The effect of fertilizer formulation on yield components and yield of hybrid maize (*Zea mays* L.) varieties in the Guinea savannah zone of Ghana

By

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DECLARATION

I hereby declare that except for references to the work of other researchers which have been duly cited, this work is the result of my own original research and that, this dissertation has not been presented for an award of a degree in part or whole elsewhere.

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ABSTRACT

The research was conducted from late June to November, 2011 to evaluate the performance of five maize hybrids namely PAN 12 and PAN 53, Obatampa GH, Mamaba and ACR ’97 TZL Comp 1-w using five different fertilizer formulations: A- Actyva (275kg/ha), + Sulfan (250kg/ha), B- ERP (250kg/ha) + Actyva (275kg/ha), + Fertilizer Blend (250kg/ha), C- Actyva (275kg/ha), + Fertilizer Blend (250kg/ha), D- ERP (250kg/ha) +N: P: K. (275kg/ha), + Urea and E- control (N: P: K. (275kg/ha), + urea (250kg/ha) in order to recommend the best performing entries for adoption in the Guinnea savanna zone of Ghana. The research was laid in Split-Plot Design. Fertilizer formulation served as the main plot factor and the variety as the sub-plot factor. Data was collected on plant count, plant height, LAI, number of days to 50% tasseling, cob and husk weight, dehusked weight and ultimately, the grain yield and 100 seed weight and analyzed. Plant samples were taken at 2 WAP, 6 WAP and at harvest and analyzed for NPK in biomass. Soil samples were also taken at planting, 6 WAP and at harvest and analyzed for NPK, pH, CEC. Interaction between variety and fertilizer formulation as well as fertilizer as a factor was not significantly different ($p<0.05$) in this study but variety affected ($p>0.05$) almost all the parameters measured. PAN 12 produced the highest of most growth parameters measured as well as the ultimate yield with Actyva + Sulfan fertilizer formulation giving the highest support.

DEDICATION

I dedicate this thesis to God Almighty for His grace that took me through the work.

It is also dedicated to my family for their love and support.

Finally, I dedicate this work to Phillipine Dzorgbenyuie Mawukoenya Aku Agbati, who I love and cherish.

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LIST OF ABBRVIATIONS

AgSSIP	Agricultural Service Sub- Sector Project
CEC	Cation Exchange Capacity
CRI	Crop Research Institute
DAP	Days After Planting
ERP	Eco Rock Phosphate
FAOSTAT	Food And Agriculture Statistics
FIG	Figure
GH	Ghana
Kg	kilogram
LAI	Leaf Area Index
LSD	Least Significant Difference
MoFA	Ministry of Food and Agriculture
NGOs	Non-Governmental Organizations
PAN	Pannar
SARI	Savannah Agricultural Research Institute
SED	Standard Error Difference
UDS	University for Development Studies
UNDP	United Nations Development Programme
WABS	Web Appointment Booking System
WAP	Weeks After Planting
WAP	Weeks After Planting
^0C	Degree Celcius

CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea mays* L.) is currently the world's third most important cereal after wheat and rice (Belfield and Brown, 2008). It is however, the most important cereal in most African countries including South Africa (Du Plessis, 2003) and Ghana (Ramatu and Jatoe, 2002). It also serves as a staple food source for some 200 million people in the developing countries, especially in Latin America and Africa.

Maize is used for three main purposes; animal feed, food and in industry as raw materials for production and brewing. It has become the most important raw material for animal feed and several industrial processes due to its low price and widespread distribution. Seventy percent (70%) of maize produced worldwide is used for livestock feed (Onimisi *et al*., 2009). It is a major food for both Ghanaian urban and rural dwellers and forms part of the everyday diet. Of an estimated 5 million small scale farming households in Ghana, more than 1 million (20%) derive their main income from production of maize.

However, maize production in Ghana is still inefficient and rudimentary due to the use of un-improved seeds and low levels of fertilizer application Hassan *et al.*, (1998). Lower rates of fertilizer application in Africa (10 kg/ha in 1993) than in the developing world (83 kg/ha in 1993) as a major cause of low yield. Heisey *et al.,* (2001) reported that, about one million more tons of maize could be added to domestic production (an increase of one-third) if farmers improve their soil fertility management practices through adequate fertilizer application. WABS Consulting Ltd, (2008) suggested similar increment but added that such high fertilizer responses could be observed when it is applied to improve hybrid maize varieties. Dankyi *et al.*, (2005), made reference to the poor seed and soil nutrition in maize production as the causes of low yield when Crop Research Institute (CRI) released Obatampa GH in 1992 and Mamaba in 1996. In response, some fertilizer companies have also come out with various formulations such as Actyva, Blend and Sulfan to replace N: P: K, sulphate of ammonia, and urea in a bid to improve upon crop nutrition for enhanced yield. Eco Rock phosphate (ERP) has also been introduced in an attempt to help improve soil nutrient supply and yield. Despite all these attempts, the use of improved hybrid seeds and adequate fertilizer remains low due primarily to poverty among farmers (Banziger *et al*., 1997).

Government of Ghana passed policies in June, 2006 to subsidize fertilizer cost and increase its availability to farmers at lower cost for increased on-farm application. In their bid to increase fertilizer input for maize production, two major Ghanaian incorporated NGOs (WIENCO Ghana Ltd and YARA Ghana Ltd) in their response to that challenge, entered a programme 'Masara N'Arziki' (maize for prosperity) in which all inputs for maize production are supplied to farmers in their communities in addition to providing technical support in the form of micro credit after which the products were absorbed at a guaranteed price. Though this came as a relief to many farmers in Northern, Brong-Ahafo, Upper East and Upper West regions where the programme is practised, it showed many lapses which include importation of seed from South Africa and Adoptive trials conducted in only two ecological zones. Considering the socio-economic and environmental implications of the limitations, there was a need to perform thorough scientific research to ascertain the best yielding variety with the best fertilizer component including local checks.

1.1 Objectives

The general objective was to evaluate the performance of five hybrids namely PAN 12 and PAN 53, Obatampa GH, Mamaba and ACR '97 TZL Comp 1 - W, using different fertilizer formulations in order to recommend the best performing entries for adoption in the Guinnea savanna zone of Ghana.

1.2 Specific objectives:

- To assess the yield performance of five hybrid maize varieties (PAN 12, PAN 53, Obatampa GH, Mamaba and ACR '97 TZL Comp 1 – W in the Guinnea savanna zone.
- To determine the effect of fertilizer formulations on the growth and yield of the five hybrid maize varieties.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The origin of maize

The origin of maize (*Zea mays* L.) may be difficult to trace with certainty (Brown and Darrah 1985). It was however believed to be the only important cereal indigenous to the Western Hemisphere, originating from Mexico. The oldest archaeological maize was discovered in Mexico's valley of Tehuacan (Brown and Darrah, 1985, Zarrillo *et al*., 2008). It was proven to be one of the most adaptable and variable members of the grass family (Kogbe and Adediran, 2003, Stephanie and Brown, 2008). Its evolution resulted in biotypes with adaptations ranging from tropics to the temperate zones, from sea level to 12,000 feet altitude and growing periods extending from 6 weeks to 13 months (Stephanie and Brown, 2008). Following discovery, maize spread quickly to Europe, Africa and Asia. Even though introduced into Africa soon after discovery, much of the maize now found in the continent comes from later introductions from the southern U.S., Mexico and parts of eastern South America (Brown and Darrah, 1985).

2.2 The economic importance of maize

More maize is produced annually more than any other grain (ITTA, 2009). The abundant production of maize could be linked to its uses for food, feed and industry. Maize has become the world's highest animal feed ingredient than any other grain. It is high in energy, low in fibre and easily digested by most livestock species (Du Plessis, 2003). Maize has remained a critical feed ingredient in Monogastric diets particularly poultry. About 78% of maize produced in the developed world is used for livestock feed (Safi *et al*., 2009). It is a primary feed grain in the United States, contributing to more than 90% of total feed production and use (USDA, 2012).

Demand for maize for poultry feed in Ghana was projected to increase from 73,000 metric tons in 2010 to 118,100 metric tons by 2015 (MiDA, 2006). Apart from feeding livestock directly with the grain, the straws were processed into hay and silage for dry season feeding. By-products obtained from distilleries are also feed to livestock. Other factors such as its wide spread and adaptability, relatively low price and ready availability contributed to its wide use for fed.

In developing countries, it is consumed directly but serves as staple diet for some 200 million people especially in Latin America and Africa (ITTA, 2009). It is boiled or roasted fresh and eaten or left to dry for the grains which are milled in dry or wet states into floor or dough for various traditional meals. The grains are rich in vitamins A, C and E (ITTA, 2009). It also contains proteins such as lysine and tryptophan (Onimisi *et al*., 2009), minerals and fat (Buah *et al*., 2009).

Industrially, alcoholic beverages are produced from maize. Starch from the grain is usedfor fabrics and adhesives (Yonli *et al*., 2010). In a processed form, it is also found as fuel (ethanol), starch converted in to sorbitol, dextrine, sorbic and lactic acid, and appears in household items such as beer, ice cream, syrup, shoe polish, glue, fireworks, ink, batteries, mustard, cosmetics, aspirin and paint (Du Plessis, 2003). It is also used for maltodextrins, corn oil, corn cyrup and biofuel. The grain served as raw material for industries which were processed it into secondary products such as corn flacks and popcorn.

The production, processing and sales of maize both locally and export as a commodity were major means of occupation and income generation for thousands of people worldwide (Bourdillon *etal*., 2003, USDA, 2009). It was the largest grain traded (3/4) in recent years. US were the world's largest producers and exporters (80 million acres) (USDA, 2012), contributing 11% of her agricultural trade in 1990s and 12% in 2008. Developing countries were the major importers of maize (70 metric million tons each year since 1999/2000). Japan is the largest importer for livestock feed and industrial starch, followed by Korea.

2.3 Agronomic requirements

2.3.1 Soil Requirements

The most favourable soil for maize production is the one with a good effective depth, suitable morphological properties, good internal drainage, an optimal moisture conditions, and balanced chemical properties with sufficient and balanced quantities of plant nutrients (Bell *et al*., 2005). The soil should be free-draining, have good reserves of moisture with compaction problems. Friable, well-structured soils allow easy rooting, penetration and absorption of both water and nutrient.

2.3.2 Nutrient Requirement

Major nutrients required by maize for optimum performance include: Nitrogen (N) required for obtaining maximum yield and quality (Nuttall, 2012), Phosphorus (P) required particularly by the growing tips of the plant for root growth (Silvia and Uchida, 2000), Potash (Potassium (K) is required in the greatest amount by maize. The assimilation of nitrogen, phosphorus and potassium reaches a peak during tasseling (Du Plessis, 2003). Maize also requires Sulphur (S) (Belen'kii, 2012) which is a constituent of protein together with nitrogen and Magnesium (Mg) an essential element in chlorophyll used for photosynthesis (Anem *et al*., 2011). It is not very sensitive to trace element deficiencies, but boron, copper, zinc, manganese and iron may occasionally be deficient on soils where there is shortage of manure (PDA, 2008).

2.4 Production of maize (tonnes) over the past 10 years

Table 1: Ghana and Africa's contribution in tonnes to total maize production (2001-2010)

Year	World total (tonnes)	Africa's total (tonnes)	Ghana's total (tonnes)
2001	615533718	41384808	937973
2002	604861919	44786809	1400000
2003	645171076	45586828	1288600
2004	727471897	46116420	1157620
2005	713696156	49990078	1171000
2006	706832229	47509721	1189000
2007	789398918	47384680	1219600
2008	827489803	55955986	1470080
2009	189704199	59037978	1619590
2010	844405181	64256358	1871700

(Source: FAOSTAT, 2012)

2.5 Development of Hybrid Maize

Selection of plants for higher yields with improved quality has been the objective of plant breeding since wild plants were domesticated by man (Kanungwe, 2009). Hybrid maize was achieved by cross-pollinating two unrelated male and female plants of different inbred lines (MacRobert *et al*., 2007). Hybrid maize breeding originated in 1909 when Henry A. Wallace studied the work of Shull and others and began his own maize breeding experiments which led to the first development, production and marketing of hybrid maize. Hybrid maize is uniform in appearance, has vigour, high yielding, selected for improved grain quality. A particular hybrid can be selected for specific pest and disease resistance or drought tolerance (Gore *et al*., 2011).

2.6 Major Hybrids in the World

International Community for Alien Research (ICAR) launched the first coordinated crop improvement project in 1957 (ikasan.com, 2000). Large number of inbred lines and hybrids were introduced from USA and maize belt regions. These inbred lines along side with exotic and indigenous hybrids were tried in multilocational trials. As a result 28 inbreds were picked up for utilization in hybrid development. Some exotic hybrids particularly from Southern USA (NC 27, Texas 26 and Dixie 18) displayed significantly higher yield but were not accepted by the Indian farmers due to their dent type grain. These dent type hybrids also had problems with seed production, as their parental lines were adapted to temperate climate .After characterisation and classification of Indian land races and simultaneous effects for extracting inbred lines both from indigenous and exotic materials, first set of yellow double cross hybrids (Ganga 1, Ganga 101, Deccan and Ranjit) were released in 1961.

These hybrids performed very well in the farmers' fields, but were limited by the problem of economic seed production. As a result in 1963 two double top cross hybrids (Histarch, ganga-safed-2) were released with the objectives of raising the levels of base population for developing agronomically better inbreds and for the commercial cultivation. Presently over 20 hybrids (including double cross, double top cross and three way cross) were released to the farmers for commercial exploitation. Five broad based gene pools in two grain colours yellow and white (AB yellow, AB white , BC yellow, CD yellow, CD white) were constituted to develop promising varieties and hybrids (ikisan.com 2000)

In Africa, Ghana was at the fore-front of Quality Protein Maize (QPM) development (Akande and Lamidi, 2006). The CRI, Kumasi, Ghana and others released a medium maturing open pollinated QPM variety called Obatampa in 1992 and three QPM hybrid varieties, Mamaba, Dadaba and

Cidaba in 1997. Abeleehi, Okomasa, Abontem, Enii-Pibi, Aburohemaa and Omankwa were currently released as drought tolerant maize varieties by CRI (Twumasi-Afriyie *et al*., 1997). Obatampa was adapted to the growing conditions in the lowland tropics and has been adopted extensively in Ghana and many other African countries (Badu-Apreku *et al*., 2006). The hybrid varieties used for the trial, their sources and characteristics are summarized in the table below.

Table 2: Characteristics of hybrid maize varieties

Hybrid variety	Source	Growth duration	Yield potential	Grain colour
PAN 12	South Africa	110 days	8 tonnes/Ha	Yellow
PAN 53	South Africa	110 days	6 tonnes/Ha	White
Obatampa GH	Ghana	110 days	4 tonnes/Ha	White
Mamaba	Ghana	110 days	4-6 tonnes/Ha	White
ACR'97TZLComp1-w	Ghana	105-110 days	4-6 tonnes/Ha	White

SOURCES: Al-Hassan and Jatoe (2002) & Kanungwe, (2009)

2.7 Adaptation of Hybrid Maize

Adaptation refers to good performance with respect to yield and other agronomic characteristics in a given environment (Brown and Darrah, 1985). The environment includes all conditions to which maize is exposed during the growth period (from pre-seedling emergence to harvest maturity). The major environmental factors are: daily maximum and minimum temperatures, soil temperature and moisture levels, humidity of the atmosphere immediately surrounding the plant, wind movement, day length, light intensity, air pollution, soil type, soil fertility, competition from other plants (intended neighbours and weeds) and the disease-insect complex. These factors interact in a complex manner to produce stress on the plant. The plant's reaction to stress is under genetic control, and differences among hybrids (Brown and Darrah, 1985)

2.8 Impact of Hybrids on Production

The highest impact of hybrids on production could be linked to the high increases in yields. For example, the yields of Obatampa could give 4-6 t/ha of grain, Mamaba 5-7 t/ha, (Buah *et al*., 2009), PANS 12, 6777, 7M-97 and 6243 are all reported to produce yields above 8 t/ha (Kanungwe, 2009) as compared to 1.5 t/ha from the local varieties such as Dorke and Okomasa. Other attributes of hybrids includes improvement in the protein nutrition of consumers (Buah *et al*., 2009), adaptation to weeds, insects, diseases, lodging, and other stresses, the ability to increase the productivity and effectiveness of other inputs such as fertilizers, agrochemicals and labour (Borrill *et al*., 2006).

Other impacts of hybrids on production were bringing changes in crop management practices. Substantial investment in maize research has generated improved production technologies that have provided farmers with the means to respond to changes in demand. Farmers who grow improved hybrids engage in more management practices such as increased use of fertilizer, herbicides and insecticides with greater frequency than those who grow local varieties because it brings to them the economic returns (Borrill *et al*., 2006). On the other hand, hybridization was reported to be resulting in loss of traditional maize and agricultural biodiversity of which these farmers and their ancestors have been stewards for centuries as global economic integration increases pressure on agro-biodiversity (Almekinders, 2001). Market integration promotes specialization and focus on high-yield varieties, as national markets become dominated by low-priced imports from the agricultural surpluses of the largest producers. This led to loss of local varieties as well as minor crops, replaced local cultural traditions with modern preferences. It increased the income of hybrid producers but lowered that of local producers.

Again, the roles of policies, institutions, and infrastructure in the adoption of improved technologies and their impact on productivity and welfare favoured hybrid at the expense of local seeds (Doss, 2006). In Ghana, the major limitation to hybrid adoption included high cost of seeds, insufficient seeds, inaccessibility of seeds at the onset of seasons, high cost of accompanying inputs such as fertilizers and chemicals, unreliable rainfall as well as price fluctuations which failed to guarantee the return for the producers. Monsanto Corporation's home page on the web projected the world population at 10 billion by 2030' and warns that 'low-tech' agriculture will not produce sufficient crop yield increases and improvements to feed the world's growing population. They stressed that biotechnology innovations will triple crop yields without requiring any additional farmland, maintaining valuable rainforests and animal habitats (Kimbrell, 1998, McMichael, 2001)

2.9 Fertilizer

Agricultural soils naturally supply very essential nutrients for the growth of the plants. However, sometimes these nutrients in soil might not be enough to stimulate the plant growth. There was therefore the need for supplementary supply of nutrients to the soils which were lacking to meet plant needs Ibeawuchi *et al*., (2007). (Dogra, 2010) described fertilizer as substances added to soil to improve growth of plants, as well as their yield (Kirshner,1997). It also improves the soil. He further grouped them into organic and inorganic but reported that the percentage content of nutrients in organic fertilizers (manures) is relatively low.

The nutrients in inorganic fertilizers are inorganic salts, obtained by extraction through physical and chemical processes. The three primary plant nutrients are nitrogen, phosphorus and potassium. The addition of substances to soil to improve its nutrient capacity was observed in the early days of farming. Ancient farmers knew that the first yields from virgin land were much better than those of subsequent years. This caused them to move to new, uncultivated areas, which again showed the same pattern of reduced yields over time. Eventually, it was discovered that plant growth on a plot of land could be improved by spreading animal manure throughout the soil.

Over time, fertilizer technology became more refined. New substances that improved the growth of plants were discovered. The Egyptians were known to have added ashes from burned weeds to soil. Ancient Greek and Roman writings indicate that various animal excrements were used, depending on the type of soil or plant grown. It was also known that growing leguminous plants on plots prior to growing wheat was beneficial. Other materials added include sea-shells, clay, vegetable waste, waste from different manufacturing processes, and other assorted trash.

Organized research into fertilizer technology began in the early seventeenth century. Glauber developed the first complete mineral fertilizer, which was a mixture of saltpeter, lime, phosphoric acid, nitrogen, and potash (Kirshner, 1997). As days went by, the chemical needs of plants were discovered, resulting to improved fertilizer compositions. The chemical fertilizer industry began with Sir John Lawes, who outlined a method for producing a form of phosphate that was an effective fertilizer. The synthetic fertilizer industry experienced significant growth after the First World War, when facilities that had produced ammonia and synthetic nitrates for explosives were converted to the production of nitrogen-based fertilizers.

Fertilizers replaced the chemical components that are taken from the soil by growing plants. They were designed to improve the growing potential of soil, and can create a better growing environment than natural soil. Fertilizers are made to suit the type of crop that is grown and provides nutrients quickly for plants use. They are easily available at most shops and quite convenient to use. Primarily, a fertilizer composes of nitrogen, phosphorus, and potassium compounds but may also contain trace elements that improve the growth of plants (Dogra, 2010).

Although organic fertilizers are still used today throughout the world, chemical fertilizers are more popular. Also, research is still being conducted to reduce the harmful environmental effects of fertilizer use, as well as discovering new, less costly sources of fertilizers (Kulkarmi, 2012)

2.10 Major fertilizer in agriculture

2.10.1 N: P: K.

This is mostly ammonium nitrate base compound fertilizer (N: P: K., N: K., N: P.). It contains some or all the following: ammonium salts, phosphate salts, potassium salt, inert fillers, secondary nutrients and coating agents. It is white grey in colour, odourless and in granules / pills form. Its pH in water solution (10%) is 4-6. The melting point depends on the composition. The nitrogen (N) is taken up by plants in the form of nitrate (NO_3) or ammonium (NH4+) ions. It combines with C, H, O, and S primarily to synthesis amino acid, the building block of proteins and enzymes. It also promotes cell division, boosts plant protein level, greenness in plants and rapid growth. Its deficiency results in stunted growth, chlorosis, reduced protein in seeds, early maturity in some plant and necrosis (Silvia and Uchida, 2000).

The phosphorus (P) is absorbed from soil by plants in H_2PO_4 / HPO_5- form. It is present in all living cells and used by plants for nucleic acids (DNA and RNA). Through energy–rich linkages (ATP and ADP), it is involved in storage and transfer of chemical energy for growth and reproduction. P is responsible for rapid root promotion from seeds planted in cold moist soils, vigorous seedling growth effective seed formation and reproduction. It also improves water use efficiency as well as promoting uniformity of crop maturity and quality. P deficiency in soil could lead to slow weak and stunted growth, dark blue-green colouration on older leavers, purpling of leaves and stems in some plants, delayed maturity and poor seed formation (Silvia and Uchida, 2000).

Potassium (K) is available to plants as the ion K^+. It remains in ionic form within cells and tissues. Its primary functions are translocation of sugars and starch formation. K is also known to be an enzyme activator that promotes metabolism, regulates plants water use by controlling the opening and closing of stomates, improves plants resistance to diseases, improve grain and seeds. Potassium deficiency could result to chlorosis along the edges of leaves, first in older leaves because K is very mobile in the plant. Luck of K also leads to slow and stunted growth, weak stem and lodging, reduced seeds and fruits quality (Du Plessis, 2003).

2.10.2 ACTYVA

The chemical composition of this fertilizer is broken down as N_{23} P_{10} $K_{53}S$ $_{2}MgO$ $0_{.3}Zn$. This contains the N: P: K. with all its functions and additionally has sulphur/sulphur (S), magnesium oxide (MgO) and zinc (Zn) (Nyalemegbe *et al*., 2012). Sulphur/sulphur (S) is absorbed by plants in SO_4/SO_2 form from air through leaves in areas where the atmosphere is rich with S compounds. It is not readily available from wettable S which is in the form of elemental S. It is a constituent of three amino acids (cystine, methionie and cystein) which are necessary for protein synthesis. S maintains dark green colour, promotes nodule formation on legumes, stimulates root formation and promotes vigorous plant growth. S deficiency leads to firing of tips and margins of lower leaves. Others such as white spots and yellowing of edges of lower leaves, scorched leaf tips and plant lodging could also be observed (Belen'kii, 2012). Magnesium (Mg) is absorbed by plants in Mg^{++} form. It is mobile in plants and can easily be translocated from older to younger leaves. Its functions include chlorophyll formation, seed formation as well as regulation of plant nutrient uptake. Mg also acts as a carrier of P in plants, whiles promoting fats and oil formation. Mg deficiencies observed includes general loss of green colour, starting from the bottom leaves and later moving up the plant, veins of leaves remaining green with loss of colour between veins, leaves curving upward along margins and weak plant stalks with long branched roots (Anem *et al*.,2011).

Zinc (Zn) is absorbed by plants in form of Zn^{++} and an important constituent of many enzyme systems in plants. It is required for growth hormones, seed and grain production. Zn also influences protein synthesis, rate of maturity of seed and stalks, height/ length of plants. Zn deficiency is common on soils with neutral or alkaline pH that are sandy with low organic matter content, and high in available phosphorus. Terminal growth zones of the plant are affected first. Other observable symptoms include decrease in stem length and resetting of terminal leaves, reduction in fruit bud formation, interveinal chlorosis and dieback of twigs after a year (Murdock and Hawe, 2001).

2.10.3 Eco Rock Phosphate (ERP)

It is reddish-grey in colour and fine textured fertilizer obtained from cracked phosphorus and calcium rich rocks. It contains 30% calcium and 37 % phosphorus. Calcium (Ca) is absorbed by plants as calcium ion (Ca^{++}). It is essential in cell walls and membranes and is required for the formation of new cells. Ca is also responsible for sugar translocation, neutralizing poisons produced by plans, encouraging fruit and seed production and improving general plant vigour and stiffness of straw. Once deposited in plant tissues, it is not remobilized. This makes young tissues affected first under deficiency conditions. Since Ca is not mobile, the requirements of a crop for Ca^{++} after early fruit set are supplied in form of nutritional sprays. Deficiency symptom of calcium includes dying back of border plants, poorly developed root hairs and blossom end rot of tomatoes.

Others include dark green vein in mid-rip of leaves, with yellowish green areas between, leaves becoming wrinkled in appearance and may defoliate.

Other major fertilizers used and their compositions include: Blend (N_{23} O_0 K_{16}), Sulfan (N_{24} S_6) and Urea (N_{45}) (Muck and Mystery, 2006). The functions of the compositions of these fertilizers are the same as those reported above.

2.11 The Effects of Fertilizer on Cereal Production

The primary effects of fertilizer on cereal production were the increase in productivity and production levels per unit area, reducing extensive farming/shifting cultivation (Mduma *et al*., 2012). In his estimating agricultural yields and effects, McArthur, (2011) reported nearly 8kg /ha boost in yield as a result of adding 1 kg/ha of fertilizer. This increased the economic returns for farmers and the general food availability throughout the world.

2.12 Adaptation and Limitation of Fertilizer Use

The rapid population growth has made Ghana and Africa to be no longer looked at as land available place where food crop supply could be increased by expansion of land used (Duflo *et al*., 2006). There is therefore a need for technology adoptions such as the use of hybrid varieties and fertilizer to maximize the outputs per unit area of arable lands. However, the rate of fertilizer use has been lower in Africa than in Asia and Latin America as observed by Byerlee and Carl (1997) and Ariga *et al*., (2006). The major factors that influence fertilizers adaption in maize fields are mechanization, farm size, credit availability, and distance to extension service, ecological potential and presence of cash crops (Haward *et al*., 1999, Mosier *et al*., 2005 and Mwabu *et al*., 2006). Ariga *et al*., (2008) and Olwande *et al*., (2009) all reported cost and access to fertilizer market, price of maize, access to extension, infrastructure and education as the key factors that influence fertilizer adaption in Sub- Sahara Africa (SSA). All things being equal, farmers would adopt fertilizer use technology based on profitability, farmer learning and observed differences among farms in farmers vicinity (Suri, 2005)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

This study was conducted at the experimental field of the University for Development Studies, Nyankpala (latitude 90 21' 41"N and longitude 00 58' 42"W with altitude 183 msl) in the Tolon Kumbungu District of the Northern region of Ghana from June- October, 2011. The site falls within the Guinea savannah zone which is characterized by low grasses interspersed with trees. It has a monomodal rainfall pattern with mean rainfall and temperature of 316 mm and 27°C respectively (SARI, 2011). The mean rainfall and temperature during the study from June- October were 106 mm and 27°C respectively. The relative humidity greatly increased during the rainy season to a maximum monthly value of 87% in September and a minimum monthly value of 44% in January, 2011 (SARI, 2011). The predominant soil within the area is fairly drained sandy loam (SARI, 2008; Dogor, 2008), classified as Nyankpala series.

3.2 Materials

Three of the hybrid seeds, namely PAN 12, PAN 53 and Obatampa GH. (Pro-seed) were obtained from WIENCO Ghana Ltd. The Mamaba seed were obtained from the Seed Unit of MoFA, Greater Accra Regional office while the ACR '97 TZL Comp 1-w seeds were obtained from the breeder (Dr. Mashark) of SARI for the trial. Fifty (50) seeds were randomly selected from each variety for germination test conducted at the Spanish Laboratory of Nyankpala campus of University for Development Studies (UDS). The selected seeds were placed on moist cotton wool laid in petri dishes and kept in the lab under temperature of 20^0C for seven days. By the end of the sixth day 100% germination was observed in all varieties except Obatampa GH., which showed 96%.

3.3 Land Preparation and Planting

Field was ploughed to a depth of 20 cm on 12 June, 2011 and later harrowed after two weeks. Lining and pegging was done on 28 June, 2011. Plot size was 5m x 5m. Maize seeds were sown on June 29, 2011at a spacing of 70cm between rows and 30cm between plants.

3.4 Experimental Design

The experiment was laid in a Split- Plot Design. The main plot treatments were the various fertilizer combinations: (A) - Actyva (275kg/ha), + Sulfan (250kg/ha), (B) - ERP (250kg/ha) + Actyva (275kg/ha), + Fertilizer Blend (250kg/ha), (C)- Actyva (275kg/ha), + Fertilizer Blend (250kg/ha), (D)- ERP (250kg/ha) +N: P: K. (275kg/ha), + Urea and (E)- control (N: P: K.) 15:15: 15 (275kg/ha), + urea (250kg/ha). Five hybrid maize varieties were used as Sub- Plot Treatment and included two exotic hybrids: PAN 12 (yellow maize) and PAN 53 (white maize) both from the PANNAR Company in South Africa, two approved local hybrids of Ghana (Mamaba and Obatampa GH.) and ACR '97 TZL comp 1-w (a white hybrid maize under test to be released soon by SARI).

3.5 Field activities

Agrochemicals used for the experiment included Touchdown (360 GL glyphosate (diamonnium salt)), Lumax -post emergence herbicide(35.7 G+L mesotrine +, 357 G+L S- metolathlor +, 125 G+L terbuthylazine) and karate (5EC)- (50g lambda- cyhalothrin per litre)insecticide against insect pests were all obtained from WIENCO Ghana Ltd. The touchdown (2.5 litres/ha) which is a systemic glyphosate was sprayed using the knapsack sprayer two weeks prior to ploughing to allow enough time for the weeds to die to root level before ploughing.

The lumax (2.5 litres/ha), a pre- emergence herbicide was sprayed using the knapsack prayer immediately after planting before the emergence of the maize plants. This forms a shealth on the surface of the soil to prevent emergence of weeds.

The karate (5EC) - (50g lambda- cyhalothrin per litre) was sprayed four weeks after planting with the knapsack sprayer. In spraying the karate, the maize plant was the focus. The plants absorb the insecticide which protected them from attack of insects especially stem borers and caterpillars.

3.6 Fertilizers and Their Formulations

Six major fertilizers (Actyva Millar (275kg/ha), ERP (250kg/ha), fertilizer blend (250kg/ha), N: P: K (275 kg/ha), urea (250kg/ha) and Sulfan (250kg/ha) were used in the trial, but combined in five different ways. Plots which received ERP had it incorporated into the soil using hoes before planting the maize seed. This served as basal application for plots with three fertilizer combinations which were later top dressed at two and six weeks after planting (WAP) with the remaining two. Plots with only two combinations however received the first dose (basal application) at 2 WAP and were top dressed at 6 WAP. N: P: K 15:15:15 and Urea combination was used as control which is the farmer's normal practice. Apart from the ERP that were mixed into the soil using hoes at the initial stage, all the others were dibbled at the depth of 20cm and 10cm distance away from the base.

3.7 Field Data Collection

3.7.1 Soil Sampling for Analysis

The core sampler was used to obtain soil samples on the trial field at three different stages for the analysis of N: P: K., CEC, organic carbon content and pH. The first sampling was done just after harrowing the field using the diagonal method of which nine samples were obtained. The samples were thoroughly mixed to obtain a uniform representative sample as the initial state of the field before any fertilizer application.

The second sampling was done six WAP (four weeks after basal fertilizer application). Samples from plots of similar treatments from the four blocks were put together, well mixed and final samples obtained for the analysis.

The third sampling followed similar procedure as in second samplingabove but was taken just after harvesting to assess how much of the fertilizer applied was left as residue in the soil. Soil analysis was done in the soil science laboratory of the University of Ghana.

3.7.2 Gravimetric Soil Moisture Content

This was determined every two WAP. The core sampler was used to obtain five random samples from each plot. The initial weights were recorded on the field and samples oven dried at 120^0C for 24hours in the AgSSIP laboratory of The University for Development Studies. The dry soils were re-weighed and the difference in weight recorded as moisture content of the sampled soil.

3.7.3 Plant Count per Plot

Number of plants on each plot was counted two weeks after planting to assess the field emergence percentage. Each plot had seven rows and sixteen plant per row. Where emergence was less than 75%, refilling was done.

3.7.4 Plant Height (M)

Five plants were randomly selected and tagged from the inner rows for this measurement. Their heights were taken at two weeks interval starting from 2WAP. The first two were done using the metre rule after which a measuring tape was used to continue until 10 WAP, when all plants were at their full heights. The average was obtained as the height of plants for each plot.

3.7.5 Leaf Area Index (LAI) Of Maize

The same five plants selected for plant height were used for LAI determination. The length and width of the bottom, middle and upper leaves were measured and their averages were used for the calculation of LAI. The data was taken at 2, 4, 6 and 8 WAP. The equation; $LAI = L \times W \times N \times 0.72 \div A$ (Watson, 1952).

3.7.6 Number of Days To 50% Tasseling

Plants were observed for tasseling on each plot daily from the onset of tasseling and the number of days to 50% tasseling was recorded.

3.7.7 Plant Sampling for Nutrient Analysis (N: P: K.)

Three plants were randomly selected and harvested from each plot at 4WAP, 8WAP and at harvest and separated into roots, stems and leaves. These components were oven dried at 50^0C for forty eight hours in the AgSSIP Laboratory of The University for Development Studies. The dry samples were milled at the Ecological Laboratory of The University of Ghana, using the electrically powered plant miller. The analysis of total N: P: K. left in the milled samples was done in the Soil Science Laboratory of University of Ghana, Legon

3.8 Harvest Data

3.8.1 Cob with Husk Weight (Kg)

The cobs harvested from each plot were put in fertilizer sack and weighed on a hanging scale and the readings recorded in kg.

3.8.2 Dehusked Cobs Weight (Kg)

After removing the husk from the harvested cobs the unshelled maize were put into sack and weighed on a hanging scale and the readings recorded in kg.

3.8.3 Grain Weight per Plot (Kg)

All grains removed from the cob were put into a sack and weighed and the readings recorded in kg.

3.8.4 100 Grain Weight (g)

From each treatment, 100 grains were randomly selected and weighed. The readings were recorded in g.

3.8.5 Straw Weight per Plot (Kg)

After harvesting, the straws were harvested, tied together and weighed. The weights were recorded in kg per plot.

3.9 Field data analysis

Data were input into excel and analysis of variance performed on the data obtained from the field and laboratory using the Genstats software version 9 and means separated by SED. Graphs were drawn using excel and results interpreted.

3.10 Laboratory data

3.10.1 Determination of soil nitrogen

The Kjeldhal method (Hesse, 1971) was used for the determination of available total nitrogen.

3.10.2 Determination of available soil phosphorus

Soil available P was determined by Bray 1 method.

3.10.3 Determination of soil available potassium

The flame photometer was standardised such that 10 mg/Kg of K gave 100 full scale deflections. The flame after standardised was used to determine the concentration potassium in the aliquot. The results were used in the calculation of the amount of potassium present in the soil as shown in the formula below.

$$K\ ((meq/100g)/soil) = \frac{R\ x\ Vol.of\ extract\ x100}{weight\ of\ soil\ x\ 39.1}$$

Where,

R is the flame photometer reading (ppm)

39.1 is the atomic weight of K

3.10.4 Determination of CEC

Twenty millilitre of sample was weighed into a beaker then 40 mL of distilled water was added and stirred for 30 minutes. The suspension was allowed to equilibrate to room temperature and EC was measured using the EC meter (JENFER pcm3)

3.10.5 Determination of soil pH

A soil of water ratio of 1:1 (20g soil: 20ml of distilled water) was prepared. The soil-liquid suspension was stirred several times for 30 minutes and the suspension was allowed to equilibrate to room temperature. Using buffer solutions of pH 4 and 7 the pH electrometer was standardised. The standardised electrode of the MV 88 pracitronic pH glass electrode was inserted into the supernatant of the suspension to measure the pH of the soil sample.

CHAPTER FOUR

4.0 RESULTS

4.1 Plant Stand per plot

The analysis of variance for the plant stands at 2WAP for the various fertilizer combinations and the varieties were observed that there were no significant differences (table 3). The plant stand at 2 WAP ranged from 71.8 to 100.7 for the various combinations.

Table 3: Effects of fertilizer formulations on varieties and plant stand / plot (2 WAP)

Fertilizer combination	Varieties				
	ACR '97 TZL Comp1-w	Mamaba	Obatampa	PAN 12	PAN 53
Actyva + Blend	71.8	87.7	78.0	100.7	82.2
Actyva + Sulfan	97.0	86.8	85.5	90.5	81.8
NPK + Urea	84.0	95.0	85.2	87.7	83.8
R. P + NPK + Urea	96.2	87.8	84.8	87.2	82.8
R. P +Actyva +Bland	93.2	87.0	89.2	80.5	80.8
LSD (0.05)	NS	NS	NS	NS	NS

4.2 Plant height

The interraction between the fertlizer and varieties did not significantly affect plant height during growth except at 8WAP where fertilizer significantly determined plant height (Fig. 1). Plant height varied significantly ($p < 0.05$) among varieties at 2, 4, 8 and 10 WAP but not at 6 WAP. Differences in the plant height among the hybrids between 4 to 6 WAP were slight but pronounced at 8 to 10 WAP. PAN 53 produced the tallest plant (152.1cm) at 8 WAP and (163.5cm) at 10 WAP

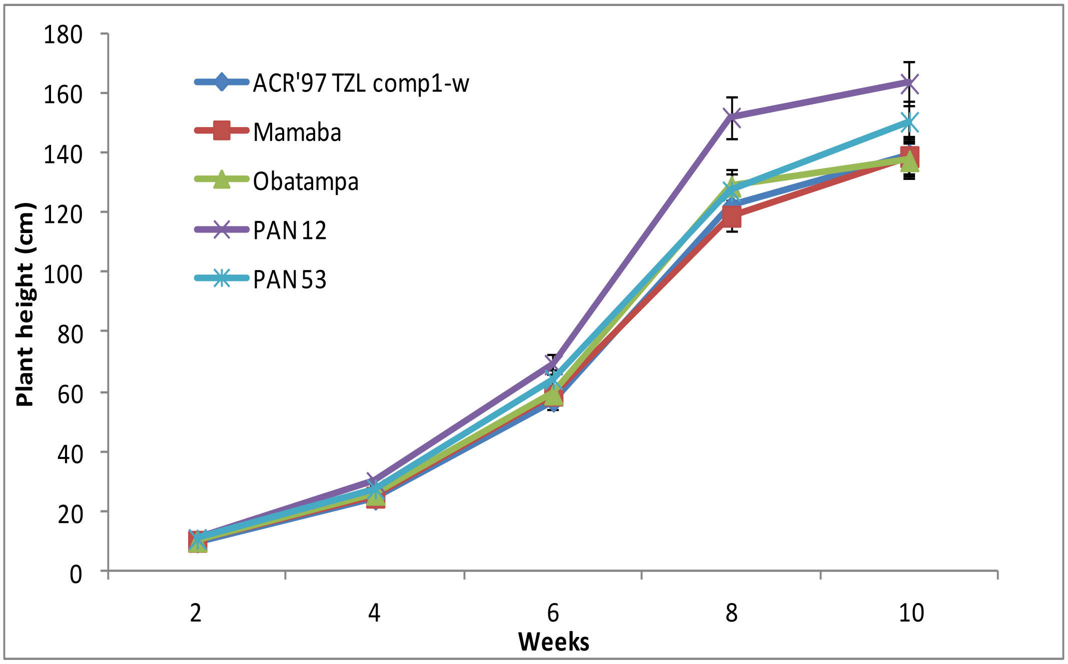

Figure 1: Plant height of hybrid maize varieties at 2, 4, 6, 8 and 10 weeks after planting. (Bars represent SED)

4.3 Leaf area index

Fertilizer formulation x variety did not significantly (p = 0.05) affect LAI. The main effects of variety and fertilizer also did not significantly dertermin LAI at the various WAP except at 10 WAP that the main effeect of variety showed significant ($p<0.05$) difference statistically. Table four and five depicted the average leaf area index (LAI) of the various maize varieties in response to the various fertilizer combinations. Generally all varieties increased in leaf area from the onset till 8 WAP and then declined. PAN 12 and Mamaba showed the highest and the lowest LAI in the sixth WAP. The highest LAI for all varieties was recorded at 8 WAP. ACR'97 TZL Comp1-w and PAN 53 showed the highest LAI at this level whilst the least was obtained from Mamaba and Obatampa respectively. PAN 12 produced average LAI observed among the five varieties at 8 WAP but its rate of decline remained gentle till 10 WAP leaving it as the second highest among others. ACR'97 TZL Comp1-w showed the highest rate of decline among all varieties, dropping from the highest at 8 WAP to the second least at 10 WAP. Obatampa however remained the variety with the least LAI at 10 WAP with PAN 12 as the average for the five.

Table 4: Effect of maize varieties on leaf area index (LAI) from 4-10 WAP

VARIETIES	LAI 4 WAP	LAI 6WAP	LAI 8WAP	LAI 10WAP
ACR'97 TZL comp1-w	2.74	4.57	3.44	0.5
Mamaba	3.11	4.79	3.47	0.59
Obatampa	3.36	4.73	3.01	0.62
PAN 12	3.12	4.91	4.62	0.65
PAN 53	3.19	5.04	3.81	0.62
LSD (p>0.05)	NS	NS	NS	NS

Table 5: Effect of fertilizer formulations on leaf area index maize from 4-10WAP

Fertilizer	LAI 4WAP	LAI 6 WAP	LAI 8 WAP	LAI 10 WAP
Actyla + Blend	0.63	3.08	4.94	4.00
Actyva + Sulfan	0.62	3.40	4.94	3.73
NPK + Urea	0.64	3.21	4.88	3.62
ERP + NPK + Urea	0.53	2.80	4.64	3.59
ERP + Actyva + Blend	0.57	3.04	4.96	3.42
LSD	NS	NS	NS	NS

4.4 Days to 50% flowering

The fertilizer x hybrid did not show significant defference on days to 50% tasseling. Also, the main effects of variety and fertilizer did not significantly vary days to 50% tasseling. It was observed that fertilizer formulations influenced the days resulting to variations in the results (Table 6). Actyva + Blend increased the tasseling days for Mamaba (56 DAP) but decreased it in PAN 53 (52 DAP) (Table 7). It however gave similarly average effect (54 DAP) in the other three varieties. Actyva + Sulfan formulations promoted early tasseling in PAN 12 (53 DAP) but delayed the process in PAN 53, Obatampa and ACR 97' TZL Comp1-w (58 DAP). N: P: K + Urea formulations promoted early tasseling in all four varieties except in PAN 53. ERP + N: P: K +

Urea promoted an equally early tasseling in three varieties but delayed the process in PAN 12 and Obatampa. ERP + Actyva + Blend formulations delayed tasseling in Obatampa but promoted the highest in ACR97'TZLComp1-w. The process was similar in the other three varieties.

Table 6: Influence of maize varieties on days to 50% Tasseling and Cob weight.

Varieties	Days 50% Tasseling	Cob plus husk wt. kg/ha
ACR'97 TZL comp1-w	55.3	5840
Mamaba	55.3	6180
Obatampa	55.7	14.85
PAN 12	52.5	5940
PAN 53	55.3	6648
LSD(P>0.05)	NS	NS

Table 7: Effect of fertilizer on days to 50% tasseling, cob weight, dehusked cob weight, straw weight, grain weight and 100 seed weight of maize

Fertilizers	Days 50% Tasseling	Cob + husk Wt.	Dehusked cob wt. kg/ha	Straw wt. kg/ha	Grain wt. kg/ha	100 seed wt. kg/plot
Actyva + Blend	54.3	6560	5324	3392	3400	35.73
Actyva + Sulfan	56.4	6560	5684	3160	3832	35.48
NPK + Urea	52.0	6692	5168	3160	3324	35.64
R. P + NPK + Urea	55.7	5760	5220	3392	3400	35.14
R. P + Actyva + Blend	55.7	5640	4616	3160	3832	34.98
LSD (0.05)	NS	NS	NS	NS	NS	NS

4.5 Straw Weight (Kg)

Straw weight was not significantly affected by the interactions of variety and fertilizer (Table 7). Variety significantly influenced straw weight (Fig.2). The highest straw was promoted in PAN 12 (5015 kg), followed by PAN 53 (4088 kg) and the least obtained from Obatampa (1872 kg). Mamaba and ACR'97 TZL Comp1-w produced similar weights for straw.

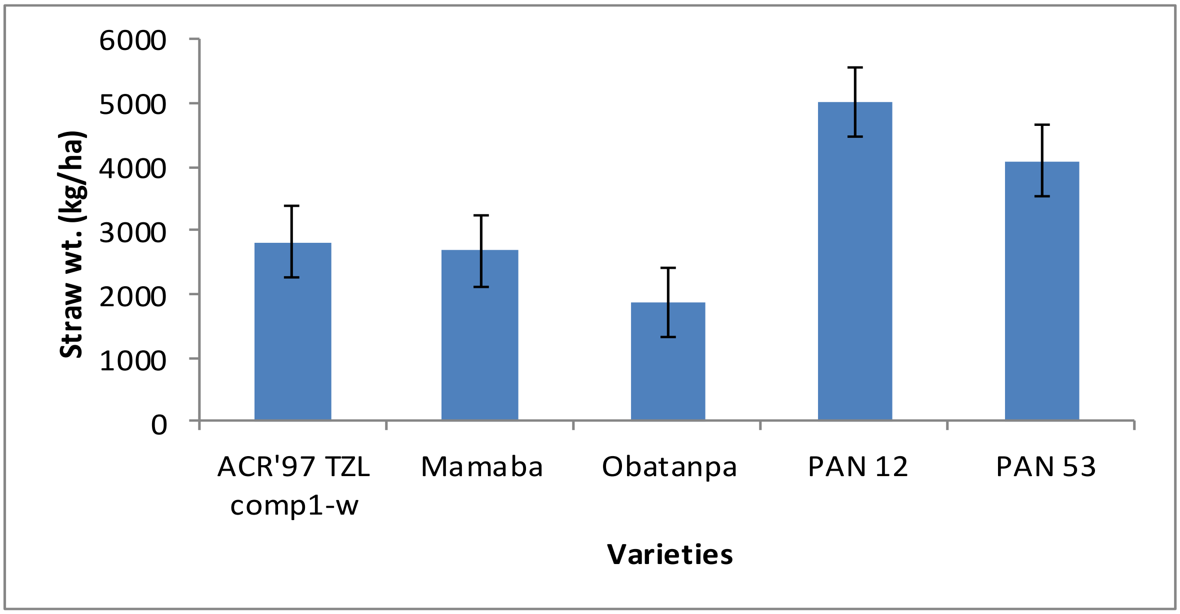

Figure 2: Straw weight of the various maize varieties. (Bars represent SED).

4.6 Cob plus husk weight (kg)

The interaction between fertilizer and varieties did not vary ($p>0.05$) cob and husk weight. Similarly, the main effects of fertilizer and varieties independently did not also have any significant effect on cob and husk weight.

4.7 Dehusked cob weight (kg)

The interaction between the varieties and fertilizers did not significantly influenced ($p>0.05$) dehusked cob weight as well as the main effect of fertilizer. However, the main effect of variety determined ($p<0.05$) dehusked cob weight. The highest cob yield was realized from PAN 12 > PAN 53 > ACR'97 TZL Comp1-w and Mamaba > Obatampa which produced the least (Fig.3). Actyva + Sulfan formulations supported the highest cob yield followed by Actyva + Blend and the least was obtained from ERP +Actyva + Blend formulations (Table 8).

Table 8: Interaction of Fertilizer x Variety on dehusked cob weight (kg)

Fertilizer combinations	Varieties				
	ACR '97 TZL Comp1-w	Mamaba	Obatampa	PAN 12	PAN 53
Actyva + Blend	11.2	11.9	8.4	18.6	16.6
Actyva + Sulfan	12.1	12.7	11.4	20.1	14.8
NPK + Urea	11.7	11.1	10.1	17.4	14.4
R. P + NPK + Urea	11.6	12.0	7.9	17.6	16.2
R. P +Actyva +Bland	10.4	10.7	8.3	16.3	12.1
LSD	NS	NS	NS	NS	NS

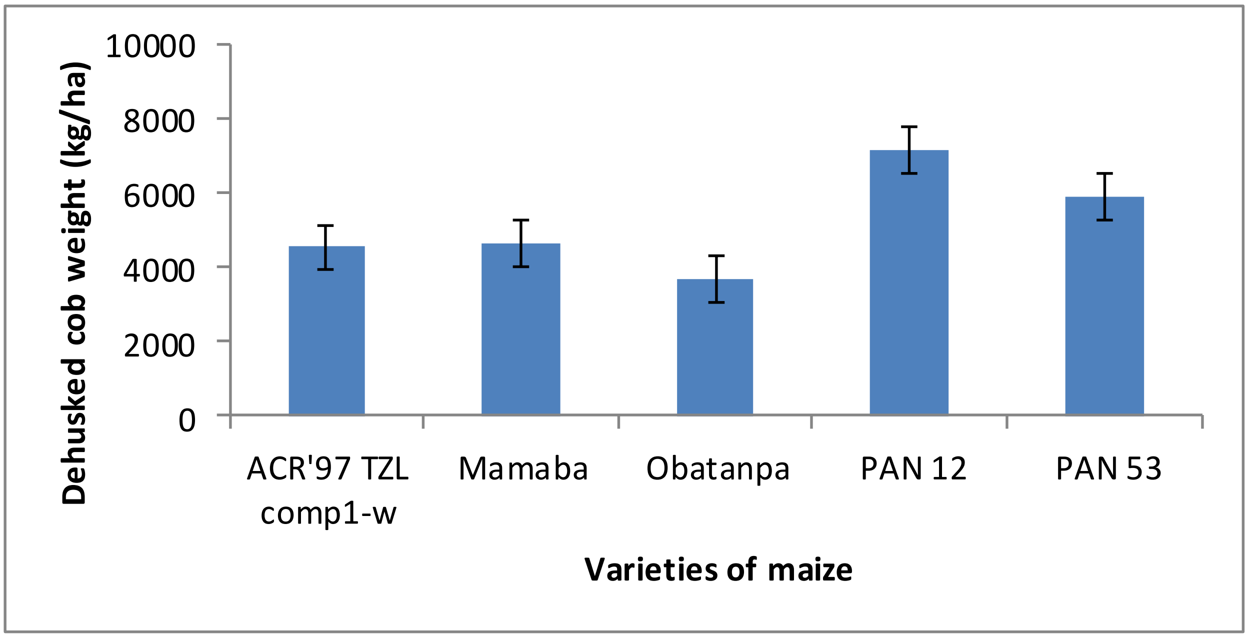

Figure 3: Effect of variety on dehusked cob weight. (Bars represent SED).

4.8 Grain weight (kg)

Grain weight was not significantly ($p>0.05$) affected by the interactions of varieties and the types of fertilizers used as well as the main effect of fertilizer. However, signicant difference ($p<0.05$) was observed for the main effect of varieties. The highest grain weight was observed in PAN 12 (273.2 kg/ha) > PAN 53 (227.9kg/ha) > Mamaba (174.6kg/ha)ACR'97 TZL Comp1-w (172.3kg/ha)>and Obatampa (121.7kg/ha) (Fig.4).

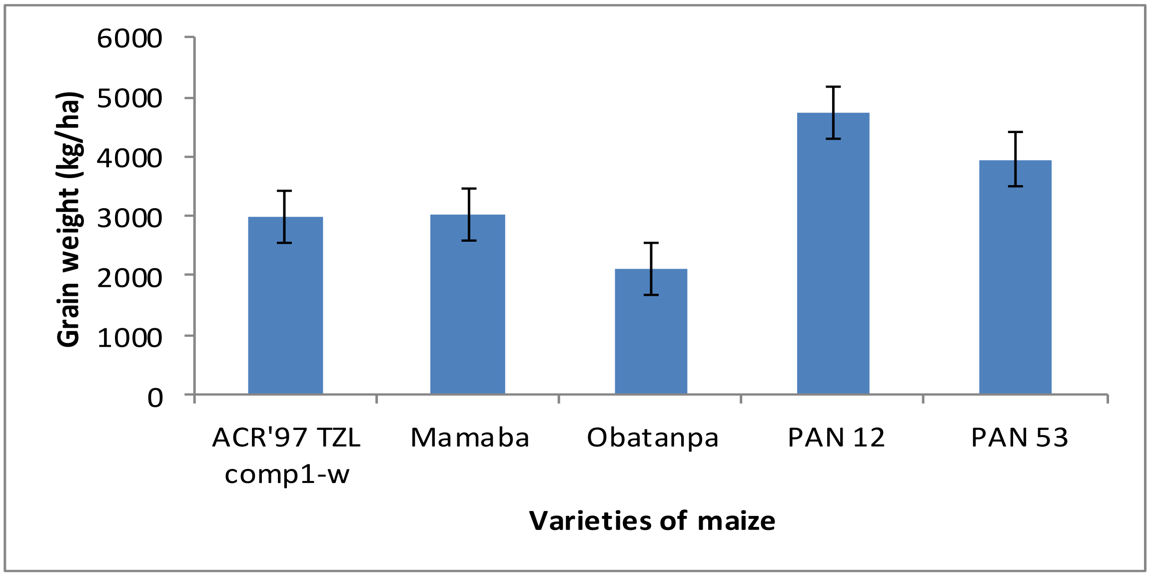

Figure 4: Grain weight (kg) per plot of the various maize varieties. (Bars represent SED).

4.9 Hundred Seed weight

There were no significant (p>0.05) difference between the two factor combinations and the main effect of fertilizer. But the main effect of variety significantly (p<0.05) affected the hundred seed weight. Generally seed weights from the two pannar varieties showed higher weights from all the fertilizer combinations than the other three (Fig 5). PANS 12 and 53 gave similarly highest results >ACR’97 TZL Comp1-w and Mamaba with Obatampa recording the least.

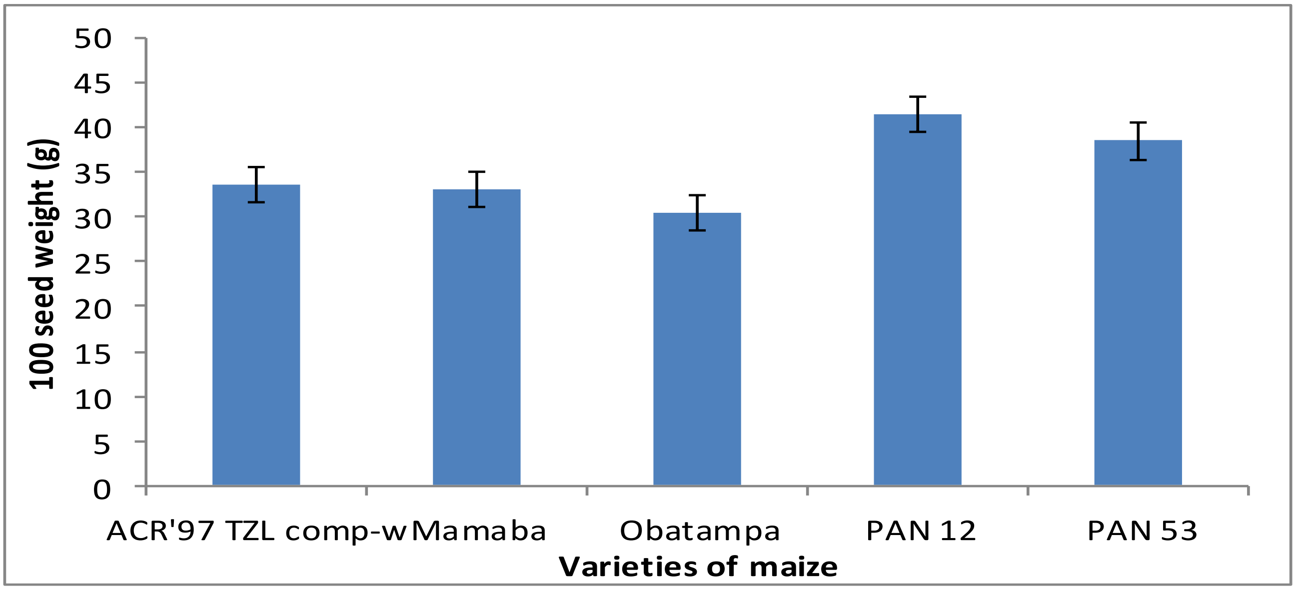

Figure 5: Hundred seed weight (g) per various maize varieties. (Bars represent SED)

4.10 Correlation analysis

Grain yield of maize positively correlated with straw weight (r=0.75**), dehusked cob weight (r=0.93**) and hundred seed weight (r=0.73**) (Table 9). The linear regression between grain weight and straw weight, dehusked cob weight and 100 seed weight were represented in (Fig.6) respectively as affected by the main effect of varieties

Table 9: Correlation between the parameters

Parameters	PH 10 WAP	LAI 8 WAP	D 50 % T	Straw wt (Kg/h)	Cob husk wt (kg/h)	Dehusked Cob wt (kg/h)	Grain wt (kg/h)	100 seed wt
PH 10 WAP	1							
LAI 6 WAP	0.26							
LAI 8 WAP	0.16	1						
D 50 % T	0.05	0.07	1					
Straw wt (kg/h0	0.37	0.34*	-0.1	1				
Cob hust wt (kg/h)	0.23	0.39*	-0.2	0.23	1			
dehusk cob wt (kg/h)	0.35	0.34*	-0.2	0.73*	0.34*	1		
Grain wt (kg/h)	0.35	0.37	-0.2	0.75**	0.34	0.93**	1	
100 Seed wt	0.29	0.41*	-0.1	0.65**	0.24	0.73*	0.73**	1

**(significant at 1%), *(significant at 5%)

The coefficient of determination value implies that (R^2=0.990) straw weight contributed about 99% to the grain weight.

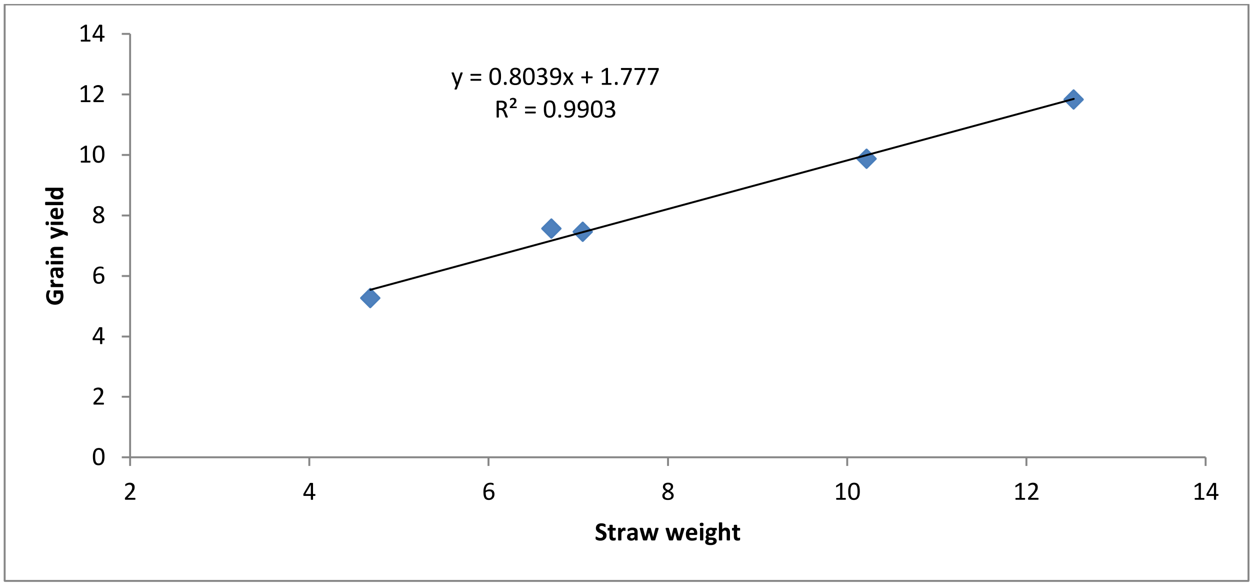

Figure 6: The relationship between straw and grain yields as affected by varieties.

4.11 Results from laboratory analysis of plant parts

ANOVA for N before fertilizer application showed no significant difference (p>0.05). Using the mean values however revealed that, ACR'97 TZL Comp1-w retained the highest amount of N whilst the other four varieties obtained similar results over the experimental season (Fig.7)

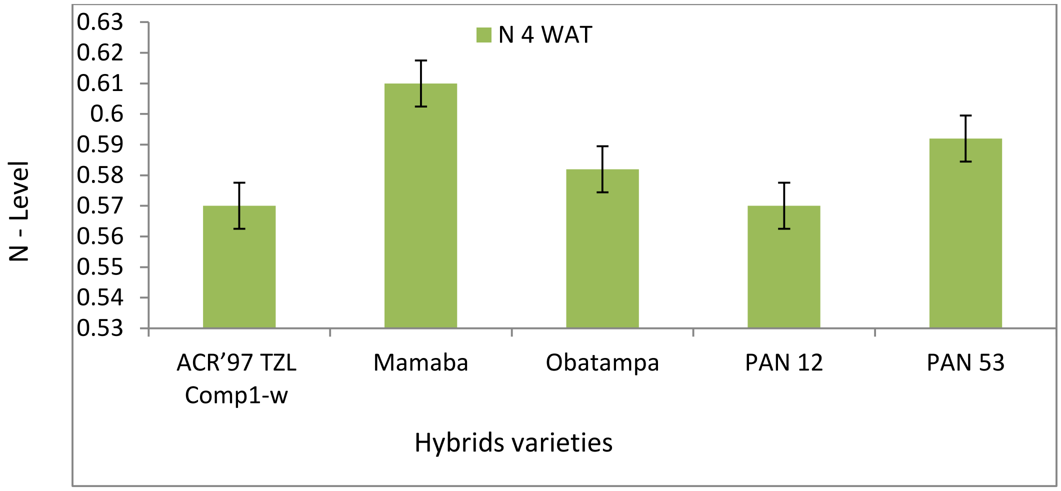

Figure 7: N content of plant biomas at 4 weeks after fertilizer treatment (4 WAT) (Bars represent SED)

N content of plants at 4 WAT showed significant effect ($p<0.05$) for both fertilizer as a factor and interaction between fertilizer and variety. Mamaba recorded the highest N > PAN 53 > Obatampa > PAN 12 and ACR'97 TZL Comp1-w which recorded similarly least values. N at harvest did not show significant difference ($p>0.05$) (Fig.14). The means however showed that the biomas of Obatampa and PAN 53 contained tsimilarly highest amount of N followed by Mamaba and ACR'97 TZL Comp1-w. PAN 12 had the least N in its biomass at harvest.

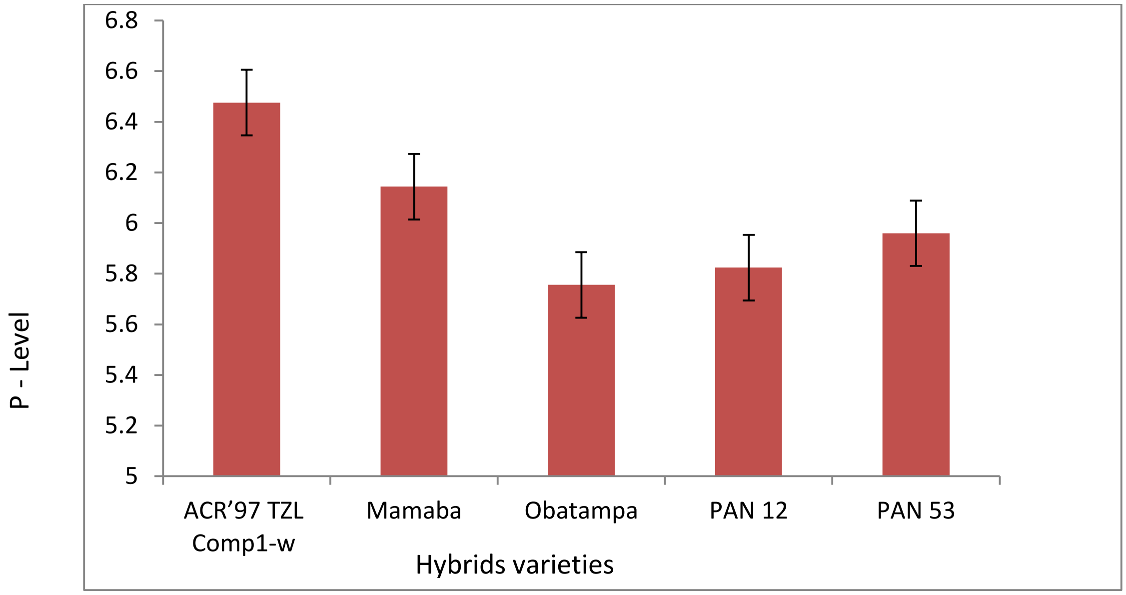

Figure 8: P content of plant biomas at 2 WAP before fertilizer treatment. (Bars represent SED).

ANOVA for P before treatment showed significant difference for both fertilizer as a factor and the interction between fertilizer and variety (p<0.05) (Fig. 15). ACR’97 TZL Comp1-w recorded the highest amount of P in plant biomass > Mamaba > PAN 53 > PAN 12 > Obatampa.

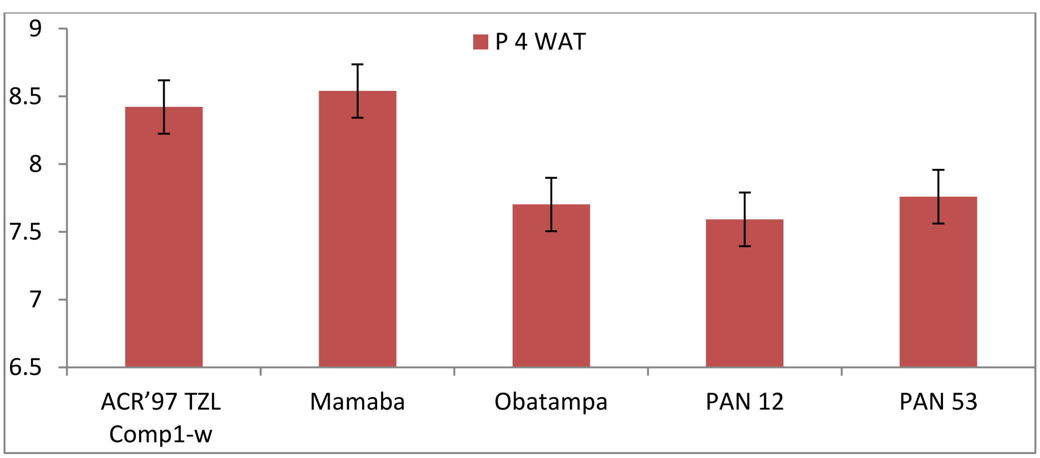

Fig. 16. P content of plant biomas at 4 WAT (Bars represent SED).

Interaction between fertilizer and variety varied (p<0.05) P in plant biomass at 4 WAT (Fig. 16). Two vareties (ACR'97 TZL Comp1-w and Mamaba) showed a similarly high P content of 8.5 whilst the other three varieties (Obatampa, PAN 12 and PAN 53) also produced a similarly average content of 7.6.

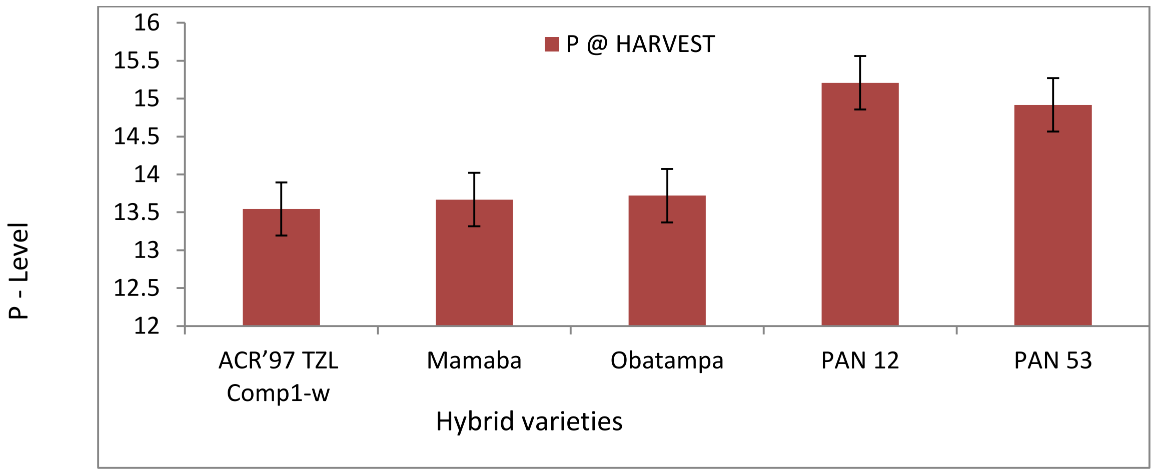

Figure 9: P content of plant biomas at at harvest. (Error bars represent SED).

P in plant biomass at harvest did not show significant difference (p>0.05) (Fig. 17). compairing various means hoever showed similarly high P in PANS 12 and 53 > an average output for the other three varieties.

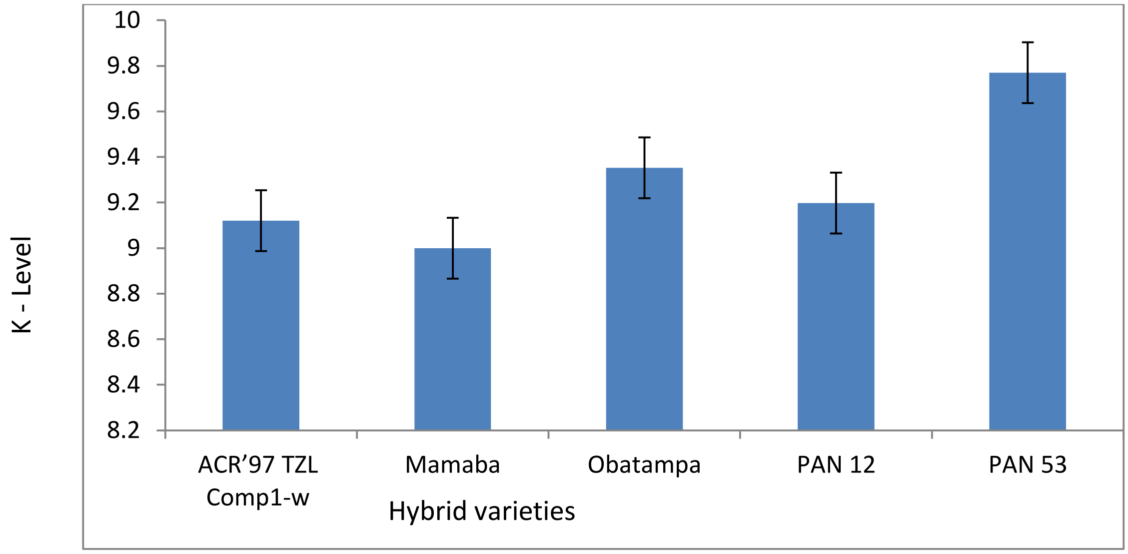

Figure 10: K content of plant biomas before fertilizer treatment. (Error bars represent SED).

Fertilizer x variety interaction for K before fertilizer treatment showed significant effect ($p<0.05$) but the main effect of variety and fertilizer did not (Fig. 18). PAN 53 exhibited the highest K content > Obatampa > PAN 12, ACR'97 TZL Comp1-w and Mamaba.

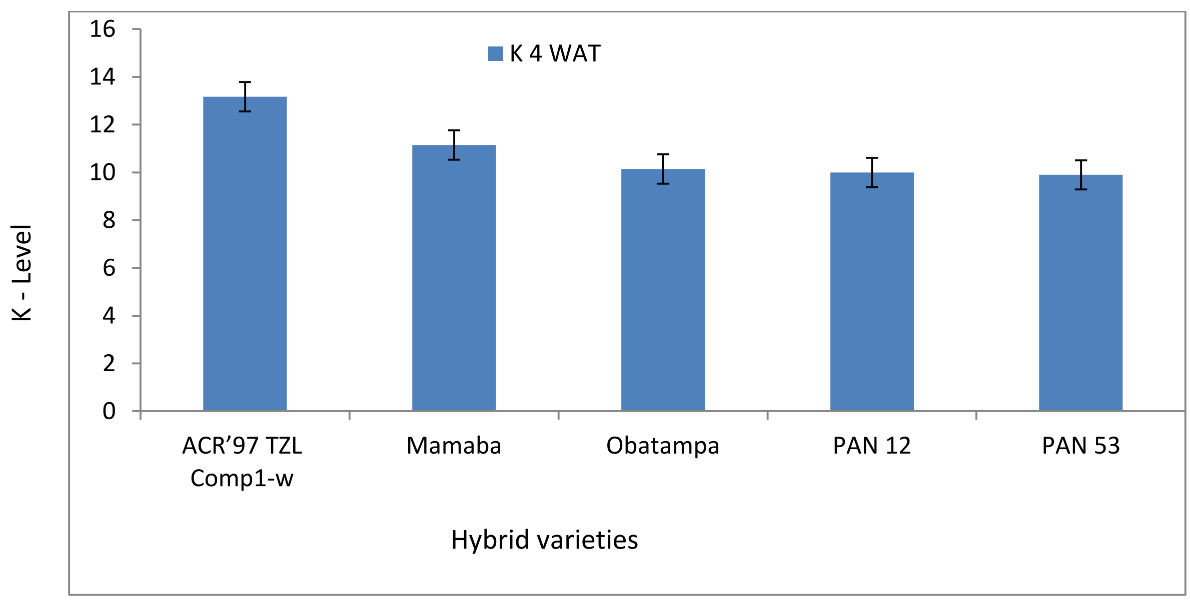

Figure 11: K content of plant biomass 4 WAT. (Error bars represent SED).

ANOVA showed significant effect (p<0.05) for fertilizer x variety interaction at 4 WAT but that of fertilizer and variety as main factor did not (Fig.19). ACR'97 TZL Comp1-w recorded the highest K content > Mamaba > Obatampa and PANS 12 and 53, which demonstrated similar contents.

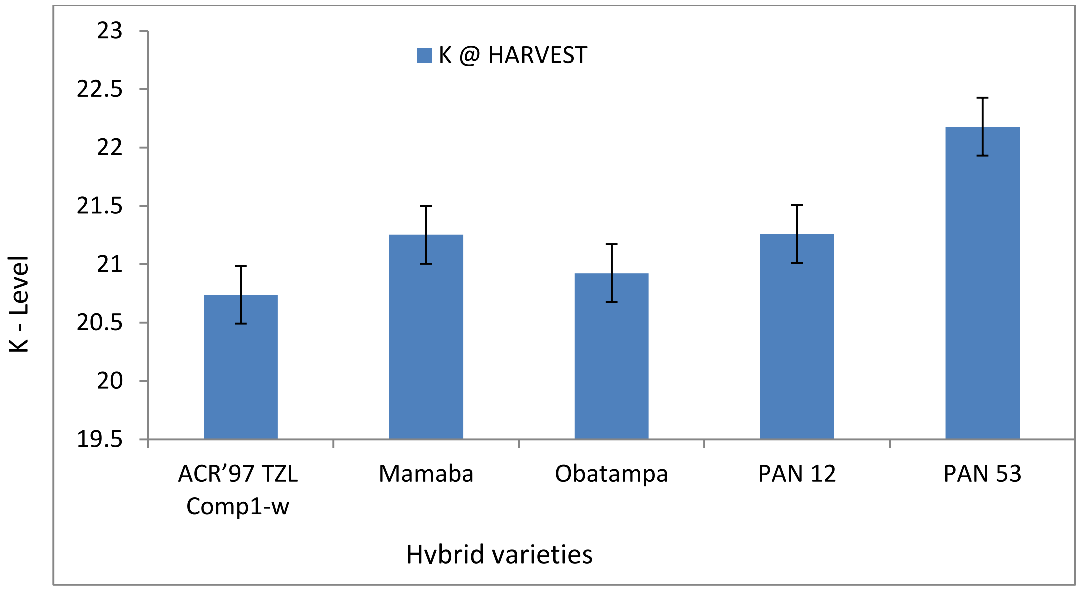

Figure 12: K content of plant biomas at at harvest. (Error bars represent SED).

Both variety and the interaction between fertilizer x variety were significantl (p<0.05) for K in plant biomass but the main effect of fertilizer did not (Fig. 20). PAN 53 was outstanding followed by PAN 12 and Mamaba which showed similar results and the least was observed in Obatampa and ACR'97 TZL Comp1-w together.

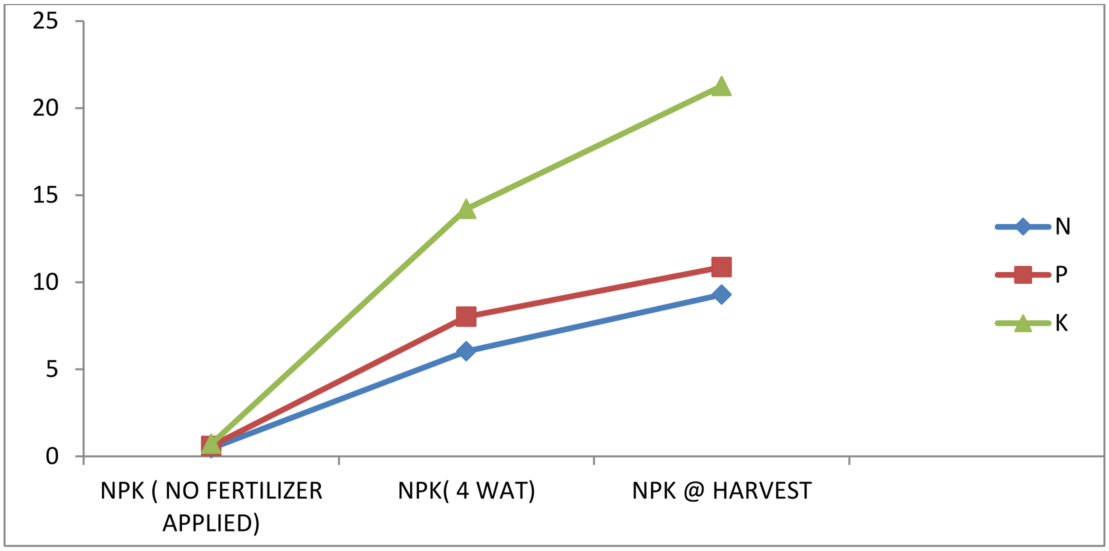

Figure 13: A graphical presentation of NPK in plant biomass over the cropping period

Initial values for NPK in plant biomass were low (all below one). Fertilizer treatments boosted the values at 4 WAT, which were again increased as a result of various top dressed fertilizers resulting to maximum values at harvest (Fig 21).

4.12 Results from laboratory analysis of soil

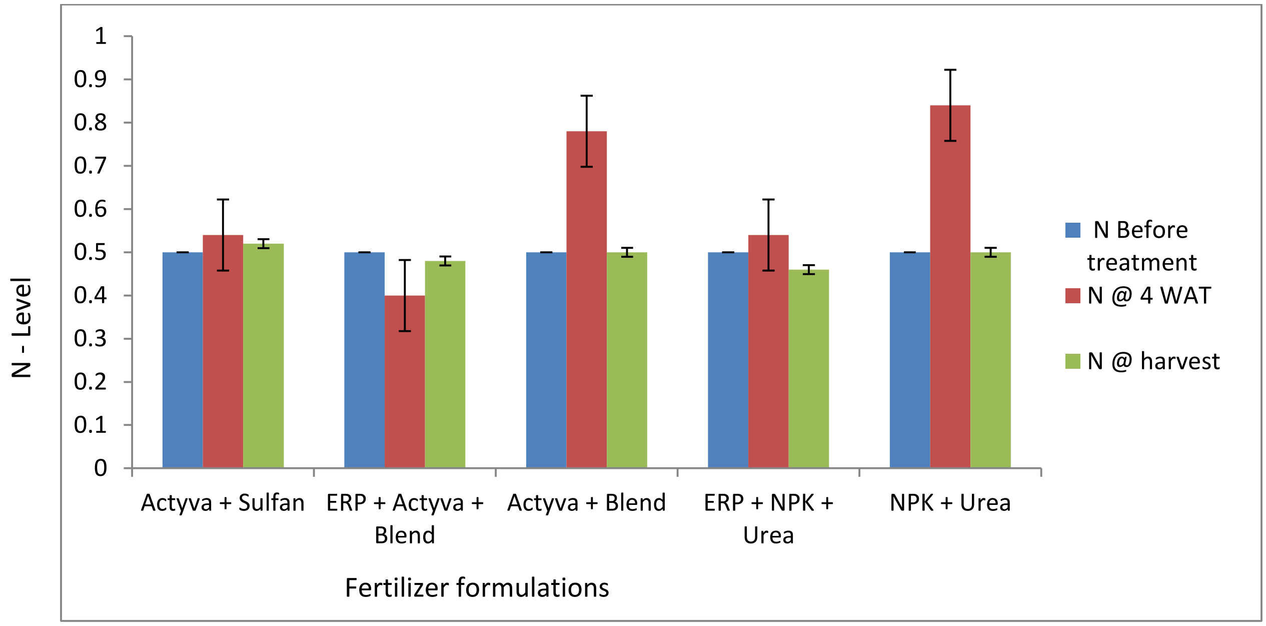

Figure 14: Effect of fertilizer formulations on N distribution in soil over the copping season (Bar represent SED)

Application of N: P: K + urea and Actyva + Blend released highest amounts of N into the soil at 4 WAT whilst the least was observed under ERH + Actyva + Blend formulations. By harvest, the N level decreased almost to what was original in the soil before treatments ware imposed (Fig.22). The other two formulations observed similar results throughout the study period.

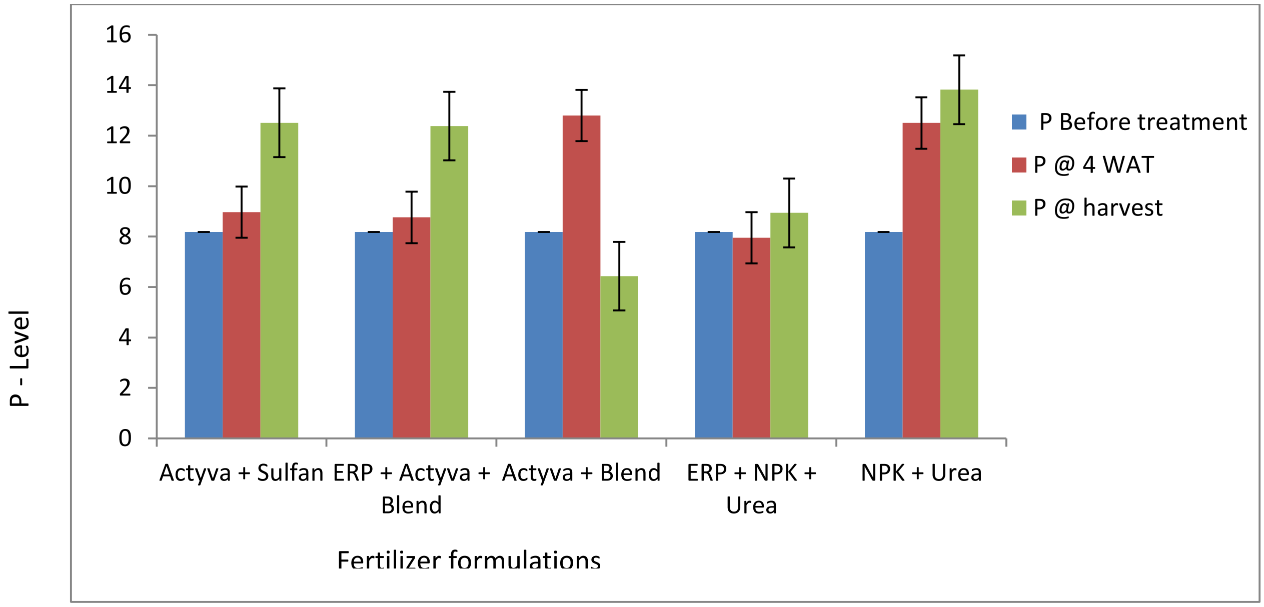

Figure 15: Effect of fertilizer formulations on P distribution in soil over the copping season (Bar represent SED)

Actyva + blend and N: P: K + urea formulations observed the highest f P in soil at 4 WAT whiles the other three showed similar results. P levels at harvest was highest under NPK +urea formulations > Actyva +Sulfan and ERP +Actyva + Blend >ERP + NPK + Urea. The least P was recorded in Actyva + Blend formulations which were less than the original soil content before treatment was imposed (fig. 23).

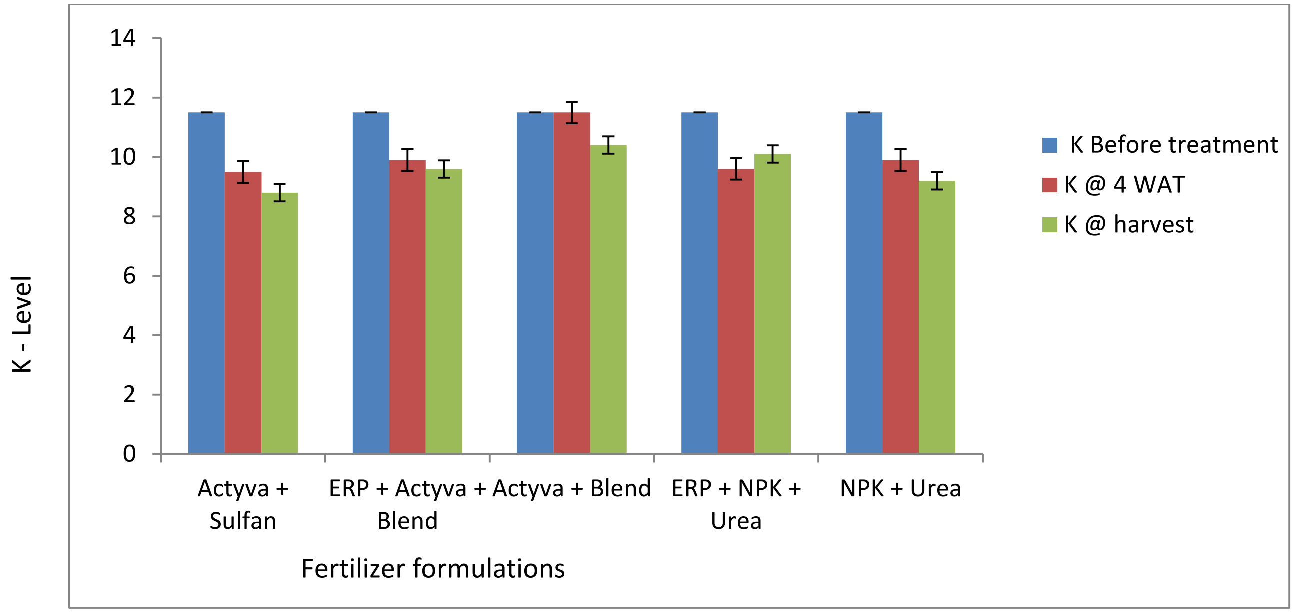

Figure 16: Effect of fertilizer formulations on K distribution in soil over the copping season (Bars represent SED)

Soil on the experimental site was saturated with K at the onset of the experiment hence its application had little contribution on soil K. All the fertilizer formulations however promoted K uptake which resulted in depletion in soil than original content by harvest (Fig. 9). Actyva + Sulfan and N: P: K + urea formulations similarly recorded the least K < ERP + Actyva + blend < ERP + N: P: K + urea, whilst Actyva + blend recorded the highest K as residual in soil at harvest (fig 24).

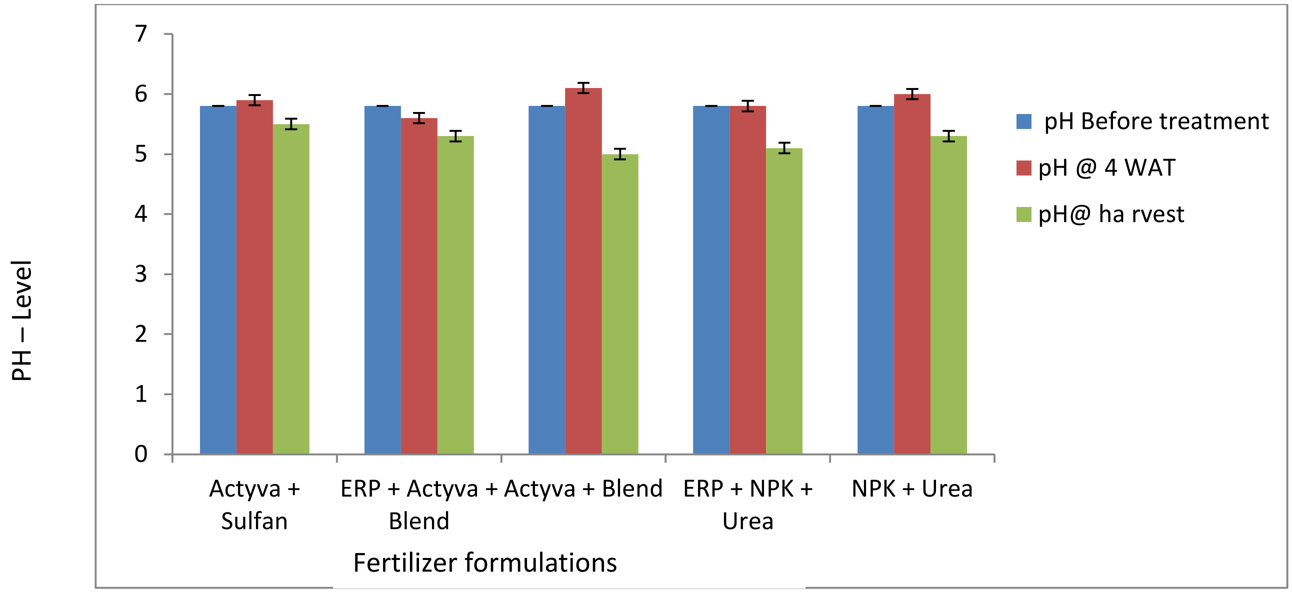

Figure 17: Effect of fertilizer formulations on distribution soil pH of over the cropping period (Bar represent SED)

Application of fertilizer treatments had very little effect on soil pH distribution. pH generally revolved round the original level before fertilizer treatment at 4 WAT, but declined drastically by harvest (Fig. 25). Actyva + blend formulations resulted in the highest decline > ERP + Actyva + blend and ERP + N: P: K + urea > Actyva + Sulfan and N: P: K + urea formulations. pH however, remained between 5 and 6 which fell within the recommendations for maize production.

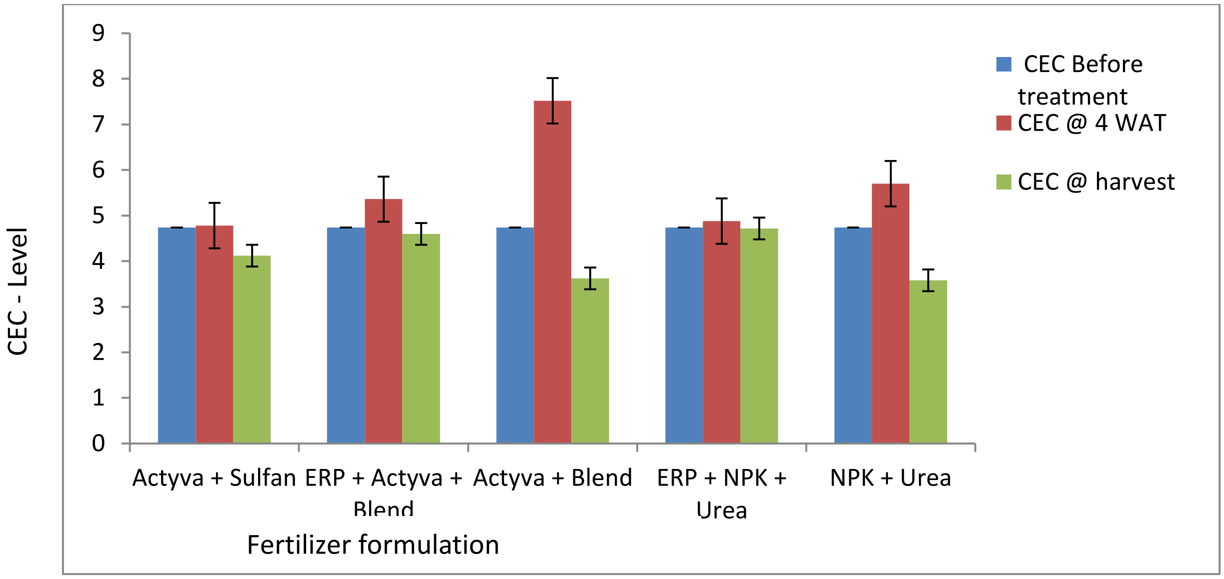

Figure 18: Effect of fertilizer formulations on CEC distribution in soil over the copping season (Bars represent SED)

The results above showed the highest exchange of ions under Actyva + blend formulation at 4WAT, a process which drastically declined to the least by harvest. Similarly high activities of ion exchange were observed in ERP + Actyva + blend N: P: K + urea and formulations but the decline was gradual in ERP + Actyva + blend formulations, returning to origin by harvest than that of N: P: K + urea which continued to decline to the level of Actyva + blend (Fig. 25). Application of ERP + N: P: K + urea formulations did not affect CEC either positively or negatively during the cropping period.

CHAPTER FIVE

5.0 DISCUSSION

The study of the effect of fertilizer formulation on yield components and yield of hybrid maize (*Zea mays* L.) varieties in the Guinea savannah zone of Ghana showed that the interaction between the fertilizer and variety as well as fertilizer formulations as a factor had no significant effect on the yield component and yield of the hybrid maize. Most of the variations were due to the dominating varietal effects.

The lower seedling emergence in the field as compared with results from the germination test conducted in the laboratory before planting was as a result of the torrential rains experienced on the third, fifth and sixth DAP which flooded the site temporarily, reduced soil oxygen as reported by Du-Plessis (2003) and created unfavourable soil environmental conditions for germination as reported by Wenkert *et al*., (1988).

Though the fertilizer formulations apart from those with ERP were not imposed by this stage, the soil laboratory analysis showed that there was adequate reserve of NPK to support the emerging plants. The soil analysis also showed conducive CEC (Alam *et. al*., 1999) and pH (Rehm, 2009) for emergence of seeds. However the roots of the maize plants were not developed to absorb soil nutrient at that stage (Xu *et al*., nd and Mollah *et al*., 2007). The variations in the emergence percentage resulted from genetic differences of the hybrid varieties that made some more resistant and tolerant to temporary flooding. Emergence percentage of more than 80% for all varieties was however high enough to permit the experiment to be carried out. Variety x fertilizer formulation interaction did not shoe significant difference for plant height at 4 and 6 WAP but variety as a factor was significant. These variations were due to genetic characteristics of the individual hybrid which exhibited different growth rates due to their abilities to form roots, compete for growth factors and convert available scarce nutrients and growth factors into physiological development. This was similar to earlier work reported by Borrill *et al*., (2006), Grassini, (2007). The variations in NPK content in plant biomass shows that hybrid varieties develop primary and secondary root systems at different rates and therefore have different abilities for nutrient uptake at various stages. Plants biomass with low NPK at 4 WAT could due to the fact that their roots were not established enough to exploit and absorb the available nutrient in the soil to such a level that could give a clear difference of varietal efficiency. This confirmed an earlier report of Xu *et al*., (nd), that limited and short borne roots reduced absorption rates of N in maize. It also agreed with Bondesio *et al*., (nd) that primary roots which develop within the first six leaf stage in maize absorbed very little soil nutrient.

The establishment of secondary roots which were responsible for soil nutrient absorption started developing from 6 leaf stage. The means however, placed ACR'97 TZL Comp1-w on the lead in N content in biomass, a character that suggested a faster root establishment for that variety over the others. This again agrees with Xu *et al*., (nd) that, as maize plant established more roots, its N absorption rate increased. The other four hybrids observed similar results at 2 WAP, which opened them to a leveled field for performance in the general experiment.

Fertilizer formulations did not affect both plant height and LAI within four (4) WAT because the active ingredients were dissolving and the roots were yet to absorb enough soil nutrients to show significant effect on the plant which shows little quantities of NPK in plant biomass between the first 4 WAT. Results from soil analysis also indicate that the initial amount of NPK in the soil was low until 6 WAT and so the plants did not have much to absorb to show significant effects on height and LAI at those stages. This phenomenon agrees with earlier study by Nyalemegbe *et al*., (2012).). All varieties therefore have equal potential establishment and competing for growth resources from both soil and their environment. Higher N absorption by ACR’97 TZL Comp1-w than others could give it advantage for better field establishment Fertilizer, however, affected all parameters measured from 6 WAT / 8 WAP including plant (a)-height, (b)-LAI, days to 50% tasseling, (c)-cob and husk weight, (d)-dehusked weight, (e)-grain yield and (f)-100 seed weight. The major factors that contributed to these results included the following:

The fertilizer imposed on the soil dissolved substantially and released nutrients that were available for roots to absorb into the plant. A soil test of N at 4 weeks after fertilizer application showed significant interaction between the varieties and various fertilizer formulations. This confirms the findings of Bondesio *et al*., (nd) that secondary roots in maize are fully developed by 6 WAP and are responsible for soil nutrient absorption. It was observed that Mamaba absorbed the highest amount of N compared to all other varieties. This may be attributed to its efficient and effective secondary root establishment, favourable environment and probably its genetic makeup as reported by Mollah *et al*., (2007), which placed the variety at most active age for nutrient absorption towards yield production. It could also be linked to favourable fertilizer formulations which promoted availability of N for that variety over the others, similar observation was reported by Akmal *et al*., (2010) and Shiluli *et al*., (2000) who reported that N is more available to maize when it has a good balance with P.

The plant biomass analysis for NPK showed that PAN 53 and Obatampa had similar N content, suggesting common requirement for the two in terms of environment, field requirement and establishment. PAN 12 and ACR’97 TZL Comp1-w recorded the least N in biomass content. This could be attributed to factors such as poor root establishment as established by Xu *et al*., (nd), fertilizer formulations that impeded release and uptake of N into and from soil, unfavourable environment which resulted to leaching and evaporation as reported by Gehl *et al*., (2005). It could also be linked to genetic characteristic which placed those varieties at their threshold for N absorption at that period as reported by Buah *et al*., (2009). The level of N supplied (375 kg/ha of Actyva as basal and 250kg/ha of blend for top-dressed doss) was however high enough for all the varieties for maximum potential yield since that was far above what was used by Buah *et al*., (2009), Gehl *et al*., (2005) and Nyalemegbe *et al*., (2012) who all reported on N levels for efficient maize performance.

N composition in plant biomass at harvest again showed no significant effect as the N was translated into grain. This confirmed Akmal *et al*., (2010) that, maize plants used N supplied for grain formation to increase their yields. The mean values however went up because of extra N fertilizers used as top dressed dosses, suggesting that the plants absorbed excess N than required. At harvest, Obatampa and PAN 53 had the highest residual. This suggested 150kg/ha N recommendation by Akmal *et al.,* (2010) could be the threshold for maximum performance for those two varieties. Low N in the biomass of Mamaba and ACR'97 TZL Comp1-w, with PAN 12 recording the least at harvest suggested a more convention of N into yield hence the 250kg/ha applied as top dressed dose in split form was recommended for them. This confirmed Mollar *et al*., (2007) that the highest yield was obtained when N fertilizer was applied in two splits. Such high residual levels suggested that the plants had maximum levels to give out yields of their maximum potentials as reported by Buah *et al*., (2009). The significant effects of variety on parameters including plant height, LAI, days to 50% tasseling at 8 WAP was very relevant because, the maize plant from this exponential growth stage was moving towards yield production and requires more nutrients for both physiological development and yield formation as reported by

Du-Plessis, (2003). Results from soil analysis show that there was adequate NPK in the soil that supported the process. Soil analysis again show that the pH ranges and CEC created the soil environment that was good for nutrient absorption by roots as reported by Rehm, (2009) Aye *et al*., (nd), and Delp, (2013). All varieties therefore exhibited their full potentials in terms of height, LAI and tasseling which resulted to optimum yield. Variety was significant for straw weight. The highest straw weight was realized in PAN 12, followed by PAN 53 > Mamaba and ACR'97 TZL Comp1-w > Obatampa (Fig. 2) except under ERP + Actyva + Blend formulation where the straws of ACR'97 TZL Comp1-w exceeded that of PAN 53 by 0.3 kg whilst the least from all fertilizer combinations came from Obatampa variety. Such a high yield of straw observed could be attributed to the high level of nitrogen sources from the Actyva, Sulfan, Urea and blend which promoted maximum vegetative growth to harness other photosynthetic factors for maximum yield. This was similar to an earlier work by Silvia and Uchida, (2000).

The presence of Zn in the Actyva probably also promoted stalk and leaf growth as reported by both Murdock and Hawe, (2001) and Muck and Mystery, (2006). Since all the varieties were subjected to the same conditions, such differences in the straw could also be due to the genetic differences among the hybrids as reported by Brown and Darrah, (2010). Also, varieties with high straw weights were linked to more advantages for photosynthesis (higher chlorophyll, sun light, water and $CO^{2)}$ absorption. This finding is supported by Kanungwe, (2009) who reported high straw in the pannar varieties and related it to maximum photosynthetic functions that resulted in higher yields. The low straw output in Obatampa despite the high nitrogen sources could be due to genetic limitations of the variety as its maximum threshold was attained. In cases where maize was cultivated for straw therefore, the pannar varieties are recommended followed by ACR'97 TZL Comp1-w and Mamaba depending on availability. Obatampa variety, on the other hand, may not be suitable. It would be economically cheaper that farmers leave out the Eco Rock Phosphate in their formulations and go for any two source formulation based on cost and availability.

Varieties with heavier straws had mere robust root system for nutrient absorption, firmer stems, higher LAI and in most cases taller in height. These made them more efficient and effective in competing and accessing growth factors including nutrient, water, sun light, air and also suppressed weeds that would have competed with them as reported by Du-Plessis, (2003). These translated into bigger and heavier cobs with well filled grain yield as reported by Buah *et al*., (2009), Kanungwe, (2009) and Borrill *et al*., (2006). Though NPK + Urea fertilizer formulation produced the highest straw weight it failed to translate into highest grain yield because the N became deficient to support the grain filling. This confirms Nyalemegbe *et al*., (2002) who reported that the Actyva has an advantage of slowly releasing nutrients throughout the crops life as compared with NPK that gives off its N quickly. Similar trends were observed for dehusked cob weight in the study. Higher grain yields were therefore attained with support from fertilizer formulations with Actyva combinations with Actyva + Sulfan and ERP + Actyva + Blend supporting the highest grain yield followed by Actyva + Blend and the least supported by NPK + Urea (control).

There were significant differences among varieties for grain yield but the main effect of fertilizer and interactions were not significant. PAN 12 produced the highest grain weight (4732 kg/ha) followed by PAN 53 (3948 kg/ha) > Mamaba (3024kg/ha) > ACR’97 TZL Comp1-w (3984 kg/ha) and the least from Obatampa (2108 kg/ha). This confirms similar results observed by Akande and Lamidi, (2006) and Al-Hassan and Jatoe (2002) where Obatampa produced a significantly lower yield than Mamaba in their comparison of yield performance of various hybrid maize varieties. This trend of Obatampa cuts across for all the yield indicators studied (height, LAI, cob + husk weight, dehusked weight). It could be that the variety was targeted towards high protein content but not high yield. Thus the other varieties were superior to it in terms of yield, hence Obatampa may not be recommended when high yield is being targeted. PAN 12 and PAN 53 exhibited higher grain yield above the other three local hybrids. This outstanding performance of the pannar corresponded with that of Kanungwe, (2009) who observed as high as 11.3 tonnes/ha from pannar trials and projected even higher results of 17.5 tonnes for the future as the breeders improved in their skills. It also confirmed the work of Nyirongo, (2011) who reported that a farmer realized 2000kg/ha yields from pannar on one hectare, which was better than other hybrid varieties. Again the result confirms those of Masara N'Arziki (2011) where 500 kg/ha of yield for the PANNAR varieties was obtained.

Though main effects of fertilizer did not produce significant difference, observed means showed that, Actyva + Sulfan and ERP + Actyva + Blend formulations similarly supported the highest grain yield (3832 kg/ha), followed by Actyva + Blend and ERP + N: P: K + Urea formulations (3400kg/ha) and the least grain yield was observed from N: P: K + Urea formulations. These results showed that, the formulation of these fertilizers determined how much of their nutrient content the plant can access and convert to yield. i.e. the pairing can enhance or reduce the uptake of the nutrients. This finding is similar to that of Hussaini *et al*., (2008) who reported that the application of N and K either enhances the uptake of nutrients or decrease their uptake.

The poor performance of NPK + Urea formulations could be as a result of the N and P failing to enhance nutrient uptake N by the roots, a similar trend reported by Hussaini *et al*., (2008) . It could also be due to poor S presence as reported by Taalab *et al*., (2008) and Nyalemegbe *et* *al*., (2012) that, P can be more effective and available when S is present which was observed in formulations including Actyva containing S. Again the poor yield output could be linked to the general poor response of the maize to P even though enough P was applied through the various formulations and supported by the ERP. These agree with the report of Nour *et al*., (nd) who reported that maize crops showed no response to P application.

In terms of fertilizer x variety, it was observed that Obatampa could not exceed its yield potential no matter how much fertilizer was supplied hence showing the least in all the yield parameters. This corresponds with Buah *et al*., (2009) who reported that additional N supplied to Obatampa after 90kg/ha did not yield corresponding increment in yield. On the other hand the pannars responded positively to high doses of fertilizer, suggesting that yields could be increased if more were supplied. This also confirms the findings of Kanungwe, (2009) who observed as high as 11.3 tonnes/ha from pannar trials and projected even higher results of 17.5 tonnes for the future as the breeders improved. It is also in support of work that corresponded to Amanullah *et al*.,(2008) who reported that hybrid maize achieve their productivity potentials when given high fertilizer levels and further suggested up to 200:100:100 N: P: K. for such hybrids. The results also showed that performance of fertilizer formulations from two sources performed similar to those from three sources hence choosing from two sourced formulations would give better economic returns.

Main effect of variety showed significant differences on 100 seed weight but that of fertilizer and interaction did not. PAN 12 proved the highest weight (1.9 KG) > PAN 53 (1.7KG) > ACR'97 TZL Comp1-w and Mamaba (1.5kg) >Obatampa (1.4kg). This means that the Pannar varieties were more efficient in converting fertilizer to yield than the local hybrids. Since results obtained from two fertilizer formulations were similar to those from three formulations, it would be more profitable to choose from the two formulation sources for production to save cost as reported by Todd, (1999). Generally the use of the eco rock phosphate had very little effect on the yield in all varieties of hybrid maize tested. This finding is in agreement with Muck and Mystery, (2006) who reported that ERP contained less than 5% plant available P and argued that it was more costly to apply than the returns it gave to the crop. They further suggested that keeping the soil pH close to neutral was the best way of improving P availability.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The hybrid varieties studied in this work revealed that, PANNAR varieties (PANS 12 and 53) imported from South Africa produced higher yields than the local hybrid varieties (Mamaba, ACR’97 TZL Comp1-w, and Obatampa GH.). Except in LAI and cob and husk weight where yield components were similar in all varieties, PAN 12 produced the highest yield components including straw weight, dehusked cob weight and the highest grain yield (4732kg/ha) which is 2.25 times that of Obatampa GH., which produced the least yield (2108kg/ha) in this study. PAN 53 ranked second in terms of yield and yield components (3948 kg/ha) of grain which again is higher than all the local hybrids. Mamaba ranked third among the varieties studied (3024) but first among the local varieties studied. ACR’97 TZL Comp1-w ranked fourth (2984kg/ha) in the general studies but second among the local hybrid verities. Interactions of fertilizer formulations x variety as well as fertilizer as a factor did not affect the experiment. All effects could therefore be linked to variations due to varieties used for the experiment. Management and beneficiaries of the Masara N’Arziki programme could use any of the fertilizer formulations that is of the least cost to produce so as to reduce cost and maximize profit.

6.2 Recommendation.

The exotic varieties (PANS 12 and 53) are recommended as the highest yielding varieties for Masara N'Arziki programme and also for all commercial maize farmers in the savannah zones of Ghana. Any of the fertilizer formulations used in the experiment with the least cost could be adapted to for the recommended varieties to reduce cost and maximize profit.

Further studies into cost benefit analysis should be done to establish the profitability of the programme on the beneficiaries including: cost of labour, land preparation, weed control, chemical and fertilizer applications harvesting and administration cost.

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APPENDICES

Soil lab analysis

Appendix 1: MC 10wap

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
Block stratum	3	9.38	3.13	0.24	
Treatment	4	58.65	14.66	1.15	0.381
Residual	12	153.24	12.77		
Total	19	221.27			

Appendix 2: Mc 2 wap

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
Block stratum	3	268.23	89.41	1.88	
Treatment	4	77.48	19.37	0.41	0.8
Residual	12	570.83	47.57		
Total	19	916.55			

Appendix 3: Mc 4 wap

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
Block stratum	3	26.542	8.847	5.59	
Treatment	4	17.86	4.465	2.82	0.073
Residual	12	18.996	1.583		
Total	19	63.398			

Appendix 4: Mc 6 wap

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
Block stratum	3	4.08	1.36	0.12	

Treatment	4	39.33	9.83	0.84	0.528
Residual	12	141.17	11.76		
Total	19	184.59			

Appendix 5: Mc 8 wap

Source of variation	**Degrees of freedom**	**Sum of squares**	**Mean squares**	**Variances**	**F pr.**
Block stratum	3	116.79	38.93	1.01	
Treatment	4	104.81	26.2	0.68	0.618
Residual	12	461.26	38.44		
Total	19	682.86			

Appendix 6: Plant stand plot

Source of variation	**Degrees of freedom**	**Sum of squares**	**Mean squares**	**Variances**	**F pr.**
Block stratum	3	4521.4	1507.1	17.58	
Fertilizer	4	218.5	54.6	0.64	0.646
Residual	12	1028.7	85.7	0.47	
Variaties	4	782.6	195.7	1.07	0.378
Fertilizer.Variaties	16	2948.5	184.3	1.01	0.459
Residual	60	10939.7	182.3		
Total	99	20439.4			

Appendix 7: pH 2 wap

Source of variation	**Degrees of freedom**	**Sum of squares**	**Mean squares**	**Variances**	**F pr.**
Block stratum	3	23.29	7.763	7.03	
Fertilizer	4	4.215	1.054	0.95	0.467
Residual	12	13.259	1.105	1.01	
Varieties	4	15.601	3.9	3.57	0.011
Fertilizer.Variaties	16	14.356	0.897	0.82	0.658
Residual	60	65.606	1.093		
Total	99	136.327			

Appendix 8: Ph 4 wap

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
Block stratum	3	229.89	76.63	2.39	
Fertilizer	4	129.92	32.48	1.02	0.438
Residual	12	383.99	32	0.84	
Variaties	4	434.96	108.74	2.86	0.031
Fertilizer.Variaties	16	552.76	34.55	0.91	0.564
Residual	60	2283.81	38.06		
Total	99	4015.34			

Appendix 9: Ph 6 wap

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
Block stratum	3	1981	660.3	10.78	
Fertilizer	4	890.1	222.5	3.63	0.037
Residual	12	734.9	61.2	0.6	
Variaties	4	1965.8	491.4	4.85	0.002
Fertilizer.Variaties	16	902.7	56.4	0.56	0.903
Residual	60	6073.9	101.2		
Total	99	12548.4			

Appendix 10: Ph 8 wap

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
Block stratum	3	9333	3111	1.01	
Fertilizer	4	21440	5360	1.73	0.207
Residual	12	37091	3091	2.06	
Variaties	4	13522	3381	2.25	0.074
Fertilizer.Variaties	16	12648	790	0.53	0.923
Residual	60	90149	1502		
Total	99	184183			

Appendix 11: LAI 4 wap

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
Block stratum	3	0.72029	0.2401	8.08	
Fertilizer	4	0.1792	0.0448	1.51	0.261
Residual	12	0.35675	0.02973	0.86	
Variaties	4	0.28355	0.07089	2.06	0.097
Fertilizer.Variaties	16	0.71061	0.04441	1.29	0.233
Residual	60	2.0655	0.03442		
Total	99	4.31589			

Appendix 12: LAI 6 wap

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
Block stratum	3	42.6598	14.2199	21.8	
Fertilizer	4	3.9525	0.9881	1.51	0.259
Residual	12	7.8276	0.6523	0.82	
Variaties	4	4.0959	1.024	1.29	0.284
Fertilizer.Variaties	16	8.5184	0.5324	0.67	0.811
Residual	60	47.6304	0.7938		
Total	99	114.6846			

Appendix 13: LAI 8 wap

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
Block stratum	3	1.5193	0.5064	0.69	
Fertilizer	4	2.1405	0.5351	0.73	0.589
Residual	12	8.8093	0.7341	1.28	
Variaties	4	2.6006	0.6501	1.13	0.351
Fertilizer.Variaties	16	15.6654	0.9791	1.7	0.071
Residual	60	34.5218	0.5754		
Total	99	65.2569			

Appendix 17: Grain wt plot kg

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
Block stratum	3	94.841	31.614	5.43	
Fertilizer	4	44.863	11.216	1.93	0.171
Residual	12	69.859	5.822	1.4	
Variaties	4	505.425	126.356	30.48	<.001
Fertilizer.Variaties	16	39.857	2.491	0.6	0.871
Residual	60	248.702	4.145		
Total	99	1003.548			

Appendix 18: Seed wt two

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
Block stratum	3	109.35	36.45	2.25	
Fertilizer	4	8.25	2.06	0.13	0.97
Residual	12	194.46	16.2	0.98	
Variaties	4	1589.24	397.31	24.04	<.001
Fertilizer.Variaties	16	214.53	13.41	0.81	0.668
Residual	60	991.53	16.53		
Total	99	3107.35			

Appendix 19: Straw w plot kg

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
Block stratum	3	91.229	30.41	3.39	
Fertilizer	4	7.553	1.888	0.21	0.928
Residual	12	107.64	8.97	1.45	
Variaties	4	775.728	193.932	31.44	<.001
Fertilizer.Variaties	16	110.489	6.906	1.12	0.359
Residual	60	370.151	6.169		
Total	99	1462.79			

Appendix 20: K 2wap

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
REP stratum	2	26.291	13.146	0.66	
Fertilizer	4	86.263	21.566	1.09	0.424
Residual	8	158.583	19.823	5.47	
Variety	4	8.656	2.164	0.6	0.667
Fertilizer.variety	16	53.083	3.318	0.92	0.558
Residual	40	144.895	3.622	1.28	
Plant_part_2wap	1	150.801	150.801	53.29	<.001
Fertilizer.plant_part_2wap	4	13.254	3.313	1.17	0.335
Variety.plant_part_2wap	4	1.881	0.47	0.17	0.955
Fertilizer.variety.plant_part_2wap	16	40.231	2.514	0.89	0.585
Residual	50	141.503	2.83		
Total	149	825.442			

Appendix 21: K 6wap

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
REP stratum	2	40.09	20.04	0.46	
Fertilizer	4	187.34	46.84	1.07	0.432
Residual	8	350.57	43.82	0.87	
Variety	4	223.98	55.99	1.11	0.365
Fertilizer.variety	16	747.72	46.73	0.93	0.547
Residual	40	2016.68	50.42	0.8	
Plant_part_6_wap	1	515.23	515.23	8.14	0.006
Fertilizer.plant_part_6_wap	4	87.66	21.92	0.35	0.845
Variety.plant_part_6_wap	4	274.5	68.63	1.08	0.374
Fertilizer.variety.plant_part_6_wap	16	958.16	59.88	0.95	0.526
Residual	50	3164.37	63.29		
Total	149	8566.3			

Appendix 22: N 2wap

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
REP stratum	2	31.66	15.83	0.47	
Fertilizer	4	85.31	21.33	0.63	0.655
Residual	8	270.58	33.82	1.13	
Variety	4	92.19	23.05	0.77	0.55
Fertilizer.variety	16	503.04	31.44	1.05	0.428
Residual	40	1195.52	29.89	1	
Plant_part_2wap	1	67.82	67.82	2.26	0.139
Fertilizer.plant_part_2wap	4	93.92	23.48	0.78	0.541
Variety.plant_part_2wap	4	91.99	23	0.77	0.551
Fertilizer.variety.plant_part_2wap	16	502.31	31.39	1.05	0.426
Residual	50	1497.55	29.95		
Total	149	4431.86			

Appendix 23: N at harvest

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
REP stratum	2	93.63	46.82	1.2	
Fertilizer	4	161.76	40.44	1.04	0.444
Residual	8	311.33	38.92	0.98	
Variety	4	157.32	39.33	0.99	0.423
Fertilizer.variety	16	639.99	40	1.01	0.468
Residual	40	1586.14	39.65	0.99	
Plant_part_at_harvest	1	41.68	41.68	1.04	0.312
Fertilizer.plant_part_at_harvest	4	156.66	39.17	0.98	0.426
Variety.plant_part_at_harvest	4	155.1	38.78	0.97	0.432
Fertilizer.variety.plant_part_at_harvest	16	635.46	39.72	0.99	0.477
Residual	50	1996.44	39.93		
Total	149	5935.52			

Appendix 24: P 2wap

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
REP stratum	2	1.993	0.996	0.45	
Fertilizer	4	41.667	10.417	4.71	0.03
Residual	8	17.704	2.213	1.21	
Variety	4	9.749	2.437	1.33	0.274
Fertilizer.variety	16	21.065	1.317	0.72	0.757
Residual	40	73.06	1.827	0.75	
Plant_part_2wap	1	28.628	28.628	11.68	0.001
Fertilizer.plant_part_2wap	4	16.008	4.002	1.63	0.181
Variety.plant_part_2wap	4	1.88	0.47	0.19	0.942
Fertilizer.variety.plant_part_2wap	16	20.79	1.299	0.53	0.918
Residual	50	122.516	2.45		
Total	149	355.06			

Appendix 25: P at harvest

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variances	F pr.
REP stratum	2	421.449	210.724	8.54	
Fertilizer	4	98.279	24.57	1	0.463
Residual	8	197.349	24.669	2.47	
Variety	4	74.534	18.634	1.87	0.135
Fertilizer.variety	16	106.993	6.687	0.67	0.805
Residual	40	399.035	9.976	1.4	
Plant_part_at_harvest	1	0.814	0.814	0.11	0.737
Fertilizer.plant_part_at_harvest	4	60.714	15.179	2.12	0.092
Variety.plant_part_at_harvest	4	5.812	1.453	0.2	0.935
Fertilizer.variety.plant_part_at_harvest	16	88.169	5.511	0.77	0.709
Residual	50	357.256	7.145		
Total	149	1810.404			