre, H., Shrivastava, L.K.; Mishra, V.N., Das, R.O., Samadhiya, V.K., Sanabria, J., & Diamond, R.(2015). Rice growth, grain yield and floodwater nutrient dynamics as affected by nutrient placement method and rate. *Agron. J.*, 100, 526–536.
- Smith, B. D., Wales, N., Cappellini, E., Skoglund, P., Fumagalli, M., Jakobsson M., A. B., Willerslev E., Nielsen R., Hufford M. B., Albrechtsen A., R.-I., & P., J. & G. M. T. (2022). *The origin and evolution of maize in the Southwestern United States. Nature Plants.* 3:1-9.
<https://doi.org/10.1038/NPLANTS.2014.3>.
- SRID (2017). National Crop production estimates 2002-2006. *Statistical Research and Information Department, Ministry of Food and Agriculture.*
- SRID (2017). National Crop production estimates 2015-2016. *Statistical Research and Information Department, Ministry of Food and Agriculture.*
- Sucipto, W.E. (2020). Starter Nitrogen Fertilization Impact on Maize (*Zea mays*) Yield and Quality in the Northern Great Plains. *Agron. J.* 98, 1569 1574.

- Sweet M., Z. Y., and Minotti N.T. (2014). Fertilizer requirements for wheat and maize in China: The QUEFTS approach. *Nutr. Cycling Agro ecosyst.*, 74: 245-258.
- Tagne, L., Bujarrabal, B., Gentile, A.-R., Jones, R. J. A., Montanarella, L., Olazabal C. and Selvaradjou, S.-K. (2021). Reports of the Technical Working Groups Established under the Thematic Strategy for Soil Protection, Office for Official Publications of the European Communities, Luxembourg EUR 21319 EN/3, p. 872.
- Tajul, C., Karuku, G. N., Onwonga, R. N., & Kathumo, V. M. (2013). Effects of Tillage Practices and Organic Cropping Systems on the Yield of Sorghum (*Sorghum bicolor* L.) and Sweet Potato (*Ipomoea batatas* L) in Yatta Sub-County, Kenya. *Journal of Agriculture and Sustainability*, New Delhi: Springer. pp. 1-20.
- Titterton, J., Paroha, S., & Mishra, R. P. (2016). Effect of storage on germination and viability of Maize (*Zea mays*) seeds. *International Journal of Current Microbiology and Applied Sciences*, 5(7): 574-663.
- Van Zyl, W. H., Bloom, M., & Viktor, M. J. (2021). Engineering yeasts for raw starch conversion. *Applied microbiology and biotechnology*, 95(6): 1377-1388.
- Vann, O.P, Sugri, I., Maalekuu, B. K., Gaveh, E., & Kusi, F. (2015). Sweet potato value chain analysis reveals opportunities for increased income and food security in Northern Ghana. *Advances in Agriculture*, 2016.
- Vasconcellos, R. L. F. & Cardoso, E. J. B. N. (2019). Rhizospheric streptomycetes as potential biocontrol agents of Fusarium and Armillaria pine rot and as PGPR for Pinus taeda. *Biocontrol*, 54(6): 807.

- Vashist, B. (2021). Crop residue management and soil health: A systems analysis. *Agricultural Systems*, 134: 6-16.
- Vitasse, E. A. & Rebetez, H. B. (2018). Improvement. *Plant, cell & environment*, 35(1): 38-52.
- Wakene, N., Fite, G., Abdena, D., & Birhanu, D. (2016). Integrated use of organic and inorganic fertilizers for maize production. In utilization diversity in land use systems: Sustainable and organic approaches to meet human needs. Conference Tropentag, 2016, October 9-12, 2016
- Wang, Q., Wang, Z., Awasthi, M. K., Jiang, Y., Li, R., Ren, X., & Zhang, Z. (2016). Evaluation of medical stone amendment for the reduction of nitrogen loss and bioavailability of heavy metals during pig manure composting. *Bioresource technology*, 220 : 297-304.
- Wasaya, L., Hernández, M., Della Maggiora, A., Cambareri, M., Barbieri, P., & Cerrudo, D. (2017). Maize water use efficiency and evapotranspiration response to N supply under contrasting soil water availability. *Field Crops Research*, 17(8) : 8-15
- Williams, S. B., Murdock, L. L., & Baributsa, D. (2017). Storage of maize in Purdue improved crop storage (PICS) bags. *PloS one*, 12(1): e0168624.
- Yao, Y., M. Zhang, Y. Tiana, M. Zhaoc, B. Zhanga, M. Zhaoa, K. Zenga, and B. Yin. (2018). Urea deep placement for minimizing NH₃ loss in an intensive rice cropping system. *Field Crops Res.* 218:254–266.
doi:10.1016/j.fcr.2017.03.013

- Yasmin, L., Corbeels, M., Nyamangara, J. & Giller, K. E. (2016). Maize–grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique. *Field crops research*, 136: 12-22.
- Yawalkar, K. O., Daniel, I. O., Ajala, M. O., & Sanni, L. O. (2015). Potential longevity of maize seeds under storage in humid tropical seed stores. *Nature and Science*, 10(8), 114-124.
- Yeboah, E., Souza, J.A.; Buzetti, S.; Filho, M.C.M.T & Moreira, A. (2016). Sources, Rates and Time of Nitrogen Application on Maize Crops under No-Tillage System. *Commun. Soil Sci. Plant Anal.* 47 : 2200–2207.
- Youdeowei, M. S. (2015). Characteristics of rice husk biochar and its influence on the properties of acid sulfate soils and rice growth in West Kalimantan, Indonesia. *The Journal of Agricultural Science* 2: 39–47.
- Zeidan, M. S., Amany, A. and Balor El- Kramany, M. F. (2016). Effect of N- Fertilizer and plant Density on Yield and Quality of maize in Sandy Soil. *Research Journal of Agriculture and Biological Sciences*, 2(4): 156-161.
- Zhang, Z., Christensen, M., Nan, Z., Whish, J. P., Bell, L. W., Wang, J., & Sim, R. (2020). Plant development and solar radiation interception of four annual forage plants in response to sowing date in a semi-arid environment. *Industrial Crops and Products*, 131:41-53.
- Zhao, H. L, Pardo, J., Chu, P. C., Liao, C. X., Huang, J., Dong, J. G., Zhou, X., Huang, Q. and Huang, B. (2015). *Journal Article* UBC13/UBC4 UBC5 Positively regulates T cell activation. *J. immunol* 174 (9): 5288-97.

- Zheng, H., Shao, R., Xue, Y., Ying, H., Yin, Y., Cui, Z., & Yang, Q. (2020). Water productivity of irrigated maize production systems in Northern China: A meta-analysis. *Agricultural Water Management*, 234, 106119.
- Zhou, B., Awasthi, M. K., Ali, A., Zhang, Z., & Mahar, A. (2018). Recovery of phosphate from aqueous solution by magnesium oxide decorated magnetic biochar and its potential as phosphate-based fertilizer substitute. *Bioresource technology*, 215, 209-214.
- Ziegler, K. E. (2019). Popcorn. *Corn: chemistry and technology*, (Ed. 2), 783-809.

APPENDICES

Appendix 1: Soil test categories (SRI soil analytical services division)

Organic matter

<1.5%	low
1.5 - 3.0	medium
>3.0	high

Total nitrogen

<0.1%	low
0.1 - 0.2	medium
>0.2	adequate

Organic carbon

<1.0	low
1.0-2.0	medium
2.0-4.0	Adequate
>4.0	High

Bray's No.1 Phosphorus (Available)

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

Exchangeable Ca

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

Exchangeable Mg

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

Exchangeable K

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

Cation exchange capacity (CEC)

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

Base saturation

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

Soil pH

<5.0	very strongly acidic
5.1 – 5.4	acidic
5.5 – 6.0	moderately acidic
6.1 – 6.4	slightly acidic
6.5 – 7.0	neutral

7.1 – 7.4	slightly alkaline
7.5 – 8.0	moderately alkaline
>8.0	alkaline

EDTA Extractable Mn

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

EDTA Extractable Fe

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

Appendix 2 ANOVA for Days_50% to_emergance at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	1.5938	0.5312	1.97	
Treatment	7	3.2188	0.4598	1.71	0.162
Residual	21	5.6562	0.2693		
Total	31	10.4688			

Appendix 3 ANOVA for Days_50% to emergence at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.7500	0.2500	0.72	
Treatment	7	0.0000	0.0000	0.00	1.000
Residual	21	7.2500	0.3452		
Total	31	8.0000			

Appendix 4 ANOVA % Plant Establishment at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	163.80	54.60	4.27	
Treatment	7	97.33	13.90	1.09	0.405
Residual	21	268.26	12.77		
Total	31	529.40			

Appendix 5 ANOVA % Plant Establishment at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	1596.70	532.23	15.93	
Treatment	7	219.74	31.39	0.94	0.498
Residual	21	701.76	33.42		
Total	31	2518.20			

Appendix 6 ANOVA for Days_to_50%_Tasseling at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	41.094	13.698	5.08	
Treatment	7	75.719	10.817	4.01	0.006
Residual	21	56.656	2.698		
Total	31	173.469			

Appendix 7 ANOVA for Days_to_50%_Tasseling at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	4.094	1.365	0.74	
Treatment	7	21.469	3.067	1.67	0.172
Residual	21	38.656	1.841		
Total	31	64.219			

Appendix 8 ANOVA for Days_to_Silking at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	27.344	9.115	3.02	
Treatment	7	66.469	9.496	3.14	0.020
Residual	21	63.406	3.019		
Total	31	157.219			

Appendix 9 ANOVA for Days_to_50%_Silking at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	8.625	2.875	0.55	
Treatment	7	55.875	7.982	1.53	0.211
Residual	21	109.375	5.208		
Total	31	173.875			

Appendix 10 ANOVA for Days_to_50% Maturity at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	126.125	42.042	6.20	
Treatment	7	35.375	5.054	0.75	0.637
Residual	21	142.375	6.780		
Total	31	303.875			

Appendix 11 ANOVA for Days_to_50% Maturity at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	126.125	42.042	6.20	
Treatment	7	35.375	5.054	0.75	0.637
Residual	21	142.375	6.780		
Total	31	303.875			

Appendix 12 ANOVA for Days to 100 % Maturity at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	49.094	16.365	2.93	
Treatment	7	312.719	44.674	8.01	<.001
Residual	21	117.156	5.579		
Total	31	478.969			

Appendix 13 ANOVA for Days to 100 % Maturity Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	51.84	17.28	1.38	
Treatment	7	94.22	13.46	1.07	0.415
Residual	21	263.91	12.57		
Total	31	409.97			

Appendix 14 ANOVA for Number of Leaves at 5 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	9.7500	3.2500	4.79	
Treatment	7	3.5000	0.5000	0.74	0.644
Residual	21	14.2500	0.6786		
Total	31	27.5000			

Appendix 15 ANOVA for Number of Leaves at 5 WAP Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	2.6250	0.8750	1.96	
Treatment	7	1.8750	0.2679	0.60	0.749
Residual	21	9.3750	0.4464		
Total	31	13.8750			

Appendix 16 ANOVA for Number of Leaves at 7 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	6.3750	2.1250	3.68	
Treatment	7	12.3750	1.7679	3.06	0.022
Residual	21	12.1250	0.5774		
Total	31	30.8750			

Appendix 17 ANOVA for Number of Leaves at 7 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	3.7500	1.2500	2.84	
Treatment	7	5.0000	0.7143	1.62	0.184
Residual	21	9.2500	0.4405		
Total	31	18.0000			

Appendix 18 ANOVA for Number of Leaves at 9 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	3.7500	1.2500	2.23	
Treatment	7	4.5000	0.6429	1.15	0.372
Residual	21	11.7500	0.5595		
Total	31	20.0000			

Appendix 19 ANOVA for Number of Leaves at 9 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	15.0938	5.0312	6.75	
Treatment	7	2.2188	0.3170	0.43	0.876
Residual	21	15.6562	0.7455		
Total	31	32.9688			

Appendix 20 ANOVA for Number of Leaves at 11 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	1.7500	0.5833	4.45	
Treatment	7	5.5000	0.7857	6.00	<.001
Residual	21	2.7500	0.1310		
Total	31	10.0000			

Appendix 21 ANOVA for Number of Leaves at 11 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	7.8438	2.6146	10.16	
Treatment	7	2.4688	0.3527	1.37	0.269
Residual	21	5.4062	0.2574		
Total	31	15.7188			

Appendix 22 ANOVA for Number of Leaves at 13 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	3.0000	1.0000	1.83	
Treatment	7	13.5000	1.9286	3.52	0.012
Residual	21	11.5000	0.5476		
Total	31	28.0000			

Appendix 23 ANOVA for Number of Leaves at 13 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	22.0938	7.3646	9.29	
Treatment	7	4.7188	0.6741	0.85	0.560
Residual	21	16.6562	0.7932		
Total	31	43.4688			

Appendix 24 ANOVA for Plant height at 5 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	724.06	241.35	19.35	
Treatment	7	276.97	39.57	3.17	0.019
Residual	21	261.87	12.47		
Total	31	1262.91			

Appendix 25 ANOVA for Plant height at 5 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	531.90	177.30	14.89	
Treatment	7	281.69	40.24	3.38	0.014
Residual	21	250.12	11.91		
Total	31	1063.71			

Appendix 26 ANOVA for Plant height at 7 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	724.06	241.35	19.35	
Treatment	7	276.97	39.57	3.17	0.019
Residual	21	261.87	12.47		
Total	31	1262.91			

Appendix 27 ANOVA for Plant height at 7 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	3414.53	1138.18	36.11	
Treatment	7	1138.31	162.62	5.16	0.002
Residual	21	661.99	31.52		
Total	31	5214.83			

Appendix 28 ANOVA for Plant height at 9 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	372.51	124.17	1.40	
Treatment	7	2870.21	410.03	4.63	0.003
Residual	21	1860.84	88.61		
Total	31	5103.56			

Appendix 29 ANOVA for Plant height at 9 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	12548.40	4182.80	50.27	
Treatment	7	1612.11	230.30	2.77	0.033
Residual	21	1747.34	83.21		
Total	31		15907.85		

Appendix 30 ANOVA for Plant height at 11 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	1135.85	378.62	8.25	
Treatment	7	280.03	40.00	0.87	0.544
Residual	21	963.48	45.88		
Total	31	2379.36			

Appendix 31 ANOVA for Plant height at 11 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	10644.33	3548.11	41.76	
Treatment	7	1982.59	283.23	3.33	0.015
Residual	21	1784.16	84.96		
Total	31	14411.07			

Appendix 32 ANOVA for Plant height at 13 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	1143.69	381.23	8.81	
Treatment	7	1017.15	145.31	3.36	0.015
Residual	21	908.58	43.27		
Total	31	3069.42			

Appendix 33 ANOVA for Plant height at 13 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	13613.23	4537.74	88.07	
Treatment	7	2733.21	390.46	7.58	<.001
Residual	21	1082.01	51.52		
Total	31	17428.45			

Appendix 34 ANOVA for 5th_Leaf at 5 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	32581.0	10860.3	16.98	
Treatment	7	2587.9	369.7	0.58	0.766
Residual	21	13428.8	639.5		
Total	31	48597.7			

Appendix 52 ANOVA for 5th_Leaf at 7 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	359.6	119.9	0.51	
Treatment	7	96839.9	13834.3	58.92	<.001
Residual	21	4931.0	234.8		
Total	31	102130.6			

Appendix 35 ANOVA for 5th_Leaf at 7 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	4443.3	1481.1	2.91	
Treatment	7	10556.2	1508.0	2.96	0.025
Residual	21	10700.1	509.5		
Total	31	25699.7			

Appendix 36 ANOVA for 5th_Leaf at 9 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	2373.2	791.1	1.50	
Treatment	7	13337.6	1905.4	3.62	0.010
Residual	21	11059.7	526.7		
Total	31	26770.5			

Appendix 37 ANOVA for 5th_Leaf at 9 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	27063.	9021.	5.80	
Treatment	7	23316.	3331.	2.14	0.084
Residual	21	32677.	1556.		
Total	31	83057.			

Appendix 38 ANOVA for 5th_Leaf at 11 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	217.4	72.5	0.25	
Treatment	7	25010.5	3572.9	12.28	<.001
Residual	21	6108.8	290.9		
Total	31	31336.7			

Appendix 39 ANOVA for 5th_Leaf at 11 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	47373.2	15791.1	29.06	
Treatment	7	32040.5	4577.2	8.42	<.001
Residual	21	11411.9	543.4		
Total	31	90825.6			

Appendix 40 ANOVA for 5th Leaf at 13 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	1648.9	549.6	4.80	
Treatment	7	35123.9	5017.7	43.82	<.001
Residual	21	2404.4	114.5		
Total	31	39177.2			

Appendix 41 ANOVA for 5th Leaf at 13 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	48381.	16127.	11.72	
Treatment	7	47969.	6853.	4.98	0.002
Residual	21	28885.	1375.		
Total	31	125235.			

Appendix 42 ANOVA for 6th Leaf at 5 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	388.9	129.6	0.63	
Treatment	7	74640.9	10663.0	51.50	<.001
Residual	21	4347.8	207.0		
Total	31	79377.5			

Appendix 61 ANOVA for 6th Leaf at 5 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	5530.5	1843.5	2.20	
Treatment	7	8519.5	1217.1	1.45	0.238
Residual	21	17613.1	838.7		
Total	31	31663.1			

Appendix 43 ANOVA for 6th Leaf at 7 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	1471.7	490.6	0.58	
Treatment	7	27668.7	3952.7	4.69	0.003
Residual	21	17706.0	843.1		
Total	31	46846.4			

Appendix 44 ANOVA for 6th Leaf at 7 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	4249.	1416.	1.33	
Treatment	7	7366.	1052.	0.99	0.467
Residual	21	22386.	1066.		
Total	31	34001.			

Appendix 45 ANOVA for 6th Leaf at 9 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	1617.5	539.2	0.98	
Treatment	7	33389.8	4770.0	8.64	<.001
Residual	21	11598.1	552.3		
Total	31	46605.3			

Appendix 46 ANOVA for 6th Leaf at 9 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	10434.7	3478.2	7.86	
Treatment	7	2889.1	412.7	0.93	0.502
Residual	21	9289.6	442.4		
Total	31	22613.5			

Appendix 47 ANOVA for 6th Leaf at 11 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	600.9	200.3	0.50	
Treatment	7	26234.5	3747.8	9.33	<.001
Residual	21	8432.4	401.5		
Total	31	35267.7			

Appendix 48 ANOVA for 6th Leaf at 13 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	32764.4	10921.5	16.20	
Treatment	7	22887.2	3269.6	4.85	0.002
Residual	21	14153.9	674.0		
Total	31	69805.5			

Appendix 49 ANOVA for 6th Leaf at 13 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	568.2	189.4	0.88	
Treatment	7	13551.1	1935.9	9.02	<.001
Residual	21	4509.3	214.7		
Total	31	18628.5			

Appendix 50 ANOVA for 6th Leaf at 13 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	32764.4	10921.5	16.20	
Treatment	7	22887.2	3269.6	4.85	0.002
Residual	21	14153.9	674.0		
Total	31	69805.5			

Appendix 51 ANOVA for 5th Leaf Chlorophyll at 5 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	169.85	56.62	1.05	
Treatment	7	160.78	22.97	0.42	0.876
Residual	21	1135.31	54.06		
Total	31	1465.94			

Appendix 52 ANOVA for 5th Leaf Chlorophyll at 5 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	569.27	189.76	4.80	
Treatment	7	82.77	11.82	0.30	0.946
Residual	21	830.18	39.53		
Total	31	1482.22			

Appendix 53 ANOVA for 5th Leaf Chlorophyll at 7 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	59.08	19.69	0.82	
Treatment	7	123.86	17.69	0.74	0.641
Residual	21	501.68	23.89		
Total	31	684.61			

Appendix 54 ANOVA for 5th Leaf Chlorophyll at 7 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	99.24	33.08	1.32	
Treatment	7	222.74	31.82	1.27	0.311
Residual	21	525.53	25.03		
Total	31	847.51			

Appendix 55 ANOVA for 5th Leaf Chlorophyll at 9 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	82.20	27.40	1.73	
Treatment	7	88.15	12.59	0.80	0.599
Residual	21	332.30	15.82		
Total	31	502.65			

Appendix 56 ANOVA for 5th Leaf Chlorophyll at 9 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	325.28	108.43	10.11	
Treatment	7	139.91	19.99	1.86	0.127
Residual	21	225.23	10.73		
Total	31	690.42			

Appendix 57 ANOVA for 5th Leaf Chlorophyll at 11 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	73.99	24.66	1.50	
Treatment	7	14.47	2.07	0.13	0.995
Residual	21	346.20	16.49		
Total	31	434.65			

Appendix 58 ANOVA for 5th Leaf Chlorophyll at 11 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	56.44	18.81	1.26	
Treatment	7	147.89	21.13	1.42	0.251
Residual	21	313.27	14.92		
Total	31	517.60			

Appendix 78 ANOVA for 5th Leaf Chlorophyll at 13 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	228.65	76.22	6.34	
Treatment	7	200.63	28.66	2.38	0.058
Residual	21	252.57	12.03		
Total	31	681.86			

Appendix 59 ANOVA for 6th Leaf Chlorophyll at 5 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	455.34	151.78	5.05	
Treatment	7	144.00	20.57	0.68	0.684
Residual	21	631.45	30.07		
Total	31	1230.79			

Appendix 60 ANOVA for 6th Leaf Chlorophyll at 5 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	371.13	123.71	3.63	
Treatment	7	135.62	19.37	0.57	0.773
Residual	21	715.74	34.08		
Total	31	1222.49			

Appendix 61 ANOVA for 6th Leaf Chlorophyll at 7 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	20.08	6.69	0.21	
Treatment	7	91.92	13.13	0.40	0.890
Residual	21	685.23	32.63		
Total	31	797.23			

Appendix 62 ANOVA for 6th Leaf Chlorophyll at 7 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	9.62	3.21	0.10	
Treatment	7	77.92	11.13	0.36	0.915
Residual	21	646.97	30.81		
Total	31	734.52			

Appendix 63 ANOVA for 6th Leaf Chlorophyll at 9 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	30.34	10.11	0.62	
Treatment	7	106.55	15.22	0.94	0.498
Residual	21	340.12	16.20		
Total	31	477.01			

Appendix 64 ANOVA for 6th Leaf Chlorophyll at 11 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	30.34	10.11	0.62	
Treatment	7	106.55	15.22	0.94	0.498
Residual	21	340.12	16.20		
Total	31	477.01			

Appendix 65 ANOVA for 6th Leaf Chlorophyll at 11 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	41.30	13.77	0.70	
Treatment	7	50.85	7.26	0.37	0.910
Residual	21	413.25	19.68		
Total	31	505.40			

Appendix 66 ANOVA for 6th Leaf Chlorophyll at 13 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	446.95	148.98	7.38	
Treatment	7	533.43	76.20	3.77	0.008
Residual	21	424.05	20.19		
Total	31	1404.43			

Appendix 67 ANOVA for 6th Leaf Chlorophyll at 13 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	56.44	18.81	1.26	
Treatment	7	147.89	21.13	1.42	0.251
Residual	21	313.27	14.92		
Total	31	517.60			

Appendix 69 ANOVA for Shoot dry Weight at 7 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	109.84	36.61	0.96	
Treatment	7	109.47	15.64	0.41	0.885
Residual	21	800.91	38.14		
Total	31	1020.22			

Appendix 70 ANOVA for Shoot_Dry_Wt_7_WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	64.25	21.42	1.36	
Treatment	7	97.00	13.86	0.88	0.539
Residual	21	330.75	15.75		
Total	31	492.00			

Appendix 71 ANOVA for Shoot dry Weight at 11 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	20.59	6.86	0.60	
Treatment	7	67.47	9.64	0.84	0.569
Residual	21	241.66	11.51		
Total	31	329.72			

Appendix 72 ANOVA for Root_Fresh_Weight_ at_7_WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	94963.	31654.	5.30	
Treatment	7	64871.	9267.	1.55	0.204
Residual	21	125360.	5970.		
Total	31	285193.			

Appendix 73 ANOVA for Root dry Weight _at_7 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	12600.3	4200.1	4.54	
Treatment	7	13078.5	1868.4	2.02	0.101
Residual	21	19431.9	925.3		
Total	31	45110.7			

Appendix 74 ANOVA for Root_Dry_Weight_7 WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	259.38	86.46	1.80	
Treatment	7	436.88	62.41	1.30	0.299
Residual	21	1008.62	48.03		
Total	31	1704.88			

Appendix 75 ANOVA for Root dry Weight _at _11 WAP at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	29159.	9720.	7.87	
Treatment	7	6477.	925.	0.75	0.634
Residual	21	25944.	1235.		
Total	31	61580.			

Appendix 76 ANOVA for Root_Dry_Weight_11WAP at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	1645.8	548.6	0.77	
Treatment	7	3809.5	544.2	0.76	0.626
Residual	21	15026.4	715.5		
Total	31	20481.7			

Appendix 77 ANOVA for Stalk_freshh _Weight at Mampong

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	76.0	25.3	0.21	
Treatment	7	1040.9	148.7	1.26	0.318
Residual	21	2486.0	118.4		
Total	31	3602.8			

Appendix 78 ANOVA for Total_Stover_Wt_Plot_Kg at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	54.501	18.167	4.08	
Treatment	7	40.475	5.782	1.30	0.299
Residual	21	93.537	4.454		
Total	31	188.512			

Appendix 79 ANOVA for Number of _Plants_Lodged at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	70.59	23.53	1.01	
Treatment	7	90.47	12.92	0.55	0.785
Residual	21	490.66	23.36		
Total	31	651.72			

Appendix 80 ANOVA for Number of _Plants_Lodged at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	177.250	59.083	17.54	
Treatment	7	6.000	0.857	0.25	0.965
Residual	21	70.750	3.369		
Total	31	254.000			

Appendix 81 ANOVA for Number of Plants Harvested at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	301.75	100.58	6.07	
Treatment	7	47.50	6.79	0.41	0.886
Residual	21	348.25	16.58		
Total	31	697.50			

Appendix 82 ANOVA for Number of Plants Harvested at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	434.25	144.75	5.04	
Treatment	7	383.00	54.71	1.91	0.119
Residual	21	602.75	28.70		
Total	31	1420.00			

Appendix 83 ANOVA for Undehusked_Cob_Wt_Plot_Kg at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	21.362	7.121	3.85	
Treatment	7	15.680	2.240	1.21	0.340
Residual	21	38.877	1.851		
Total	31	75.920			

Appendix 84 ANOVA for Undehusked_Cob_Wt_Plot_Kg at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	34.9509	11.6503	19.07	
Treatment	7	15.3322	2.1903	3.59	0.011
Residual	21	12.8266	0.6108		
Total	31	63.1097			

Appendix 85 ANOVA for Dehusked Cob weight Plot Kg at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	13.090	4.363	2.88	
Treatment	7	16.645	2.378	1.57	0.199
Residual	21	31.820	1.515		
Total	31	61.555			

Appendix 86 ANOVA for Dehusked Cob weight Plot Kg at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	29.5984	9.8661	17.78	
Treatment	7	11.8247	1.6892	3.04	0.022
Residual	21	11.6541	0.5550		
Total	31	53.0772			

Appendix 87 ANOVA for Number of Cobs Plot at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	437.34	145.78	12.81	
Treatment	7	178.72	25.53	2.24	0.072
Residual	21	238.91	11.38		
Total	31	854.97			

Appendix 89 ANOVA for Number of Cobs Plot

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	245.59	81.86	2.14	
Treatment	7	656.22	93.75	2.45	0.053
Residual	21	805.16	38.34		
Total	31	1706.97			

Appendix 90 ANOVA for Number of Seeds Cob at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	8393.	2798.	1.28	
Treatment	7	13960.	1994.	0.91	0.518
Residual	21	46070.	2194.		
Total	31	68424.			

Appendix 91 ANOVA for Number of _Diseased Cob Plot at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	26.125	8.708	3.74	
Treatment	7	28.875	4.125	1.77	0.146
Residual	21	48.875	2.327		
Total	31	103.875			

Appendix 92 ANOVA for Number of _Diseased Cob Plot at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	1.250	0.417	0.17	
Treatment	7	45.500	6.500	2.59	0.043
Residual	21	52.750	2.512		
Total	31	99.500			

Appendix 93 ANOVA for Cob Diameter at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.3622	0.1207	1.19	
Treatment	7	0.3773	0.0539	0.53	0.803
Residual	21	2.1397	0.1019		
Total	31	2.8792			

Appendix 94 ANOVA for Cob Diameter at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.56154	0.18718	5.08	
Treatment	7	0.35479	0.05068	1.38	0.266
Residual	21	0.77316	0.03682		
Total	31	1.68949			

Appendix 95 ANOVA for Cob Length at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	4.135	1.378	1.36	
Treatment	7	7.488	1.070	1.05	0.426
Residual	21	21.329	1.016		
Total	31	32.952			

Appendix 96 ANOVA for Cob Length at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	35.519	11.840	8.43	
Treatment	7	9.346	1.335	0.95	0.490
Residual	21	29.492	1.404		
Total	31	74.356			

Appendix 97 ANOVA for Stover_Weight_Plot_Kg at Mampong

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	0.8559	0.2853	2.40	
Treatment	7	0.6072	0.0867	0.73	0.649
Residual	21	2.4966	0.1189		
Total	31	3.9597			

Appendix 98 ANOVA for Stover_Weight_Plot_Kg at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	36.6834	12.2278	26.63	
Treatment	7	12.5647	1.7950	3.91	0.007
Residual	21	9.6441	0.4592		
Total	31	58.8922			

Appendix 99 ANOVA for Number of Seeds Cob at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.06125	0.02042	1.32	
Treatment	7	0.27375	0.03911	2.54	0.047
Residual	21	0.32375	0.01542		
Total	31	0.65875			

Appendix 100 ANOVA for Number of Seeds Cob at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	33212.	11071.	4.26	
Treatment	7	24257.	3465.	1.33	0.284
Residual	21	54588.	2599.		
Total	31	112058.			

Appendix 101 ANOVA for 100- Seed_Weight at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	8.250	2.750	0.94	
Treatment	7	20.000	2.857	0.97	0.477
Residual	21	61.750	2.940		
Total	31	90.000			

Appendix 102 ANOVA for 100- Seed Weight at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	31.594	10.531	3.77	
Treatment	7	28.969	4.138	1.48	0.227
Residual	21	58.656	2.793		
Total	31	119.219			

Appendix 103 ANOVA for Total_Grain_Weight_Kg at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	2.3634	0.7878	3.19	
Treatment	7	9.9597	1.4228	5.76	<.001
Residual	21	5.1891	0.2471		
Total	31	17.5122			

Appendix 104 ANOVA for Total_Grain Weight Kg at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	9.6213	3.2071	15.63	
Treatment	7	3.3388	0.4770	2.32	0.064
Residual	21	4.3088	0.2052		
Total	31	17.2688			

Appendix 105 ANOVA for Tonnes per Hectare at Bunuso

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	3	2.9178	0.9726	3.19	
Treatment	7	12.2959	1.7566	5.76	<.001
Residual	21	6.4062	0.3051		
Total	31	21.6200			

Appendix 106 ANOVA for Tonnes per Hectare at Ejura

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	11.8781	3.9594	15.63	
Treatment	7	4.1219	0.5888	2.32	0.064
Residual	21	5.3194	0.2533		
Total	31	21.3194			