PRODUCTIVITY OF NEWLY RELEASED MAIZE VARIETIESBY FERTILIZER APPLICATION IN MOSHI RURALDISTRICT, KILIMANJARO REGION

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP SCIENCE AT SOKOINE UNIVERSITY OF AGRICULTURE, MOROGORO, TANZANIA.

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ABSTRACT

In Northern Tanzania, yield of maize ranges between 0.5 – 0.8 t ha^{-1} compared with the yield potential of 4–6 t ha^{-1} under research conditions resulting to yield gap of 5.2 t ha^{-1}. Major cause of low maize yield is low soil fertility due to insufficient use of fertilizers. A study was undertaken at Miwaleni (3º 25´ 30´´S and 37º 26´ 45´´ E) to determine the productivity of newly released maize varieties by fertilizer application in maize growing area of Moshi rural districtin Kilimanjaro region. Soils sampleswere collected from the experimental site. The objective of the study was to determine the response of maize yield on Nitrogen (Urea), Phosphorus (DAP, Minjingu Mazao, NPK cereal) fertilizers.The first experiment was conducted as split plot design in randomized completete block layout replicated three times. The factors were maize varieties (*Situka* MI, *Meru* HB 513 and *Faru* HB) while subplot factors were fertilizers types namely; DAP, at 62kg Pha^{-1}, *Minjingu Mazao*at 71kg P ha^{-1} and NPK Cereal at 124kgP ha^{-1}. The second experiment was conducted as split split plot design in randomized completete blocklayout replicated three times. In the second experiment main and subfactor comprised four levels that were nitrogen ratesnamely; Nitrogen at 37.5, 50, 62.5 kg N ha^{-1} and no fertilizer application. Results obtained from the site, showed that the three phosphatic fertilizers applied, top dressed with respective nitrogen levels produced highly significant ($P<0.001$) grain yield over the control. Also *Meru* HB 513 and *Faru* HB produced highly significant ($P<0.001$) yield results than Situka M1 variety. Overal, the study results indicated that Minjingu Mazao and NPK fertilizers top dressed with nitrogen rates at 50kg Nha^{-1} and 62.5kg Nha^{-1} when applied on maize varieties (*Meru* HB 513, *Faru* HB) are the best strategies in improving maize grain yield in the study area.

DECLARATION

I **Focus Edward Muhogora,**do hereby declare to neither the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

Focus Edward Muhogora Date

(MSc Candidate)

The above declaration is confirmed by;

Prof. Cornel L. Rweyemamu Date

(Supervisor)

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LIST OF ABBREVIATIONS AND SYMBOLS

<	Less than
>	Greater than
^0C	Degree Celsius
ANOVA	Analysis of variance
CEC	Cation exchange capacity
CGR	Crop growth rate
cm	Centimetre
cmolc (+) kg-1	Centimole (+) per kilogram
CV	Coefficient of variation
DAP	Diammonium Phosphates
DTPA	Diethylenetriamine penta-acetic acid
et al	And others
FAO	Food and Agriculture Organization of the United Nations
g	Gram
H_2PO^{-4}	Othophosphate
HB	Hybrid
HCl	Hydrocloride acid
HNO_3-H_2O_2	Nitric acid-Hydroperoxide
K	Potassium
K_2O	Potassium oxide
KCl	Potassium chloride
LAI	Leaf Area Index
masl	Metres above sea level
mg kg^{-1}	Milligrammes per kilogram

mm	Millimetre
MM	Minjingu Mazao
N	Nitrogen
NaOH	Sodium hydroxide
NAR	Net assimilation rate
NH_4^+	Ammonium ion
NO_3^-	Nitrate ion
NPK	Nitrogen, Phosphorus, Potassium
OC	Organic carbon
P	Phosphorus
P_2O_5	Phosphorus pentoxide
pH	Negative logarithm of hydrogen ion concentration
RGR	Relative growth rate
S	Sulphur
SO_4^{2}-	Sulphate ion
SSA	Sub Saharan Africa
SSSA	Soil Science Society of America
SUA	Sokoine University of Agriculture
t ha^{-1}	Ton per hectare
USDA	United States Department of Agriculture
Yr	year
Zn	Zinc
µg	Microgram

CHAPTER ONE

1.0 INTRODUCTION

1.1 Maize Production in Tanzania and Soil Fertility

Maize (*Zea mays* L) is a cereal crop used as the main staple food by over 80% of Tanzanians (Kanyeka *et al*., 2007). The national average consumption per capita is 113 kg per year; which contributes 60% of dietary calories and more than 50% of utilizable protein to Tanzanians. The crop is cultivated on an average of 4.9 million hectares that is nearly about 45% of the cultivated area in the country (Kaliba *et al*., 2000).

The major production areas are southern highlands zone including Iringa, Rukuwa, Ruvuma and Mbeya. These regions produce 50% of the national maize volume and have a maize surplus (Mdadila, 1995). The northern and central regions however, do not grow enough maize to meet demand. These include Morogoro, Dodoma, Kilimanjaro and Tabora regions (Economic Survey 2012). The national average maize yield is 1.69 t ha^{-1} while the potential is 4.0 - 6 t ha^{-1} (Mbwanga and Massawe, 2000). However, many factors limit maize production. These factors are inappropriate crop rotation, unreliable rainfall, use of traditional varieties, insect-pests attacks and diseases incidence (Homann-Kee *et al*., 2013). Apart from those factors, low soil fertility is a major constraint in maize producing areas. Improving soil fertility status is therefore very important in order to increase maize production. One of the possible solutions is to assess nutrients status of soils to know the plant nutrients deficit and the required amount to be added for the crop to complete its life cycle (Onyango *et al*., 1999).

1.2 Maize Production Trend in Tanzania

There has been a decreasing trend in maize production in Tanzania. Maize production was 3 302 000, 3 555 000 and 3 324 000 tones in 2007, 2008 and 2009 respectively (Economic

Survey, 2009). Furthermore, in 2008/09 National food production for maize was 3 424 984 tones while the requirement was 4 131 782 tones resulting into a deficit of 706 797 tones (MAFSC, 2012).

1.3 Problem Statement and Justification

In Northern Tanzania, yield of maize varieties such as *Situka*M1, *Katumani, Kilima, Vumilia* K1 ranges between 0.5 – 0.8 t ha^{-1}compared with the estimated yield potential of 4–6 t ha^{-1}under research conditionsresulting to yield gap of 5.2 t ha^{-1} (Maghehema *et al*., 2014). One of the major causes of low maize yield is declining soil fertility due to insufficient use of inorganic fertilizers resulting in severe nutrient depletion of soils (Nyaki, 1997). Studies have shown that fertilizer use in maize crop for small holder farms can give yield as high as 1.8 t ha^{-1}in Northern Tanzania (Maghehema *et al*., 2014). Most small-scale farmers in Northern Tanzania apply little fertilizers about 9 kg ha^{-1} year^{-1}or no mineral fertilizers to their crops.Only 12% of smallholder farmers are using fertilizer in maize production compared with other maize growing areas such as southern highlands where about 42% of farmers use fertilizers (MAFC, 2012). Nutrients such as N, P and K are mined in maize grain at 32kgN ha^{-}1, 5.28 kgPha^{-} and 20.75 kgKha^{-1}respectively. Similarly, straw harvesting results in mining N, P and K nutrients at 0.48 kg N ha^{-1} 0.06 kg P ha^{-1} and 1.7 kg K ha^{-1} respectively (MAFC, 2012). Blanket recommendations do not consider the actual fields or site specific soil characteristics and therefore contributing to low fertilizer usage.For example,for Nitrogen, it is recommended to apply 50 kg N ha^{-1}, Phosphorus 40 kg P ha^{-1} and Potassium 60 kg K ha^{-1} (Maghehema *et al.*, 2014). These recommendations were given based on old varieties such as *Situka* M1 released in 2001, *Katumani, Kilima, Vumilia* K1 released in 1994. The current released maize varieties (*Meru* HB 513 and *FARU* HB released in 2012, are known to be high yielding when given appropriate packages (Amuri *et al*., 2013).

1.4 Objectives

1.4.1 Overall objective

To establish the appropriate fertilizer types and rates for the recently released improved maize varieties recommended for the low altitude in the Northern Tanzania agro-ecological zone.

1.4.2 Specific objectives

The specific objectives of this study will be

i) To evaluate performance of two new maize varieties based on growth and development characteristics when applied with fertilizers.

ii) To determine the response of maize varieties by application ofthree fertilizers on yield and yield components.

iii) To evaluate appropriate fertilizer rates that may result into optimum yield when applied to modern varieties.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin of Maize

Maize (*Zea mays* L.) or corn as it is called in the USA was first domesticated in Mexico for use as a cereal food crop. The crop was extensively cultivated in Mexico as early as 5000 years ago (Manglesdorf, 1974). With time, maize has became the cornerstone of agriculture worldwide and was called the golden crop (Jayne and Jones, 1997). Maize was not known outside the Americas until 16^{th} century when explorers introduced maize seed grain to Europe and Africa (Marvin, 1965). Maize was introduced in Africa from Mexico at the beginning of 16^{th} century by the Portuguese (Bisanda *et al*., 1998). Currently, maize is grown all over Africa particularly the SSA countries.(Wambugu and Wafula, 1999).

2.2 Maize as a Staple Food

Maize is the main staple food crop in Tanzania (FAO, 2012) and over 80% of the population of Tanzania depends on maize for food (Bisanda and Mwangi, 1996). It is estimated that the annual per capita consumption of maize in Tanzania is 112.5 kg, translating to about three million tons per year (Msaky *et al*., 2010). It has been reported that maize contributes about 60% of the dietary calories to Tanzanian consumers (Bisanda *et al*., 1998). Maize provides more carbohydrates than wheat and sorghum, and it is a good source of phosphorus and contains small amounts of calcium, iron, thiamine, niacin and fats (Brandes, 1992). Also maize contains appreciable levels of proteins with high levels of the essential amino acids like lysine, isoleucine, methionine and threonine (Adeyemo, 1984).

2.3 Maize Production Systems in Sub-Saharan Africa (SSA)

The cropping systems of maize production in SSA include sole cropping, mixed cropping, intercropping and alley cropping. Mixed cropping is a common practice in most of the small scale farming systems of SSA, including Tanzania (Dixon *et al.*, 2001). Crops intercropped with maize include legumes like beans (*Phaseolus vulgaris*), cowpeas (*Vigna unguiculata*) and soybeans (*Glycine max*); root crops such as sweet- potato (*Ipomoea batatas*), Irish potato (*Solanum tuberosum*) and horticultural crops like watermelon (*Citrullus lanatus*) (Tuaeli *et al*., 2003). In Northern Tanzania, the most common practice is maize - beans mixed cropping system. Beans are intercropped or mixed with maize because it is used as a complement in most local dishes. Other reasons for mixed cropping include maximizing land use, spreading economic and climatic risks and improving soil productivity through biological nitrogen fixation and biomass production (Tuaeli *et al*., 2003).

Intercropping of maize and cowpeas (*Vigna unguiculata*) is especially beneficial in soil will low nitrogen content (Vesterager *et al*., 2008). The cowpeas make use of the N in the atmospheric through the process of biological N-fixation (BNF), they do not vigorously compete with maize and other crops for the nitrogen in soils. Intercropping of maize and cowpeas is more economical than maize monocropping when phosphate fertilizers are not applied as compared with applications of 30 or 60 kg P ha^{-1} (Mongi *et al*., 1976). Mongi *et al*. (1976) found alternate row intercropping maize and cowpeas to give 34% more monetary return than monocropped maize, while maize and cowpea planted in the same hills had an increase of 29% in monetary returns. Growing of cowpeas in the maize field provides an important protein source for humans and livestock; improves soil fertility, suppresses weeds and insurance against total crop failure when one crop fails (Mongi *et al*., 1976). Maize and sweet potato are a common intercropping combination in the semi-arid Rift Valley of East Africa. Using an early maturing variety of maize would increase total yield over several years as compared with a mid-late maturing variety (Amede *et al*., 2001). Sweet potato yield was significantly reduced in dry years due to inability to tuberise. But intercropping did not reduce sweet potato vines production. Sweet potato vines are commonly used as fodder for livestock. Since the vines are not included in the land equivalent ratio calculations, their use significantly increases the benefits of intercropping maize and sweet potato (Amede *et al*., 2001).

Qureshi (1990) reported maize yields of about 6 t ha^{-1} that were realized when mixed with soybean compared with the yields of 5.1t ha^{-1} in pure stand as reported by Akhtar *et al*. (2010). According to Akhtar *et al*. (2010), mixed cropping of a cereal crop with legumes and incorporation of the legume crop residues improved soil fertility attlibuted to the increase in soil organic carbon in addition to other plant nutrients for the subsequent cropping seasons.

2.4 Maize Production in Tanzania

The maize crop in Africa is produced in diverse environments by resource limited small holder farmers who cultivate/grow self open pollinated seed from one season to the next (Bigirwa *et al*., 2001). Maize in Tanzania is grown almost in all parts of the country, mainly by smallholder farmers contributing to about 85% of the total maize produced (Aloyce *et al.*, 1998). The crop is produced over a wide range of altitudes, from near sea level to about 2400 m above sea level. The crop is produced in almost all ecological zones like Lake, Western, Northern, Southern, Central, Southern highland and Eastern zones. The Southern Highlands alone with land area of about 28% of mainland Tanzania, accounts for more than 50% of total national maize production (Mdadila, 1995). The Ministry of Agriculture provided the trends of the maize production in Tanzania for the period 1994 to 2002 which showed that maize production increased rapidly from 1.5 in 1994 to nearly 3 million tons in 1995 and thereafter decreased to about 2 million tons in 1998. The report by Leliveld *et al.* (2013) specifically insist that; the production trends seemed to increase gradually in all years as from 2000 to 2002 as presented in Fig. 1. This might be due to increased production areas from 790 000 hectares in 1961 to 3 288 000 hectares in 2011 with the increase in production from 590 m/kg to 4,341 m/kg respectively. Then, the yield of the crop has increased 747 kg /ha to 1 320 kg/ha.

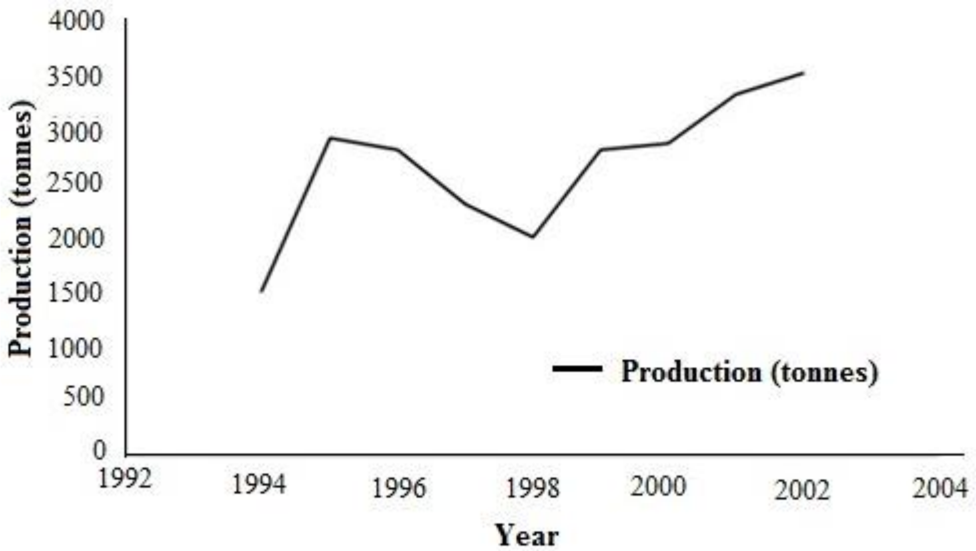

Figure 1: Maize Production Trends in Tanzania (1994 - 2002)

Source: Ministry of Agriculture and food security (MAFC)(2009)

2.5 Maize Production Constraints

Currently, maize production is rapidly spreading into marginal areas, where the soils have low fertility status. This situation has expanded the area of cultivation to marginal maize growing areas/lands with consequent increased risks in maize production (Bigirwa *et al*., 2001) with consequent soil/land degradation.

2.6 Climatic Requirements of Maize

2.6.1 Temperature

Maize is a warm weather crop and optimum temperature for growth is 18 – 32^{0}C (Rowhani *et al*., 2011). Minimum temperature for maize seed germination is 10^{0}C and 21

- 30 ^{0}C is ideal at tasselling stage. Low temperature is really a limiting factor for maize production.The temperature affects both vegetative and reproductive growth stages of maize (node and leaf appearance rate). Vegetative and reproductive growth stages increases as temperatures rise to the optimum level which is 30^{0}C (Marschner 1986). Flowering occurs best at temperatures ranging from 19 to 25^{0}c. Maize pollen viability decreases with exposure to temperatures above 35 °C (Nkonya, 1994). In general, extreme high temperatures during the reproductive stage will affect pollen viability, fertilization, and grain or fruit formation (Hatfield *et al*., 2011). Chronic exposures to extreme temperatures during the pollination stage of initial grain or fruit set will reduce yield potential (Nkonya, 1994).

2.6.2 Rainfall/water requirements

The amount of water during the maize growing period is between 600 and 900 mm in the tropics (Fageria *et al*., 1997). Maize is very sensitive to water deficits at any stage of growth and the damage depends on the growth stage of the crop, the time of stress, the severity and the duration of the stress (Fageria *et al.*, 1997). Adequate moisture is required for maize seed emergence. According toJoseph *et al.* (2009), maize seeds begin germination when the seed contains at least 30% moisture. However, pollination, silking and grain filling stage constitute the most sensitive stages and when a dry period is experienced during those stages can lead to a total loss of the harvest (Fageria *et al*., 1997). According to Fageria *et al.* (1997), maize requires a quantity of 0.8mm of water per day during its high water demand which is usually at tasselling, silking and grain filling stages. Stress during vegetative growth has an effect on kernel number due to the fact that the size of the ear and number of ovules formed are determined during this stage (Joseph *et al.*, 2009). It has been found that ears per m^2 is reduced by water stress early in vegetative growth, with longer periods of water stress resulting in a fewer ears (Joseph *et al.,* 2009).

2.6.3 Sunlight

Plant leaves absorb sunlight and use it as an energy source in the process of photosynthesis (Joseph *et al.,* 2009). Maize requires 12.5 hours of sunlight per day. A crop's ability to collect sunlight is proportional to its leaf surface area per unit of land area occupied, or its "leaf area index (LAI). At "full canopy" development, a crop's LAI and ability to collect available sunlight are maximized. From full canopy through the reproductive period, any shortage of sunlight is potentially limiting to maize yield.When stresses such as low light limit photosynthesis during ear fill, maize plants remobilize stalk carbohydrates to the ear. This may result in stalk quality issues and lodging at harvest.The most sensitive periods of crop growth (e.g., flowering and early grain fill) are often the most susceptible to stresses such as insufficient light, water or nutrients (Joseph *et al.*, 2009).

2.6.4 Soils

Maize grows on a great variety of soil types; however, fertile, deep, naturally rich and medium to coarse textured and easily tilled soil is preferred (Fageria *et al*., 1997). The soil should be free from restrictive layers (hardpan) and soils with a pH of 6-8 are preferable. Maize does not do well in acidic soils. Aluminum toxicity could become a problem on soils with pH less than 5.0 (Al > 40%). Maize is moderately sensitive to salinity, which reduces uptake of nutrients and decreases total dry matter production. The most suitable soil type for maize production is a soil with a good effective depth, favorable physical properties (especially texture and structure), good internal drainage, and optimal moisture regime and sufficient and balanced quantities of plant nutrients

2.7 Fertilizer Recommendations for Maize in the Tropics

In tropical countries, fertilizer recommendation for N, P and K are variable. Western part of Kenya N range from 20 – 50 kg N ha^{-1}, P between 20 – 50 kg P ha^{-1} while K to be 13 kg K ha^{-1}(FAO – STATISTICS, 2004). In Uganda, a recommended dose for high yield is 50 – 90 kg N ha^{-1}, 17 – 26 kg P ha^{-1} and 16 – 33 kg K ha^{-1} and in some areas Potassium is not applied (Oluoch – Kosura *et al.*, 1999). In Ethiopia, some part of Adigudom, the fertilizer recommendation is 90 kg N ha^{-1}, 93 kg P ha^{-1}; Maychew 115 kg N ha^{-1}, 65 kg P ha^{-1} ; Adwa 98 kg N ha^{-1}, 70 kg P ha^{-1}, Wobro 111 kg N ha^{-1}, 57 kg P ha^{-1} and Shire 106 kg N ha^{-1} and 95 kg P ha^{-1} (Fassil and Charles, 2009). In general, Ethiopian soils have high levels of potassium as they do not show responses to applied K in maize production (Fassil and Charles, 2009). In Minnesota, a recommended dose required for high yield in loamy fine sand soil is 80 – 100 kg N ha^{-1}, 17 – 26 kg P ha^{-1} and 16 – 33 kg K ha^{-1} and in some areas, Potassium is not applied (George, 2006). While in Thailand, fertilizer recommendation is 100 – 125 kg N ha^{-1}, 10.8 – 27.3 kg P ha^{-1} and 29 – 43 kg K ha^{-1} and in some areas phosphorus is not applied (Russel and Tasnee, 2006). In Nigeria, a recommended dose required for high yield in maize is 90 – 120 kg N ha^{-1}, 10 – 26 kg P ha^{-1} and 16 – 33 kg K ha^{-1} and in some areas K is not applied (Oluoch-Kosura *et al*., 1999). Also in the case of Malawi the recommendations are based upon four rates of fertilizer. These are the kilograms of nitrogen: phosphate: potassium + sulphur (S) applied per hectare in the fertilizer. The most common recommendation if producing for home consumption is 92:21:0+14, while 35:10:0+12 is the general recommendation when growing maize for the market (Benson, 1999). In Tanzania, fertilizer recommendations are based on the agro – ecological zones such as Southern zone of Tanzania are 17 kg P $ha^{-1}$and 60 – 100 kg N ha^{-1}. Northern zone is 20 - 40 kg P ha^{-1} and 20 – 50 kg N ha^{-1}, Eastern zones 8.7 – 17 kg P ha^{-1} and 60 –100 kg N ha^{-1} and the Lake zones are 17 – 26 kg P ha^{-1} and 80 – 100 kg N ha^{-1} (Kanyeka *et al.*, 2007).

2.8 Nutrient Requirement for Maize Crop

Maize requires at least 17 nutrients for normal growth and for completion of its life cycle. Those used in the largest amounts include carbon, hydrogen and oxygen and are supplied by air and water. The other 14 nutrients are taken up by plants only in mineral forms from the soil or must be added to the soils as fertilizers. Maize needs relatively large amounts of nitrogen (N), phosphorus (P) and potassium (K). These nutrients are referred to as primary nutrients because usually are lacking from the soil first and plants use large amounts for their growth and survival. They are frequently supplied to plants as fertilizers. Secondary nutrients are usually enough nutrients in the soil so fertilization is not always needed; these are calcium (Ca), magnesium (Mg) and sulfur (S). Other nutrients essential for maize plant growth which are needed in only very small quantities, are called micronutrients include iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (Bo), molybdenum (Mo), chlorine (Cl) and nickel (Ni) (Johnson *et al*., 2000).

2.9 Response of Maize to N and P Containing Fertilizers

Decline in soil fertility is considered as a major limiting factor to achieving household food sufficiency in the majority of smallholder farming systems in SSA (Okalebo *et al*., 2007). Declining maize productivity is partly attributed to low plant populations, higher incidences of pest and disease pathogens, weed infestations which are correlated to a number of soil related bio-physical limitations (Jama *et al*., 1997). Continental, district (Smaling *et al*., 1997) and farm (Shepherd *et al*., 1996) scale studies showed widespread deterioration in soil chemical, biological and physical properties in most smallholder cropping environments. These studies further revealed negative nutrient balances such as N > 46 kg ha^{-1} and P > 3 kg ha^{-1} in most countries in SSA, with average N mining in some parts of western Kenya estimated at up to 112 kg N ha^{-1} (Bekunda *et al*., 1997).

Despite numerous studies that gave positive maize crop yield responses to mineral N and P containing fertilizer additions, fertilizer costs versus revenue from maize sales prohibit their use in smallholder cropping systems which are largely subsistence (Odendo *et al*., 2007). However, integration of modest amounts of inorganic fertilizers with organic amendments such as manures or nutrient rich legume residues, offers a strategy to meet smallholder maize crop nutrient requirements (Jama *et al*., 1997).

2.10 Assessment of Nutrient Status in Maize by Plant Analysis

Plant analysis is based on the relationship between nutrients in the plant and nutrients availability in the soil. Since a nutrient shortage limits growth, other nutrients may accumulate, regardless of their supply. Plant analysis are performed for the following reasons: (1) to identify deficient symptoms and to determine nutrient shortage before they appear as symptoms, (2) to aid in determining the nutrient supplying capacity of the soil (employed in conjunction with soil tests and management history), (3) to aid in determining the effect of nutrient additions on the nutrient supply to the plant and (4) to study the relationship between nutrient status of the plant and crop performance (Halvin *et al*., 2005). Generally, plant analysis includes extraction of cell sap, nutrient extraction using chemical reagents and total plant material analysis for the quantification of the nutrients in the plant.

2.11 Nutrient Uptake and Concentration

The pattern of nutrient uptake follows a sigmoid (S – shaped) curve in most cases, being first low in the early stages of crop growth, increasing rapidly when dry matter production is maximum and then declining towards crop maturity (Roy *et al*., 2006). Usually N, P and K are mainly taken up during active vegetative growth for high photosynthetic activity. The rate of N uptake generally exceeds the rate of dry matter production in the early stages. Phosphorus has an additional small peak requirement for early root growth and modern high – yielding grain varieties continue to absorb P close to maturity. Like N, 70 – 80 % of absorbed P ends up in the ear heads or panicles (Roy *et al*., 2006). It has been reported that field crops generally absorb K faster than they absorb N and P. Unlike N and P, only 20 – 25 % of absorbed K is transferred to the grain and the rest remaining in the straw (Roy *et al*., 2006). During the final stages of growth, and as the plant approaches its reproductive phase before maturity, nutrient uptake decreases. However, the highest concentration of nutrients is found in leaves at early growth stages and the lowest in leaves near harvest. This decrease in nutrient concentration over time is attributed to the transfer to other organs and also what is called the dilution effect, which results from a larger increase in dry matter than in nutrients content (Roy *et al*., 2006). The dilution effect makes the interpretation of plant analysis results difficult as reported by Roy *et al*. (2006). Mohd *et al*. (2007) reported that the nutrient uptake and concentration in leaves depend on the fertilizer types applied and the nutrient available in soil for plant uptake. In their experiment, sole application of 100% inorganic fertilizer and their combination with compost at different rate (80% N inorganic + 20% N from compost, 60% N inorganic + 40 N from compost) resulted in high N concentration in maize leaves significantly different from the control.

2.12 Maize Yield and Yield Components

Average grain yields of maize vary substantially among the temperate, subtropics and tropical regions. According to Fageria *et al*. (1997), a maximum yield of 22, 12 and 10 t ha-1 has been reported from experiments in Michigan, Zimbabwe and Kenya respectively. Low maize yield have been attributed to several reasons including drought and nutrient stresses (Senkoro *et al*., 2006), inadequate pest control measures and the use of poorly adapted cultivars with low potential (Fageria *et al*., 1997). Low grain yield of most tropical maize cultivars have also been attributed to short growth period and poor partitioning of total dry matter to the grain (Fageria *et al*., 1997). Researchers such as Odongo and Bilaro (1980, 2008) reported that maize yields are positively correlated with seed weight, seed number per cob, cob length, cob girth and ear number per plant. Further, Odongo *et al*. (1980) and Bilaro (2008) reported also that maize grain yield is correlated to plant height; days to 50% pollen shed and 50% silking. Fageria *et al*. (1997) reported that large differences in maize grain yield are usually the result of the fluctuation in grain number while grain weight is the most stable yield component.

CHAPTER THREE

3.0 MATERIALSAND METHODS

3.1 Location of the Study

The research was conducted at Miwaleni in Koresa village, Kirua vunjo ward,Moshi rural district inKilimanjaro region. The Miwaleni site, located in Moshi rural district at 3º 25´ 30´´S and 37º 26´ 45´´ E, represents low altitude agro-ecological zones with altitudes of 720 meters above sea level (m.a.s.l). This site is characterized by relatively low annual precipitation (500–700 mm/year), low to medium relative humidity (56–71%), and relatively high temperatures ranging (10–39˚C). However, seasonal distributions of rain can be very sporadic with 48% of the rain falling towards the end of the growing season giving little advantage to crop growth and yield (Sadiki *et al.,* 2009). Soils are diverse but dominated by highly weathered tropical soils with pH of 5.2 (Meliyo *et al.,* 2014).

3.2 The Field Experiment

3.2.1 Land preparation

Land ploughing and harrowing activities were done by tractor during the third week of October 2017. The condition was dry enough to hinder sprouting of many weeds prior to planting and for proper pulverization of the soil to get the seed bed fine enough for the establishment of maize crop.

3.2.2 The experimental design and treatments

The first experiment was conducted as split plot design in randomized complete block layout replicated three times. Factor (a) was main plot with three levels which were maize varieties (*Situka* MI, *Meru* HB 513 and *Faru* HB) while factor b, constisted three levels that were fertilizers types namely; DAP at 62 kg P ha^{-1}, *Minjingu Mazao* at 71 kg P ha^{-}

[1]and NPK Cereal at 124 kg P ha^{-1} and absolute control (without fertilizers). Each main plot was subdivided into four sub plots of size being 3m x 12m = 36m^2, the distance between sub plots was 1m, one main plot has the length of 48m and width of 3m,the distance between main plot/blocks was 1 m,so the length of a replication was (36 m^{2}x 4 x 3) + 11m = 443 m^2, this makes replication area to be (443 m x 3 m) + 2m = 1331m^2.

3.2.3 Subplot treatment per replication

Subplot treatments at the site were designated as shown below:

V_1F_1	V_2F_1	V_3F_1
V_1F_2	V_2F_2	V_3F_2
V_1F_3	V_2F_3	V_3F_3
V_1F_4	V_2F_4	V_3F_4

The second experiment was conducted as split split plot design in randomized completete block layout replicated three times. During seedbed preparation, each sub plot was subdivided into four sub sub plots each plot size being 3m x 3m = 9m^2, the distance between subsub plots was 1m, one sub sub plot has the length of 3m and width of 3m,so the length of a replication was (9m^2 x16 x 3) + (15m x 3) + 2m = 479m^2, this makes replication area to be (479 m x 3 m) + 2m = 1 439m^2.

3.2.4 Sub- sub plot treatment per replication

$V_1F_1N_1$	$V_1F_1N_2$	$V_1F_1N_3$	$V_1F_1N_4$	$V_1F_2N_1$	$V_1F_2N_2$	$V_1F_2N_3$	$V_1F_2N_4$
V_1 F_3N_1	$V_1F_3N_2$	$V_1F_3N_3$	$V_1F_3N_4$	$V_1F_4N_1$	$V_1F_4N_2$	$V_1F_4N_3$	$V_1F_4N_4$
$V_2F_1N_1$	$V_2F_1N_2$	$V_2F_1N_3$	$V_2F_1N_4$	$V_2F_2N_1$	$V_2F_2N_2$	$V_2F_2N_3$	V_2 F_2N_4
$V_2F_3N_1$	$V_2F_3N_2$	$V_2F_3N_3$	$V_2F_3N_4$	$V_2F_4N_1$	V_2 F_4N_2	V_2 F_4N_3	V_2 F_4N_4
$V_3F_1N_1$	$V_3F_1N_2$	$V_3F_1N_3$	$V_3F_1N_4$	$V_3F_2N_1$	$V_3F_2N_2$	$V_3F_2N_3$	$V_3F_2N_4$
V_3F_3 N_1	$V_3F_3N_2$	$V_3F_3N_3$	$V_3F_3N_4$	$V_{34}N_1$	V_3 F_4N_2	V_3 F_4N_3	V_3 F_4N_4

3.3 Experimental Materials

The test crop in this study were maize varieties *Situka* MI, *Meru* HB 513 and *Faru* HB, drought resistant, tolerant to maize streak virus and leaf blight and rust and suited to areas with altitude 720 m.a.s.l, rainfall 500 - 700 mm and medium to light, fertile and well drained soils (Kanyeka *et al*., 2007). Agronomic characteristics of *Situka* MI, *Meru* HB 513 and *Faru* HB maize varieties are grain yield of 4.5 t ha^{-1}, 90 days to maturity, 6.0 – 7.0 t ha^{-1}, 100 days to maturity and 6.0 – 7.0 t ha^{-1}, 105 days to maturity respectively. Kanyeka *et al*. (2007). The fertilizer used were *Minjingu Mazao* (N10%, P_2O_5 20%, S 5%, Zn 0.5%, B 0.1%, Cao 17.4%, MgO 1.9%), DAP(N18%, P_2O_5 46%), NPK cereal (23-10-5 + 2MgO +3 S + 0.3 Zn), Urea (46% N) to supply N.

3.4 Irrigation

Before planting, irrigation was done by splinker methodon 17th November 2017 to attain moisture for germination of maize seeds. According toJoseph *et al.* (2009), maize seeds begin germination when the seed contains at least 30% moisture.

3.5 Planting

Planting was done on 20th November 2017. Two seeds were planted per hole, and thinned to one seedling seven days after emergence.

3.6 Fertilizer Application

Minjingu Mazao at 71kg P ha^{-1}, DAP at 62 kg P $ha^{-1,}$ and NPK Cereal at 124 kg P ha^{-1} were applied as a source of P. Along with phosphatic fertilizers application, one third of nitrogen as starter dose contained in these fertilizers was also applied. Nitrogen fertilizer Urea (CO $(NH2)_2$) was applied as top dressing in two splits: First dose of N was applied 21 days after planting, and second dose just before tasselling. The split application was done for effective utilization of N by plants to avoid excessive leaching.

3.7 Crop Management Measures

Weeds such as love grass (*Eragrostis curvula*), Blackjack (*Bidens Pilosa*), and Star grass (*Cynodon dactylon*) were controlled by hand hoe weeding.Two weeding operations were done where by first weeding was done at 21 days after plantingand the second before tasseling. Other agronomic practices such as irrigation, was done by using drip method as described by Kanyeka *et al*. (2007). Fall army wormpest was controlled by using insecticide (Belt SC 480) at the rate of 250mls ha^{-1}using knapsack, from vegetative fourth leaf tovegetative tasselling growth stages at weekly interval.

3.8 Data Collection

3.8.1 Soil sampling, preparation and analysis

Composite soil samples from the field experimental site were sampled at 0 - 30 cm depth by using soil auger 2 month before planting. Soil samples were obtained randomly in the experimental field using the method described by Kimaro (2009) and each composite soil samples was prepared from 6 point samples from the site. The composite samples were packed, labeled and taken to the Department of Soil Science Laboratory at SUA for physical and chemical analysis. Soil samples were air-dried, ground, sieved through 2 mm sieve and analyzed for particle size distribution, pH, total Nitrogen (N), available P, Cation Exchange Capacity (CEC), Exchangeable Bases (Ca, Mg, K and Na), extractable micronutrients and Organic Carbon using the analytical methods as outlined in Table 1.

Table 1: Methods Used in Chemical and Physical Analysis of the Composite Soil Sample

Parameter	Method of Analysis	References
Soil texture	Bouyocous hydrometer.	Gee and Bauder (1986)
pH	Electrometrically in 1:2.5, soil: 0.01M $CaCl_2$ suspensions.	Thomas (1996)
Organic Carbon	Wet oxidation by Black Walkley method.	Nelson and Sommers (1982)
Total Nitrogen	Micro Kjedahl method.	Bremner (1996).
Available Phosphorus	Bray 1 method.	Olsen and Somners (1982)
CEC	Saturation with buffered neutral 1M NH_4-Ac solution (CH_3COONH_4)	Rhodes (1982)
Exchangeable Bases (K^+, Mg^{2+}, Ca^{2+} and Na^+)	NH_4^+ displacement method and quantified by AAS.	Lindsay and Norvel (1978)
Extractable micronutrients (Fe, Cu, Zn and Mn)	DTPA extraction and quantified by AAS.	Lindsay and Norvel (1978)

3.8.2 Weather data

Weather data (temperature maximum and minimum (^{0}C), rainfall (mm), and relative humidity (%) were collected from Tanzania Meteological Agency (TMA) at Uchira sub station in daily basis.

3.8.3 Plant height (cm)

The heights of 5 randomly selected maize plants were measured from the ground level to the tip of the terminal leaf by using a tape measure at vegetatibe fourth leaf (V4), vegetative tasselling (VT), reproductive dough stage (R4), and physiological maturity (R6) and at harvest maize growth stages.

3.8.4 Days and date of different crop growth stages

Days and date of planting, crop emergence, fourth leaf stage,firsttasselling, 75% tasselling, silking stage, physiological maturity, days to anthesis, days from emergence to physiological maturity and harvest were recorded.

3.8.5 Leaf area(A)and Leaf area Index (LAI)

Leaf area was measured by taking the length and width of a leaf and using weighted regression equations to get the leaf area as per Hunt *et al.* (2002)

Leaf area (A) = length (L) x width (W) x leaf shape coefficient (K)…………….(i)

Leaf area Index was determined by calculating total leaf area divide by unit land area using the formula as per Hunt *et al.* (2002).

Leaf area index (LAI) = Total leaf area/Unit land area……..……………..……..(ii)

3.8.6 Total dry matter (g/m^2)

Total dry matter per metre square at V4, VT, R4, R6 and at harvest stages was determined by measuring the fresh weight of 5 randomly plants samples that were cut at the surface of the soil.The samples were dried at 70° C for 48 hours to attain constant weight. The following formula was used to calculate total dry matter according to Hunt *et al.* (2002).

Total dry matter = Total fresh weight - (Total fresh weight x % MC)………..……(iii)

Where %MC = (Fresh weight – Dry weight) / (Fresh weight) x 100 ……………..(iv)

Growth and development characteristics data such as crop growth rate, relative growth rate and Net assimilation rate were calculated according to Hunt *et al.* (2002)

Crop growth rate was determined using the following formula as per Hunt *et al.*,(2002).

Crop growth rate (g/m^2/day) = $(W_2 – W_1) / P(t_2 – t_1)$ ………………………..………(v)

Where P = ground area

t_1& t_2 = the interval time (days)

W_1 = dry weight of plant in plants/m^2 at time t_1

W_2 = dry weight of plant in plants/m^2 at time t_2

Relative growth rate was determined by using the formula as per Hunt *et al.* (2002)

Relative growth rate (g/g/day) =(1/W) X (Change in w/ change in t)…………………..(vi)

Where W = Total dry weight

Change in w = Dry matter increase amount

Change in t = Time difference

Net assimilation rate was determined by using the formula as described by Hunt *et al.* (2002)

Net assimilation rate = crop growth rate/LAI……………….…………………..……(vii)

3.8.7 Sampling and analysis of plant materials

Before tasselling, 5 ear-leaves from inner rows per plot were randomly sampled and air-dried then oven-dried at 70° C to constant weights. The samples were then cut to small pieces and ground to pass through 0.5 mm sieve and were analyzed for N, P, K, S, Ca, Mg, Zn and B contents. Nitrogen contents in the maize plants leaves were determined by the micro – Kjeldahl digestion and distillation method (Bremner, 1996). Phosphorus contents in the maize leaves were determined by wet digestion with H_2SO_4 - H_2O_2, and phosphorus content from H_2SO_4 - H_2O_2 digests were quantified by calorimetric method. Zinc was determined using Atomic Absorption Spectroscopy at 213.9 nm. K, Mg, Ca, S,and Boron were determined using a flame spectrophotometer at 768 nm.

3.8.8 Nutrient uptake (%)

The uptake of a particular nutrient wasdetermined per plant according to Moberg (2000) by using the following equation;

Nutrient uptake (Kg ha^{-1}) = Nutrient content (%) x Dry matter yield (Kg ha^{-1})/100 …(viii)

3.8.9 Yield and yield components

Maize yield was determined by harvesting and threshing maize after attaining moisture content of 15%. Ten maize cobs were harvested, sun-dried, threshed manually and grain yield and yield components such as plants/m^2, number of grains per cob, grain weight per plot, cob length, 1 000 grain weight were recorded. Maize grain yield were obtained at moisture content of 12% which were then converted into t ha^{-1} by using the following formula as described by CIMMYT (2013).

$$\text{Grain yield (t ha}^{-1}\text{)} = \frac{\text{Plot yield (kg) x 10000 m}^2}{\text{Plot size (m}^2\text{) x 1000 kg}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(ix)}$$

3.8.10 Data analysis

For objective I and 2, the data collected for each variable were analyzed by the analysis of variance using Gen STAT Discovery Inc. Version 15th (2012). The statistical model for split plot design is given below:

$$Y_{ijkm} = \mu + \beta_i + A_j + \sigma_{ij} + B_k + BC_{km} + E_{ijkm} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(x)}$$

Where

Yijkm = Response, μ = General effect, βi = Replication or block effect, A_j = Main factor effect,σ_{ij}= Main plot random error effect, B_k = Subplot factor effect , BC_{km} = Interaction effect, Eijkm = Subplot random error effect.

Mean separation was done by using Tukey's Honestly Significant Difference (HSD) test at $P \leq 0.05$.

For objective 3, the data collected for each variable were analyzed by the analysis of variance using Gen STAT Discovery Inc. Version 15th (2012). The statistical model for split split plot design is given below:

$Y_{ijkm} = \mu + \beta_i + A_j + \sigma_{ij} + B_k + AB_{ik} + (f)_{ijk} + C_m + AC_{im} + BC_{km} + ABC_{jkm} + E_{ijk}$............(xi)

Where; Y_{ijkm} = Response, μ = General effect, βi = Replication or block effect, A_j = Main factor effect, σ_{ij}= Main plot random error effect, B_k = Subplot factor effect, AB_{ik} = Interaction effect for factor A and B, $(f)_{ijk}$ = Subplot random error effect, C_m = Sub sub plot factor effect, AC_{im} = Interaction effect for factor A and C, BC_{km} = Interaction effect for factor B and C, ABC_{jkm} = Interaction effect for factor A, B and C, E_{ijk} = Sub sub plot random error effect,

Mean separation was done by using Tukey's Honestly Significant Difference (HSD) test at $P \leq 0.05$.

Simple Correlationswere analysed ($P \leq 0.05$) between yield components and yield to observe the relationships.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The soil physical and chemical properties are shown in Table 2. As indicated the soils at the site are sandy clay loam (Sand 67%, Clay 26%, Silt 7%). According to Landon (1991), these soils are appropriate for most crops due to moisture retention capacity.

Table 2: The physical and chemical properties of soil at the experimental site

Parameter	SI Unit	Value	Rating
Particle size distribution (%)			
Clay	%	26	
Silt	%	7	
Sand	%	67	
Textrural class			Sandy clay loam
pH		6.1	moderately acidic
Soil organic carbon		1.2	Very low
Soil Organic Matter (%)	%	2.00	Low
Total Nitrogen (%)	%	0.04	Very low
Available P (mg kg-1)	mg/kg	10.6	Low
CEC (cmol (+) kg^{-1})	(cmol (+) kg^{-1})	8.10	Low
Exchangeable bases	cmol (+) kg^{-1}		
Ca	cmol (+) kg^{-1}	1.11	Very Low
K	cmol (+) kg^{-1}	0.01	Low
Mg	cmol (+) kg^{-1}	0.01	Low
Na	cmol (+) kg^{-1}	0.17	Low
DTPA extractable micronutrients (mg kg-1)			
Zn	mg/kg	0.79	Low

4.1 Soil pH

The soil pH value was 6.1 (Table 2). According to Timbula (2003), this pH favours maize production due to availability of macronutrients and micronutrients.According to Bianchini and Mallarino (2002), a pH of 6 – 7 resulted to increase of maize yield in the experiment conducted at Ohio state university. However, if proper management practices like supplementing with fertilizers containing N, P and addition of organic materials can support maize production.

4.2 Total Nitrogen

The result for total N in soil is presented in (Table 2). The value of total N in the soil sample was 0.04%. The level of total N was observed to be very low in the soil sample. The low Nitrogen content could be attributed to the low organic matter content following higher rates of organic matter transformation in the respective soils. The transformation processes include, decomposition, mineralization and oxidation of the organic compounds, which normally takes place in tropical soils, at high rates because of the high temperatures and humidity, hence higher microbial activities (Timbula, 2003). The low level of N therefore can hardly support plant growth and development. Therefore, application of N fertilizers to these soils (organic/inorganic) for increased crop production is inevitable.

4.3 Available Phosphorus

Available phosphorus is presented in (Table 2). The results indicated that the P– value was 10.60 mg kg^{-1}. Landon (1991) rated P ranges as 10 – 15 mg kg^{-1}as low. This shows that P level in the study site was low.The low levels of P in the soils could probably be due to low levels of P in the parent materials of the soils and conversion of soil P into forms not easily extractable by the Bray-1 reagents (Eliuth, 2004). Further, P is deficient in most agricultural soils under subsistence and smallholder farming systems due to continuous uptake of the P by plants and lack or low rates application of P containing fertilizersKisetu and Honde (2014). Furthermore, It could also be argued that the low contents of P might be one of the limiting factors for high maize production in the study areas. The need for P fertilization to increase and sustain maize production in the study area is thus mandatory.

4.4 Exchangeable Potassium

Exchangeable K level in the soil sample is presented in (Table 2). From the study area, K was very low in the soil. Since maize requires 60 kg K ha^{-1} ha according to Maghehema *et al*. (2014) in order to optimize maize yield, potash fertilizer is required in this research for optimization of yield.

4.5 Soil Organic Carbon

The organic carbon (OC) contents in soil was 1.2% (Table 2) and categorized as very low . The low levels of OC is a reflection of low soil organic matter (OM) that migtht be attributed by high rate of decomposition, mineralization and oxidation of organic residues (Landon, 1991). Soil organic matter plays a number of roles in the soil. It influences many soil biological, chemical and physical properties that influence nutrient availability (Tisdale *et al*., 1993). It acts as a conditioner by improving soil structure, moisture and ion retention besides being an important source of nutrients elements (Uriyo *et al*., 1979).

4.6 Cation Exchange Capacity

Results on CEC in the soil are shown in (Table 2). The value of CEC was 8.10 cmolc (+)/kg in the soil sample which is low. This is related to the low organic matter content which leads the soils to be marginally suitable for maize productionUriyo *et al.* (1979). Organic matter is known for its contribution to pH dependent charges which improve ion retention (Uriyo *et al.*, 1979).

4.7 Ca, Mg and Micro Nutrients

The results for Ca, Mg, Na, and Zinc in the soil are presented in (Table 2). Since the results indicated low values of Ca, Mg, Na, and Zn and all these are contained in *Minjingu Mazao* and NPK cereal fertilizers, it is advised in order to increase maize yield in this area, fertilizers such as *Minjingu Mazao* and NPK cereal which contains these nutrients should be applied at recommendedrate in the study area.

4.8 Weather

Results for weather condition is shown in Figure 1. Weather conditions in Miwaleni resultedtoaverage temperatures within the normal range with varied levels of precipitation. According to Sadiki *et al.* (2009), the minimum temperature ranged from 21^0C to 22^0C, while maximum temperature ranged from 32^0C to 33^0C and was within the preferred range for maize production. Precipitation was inadequateand observed in December (20mm), February (20 mm) and March (20 mm) while in November and January recorded 0mm. Such conditions were supplemented with irrigation water during the crop growth after observing signs (leaf wilting) of water deficit. Relative humidity ranged from 52 – 64% and accordingSadiki *et al.* (2009), was within the preferred range for maize production.

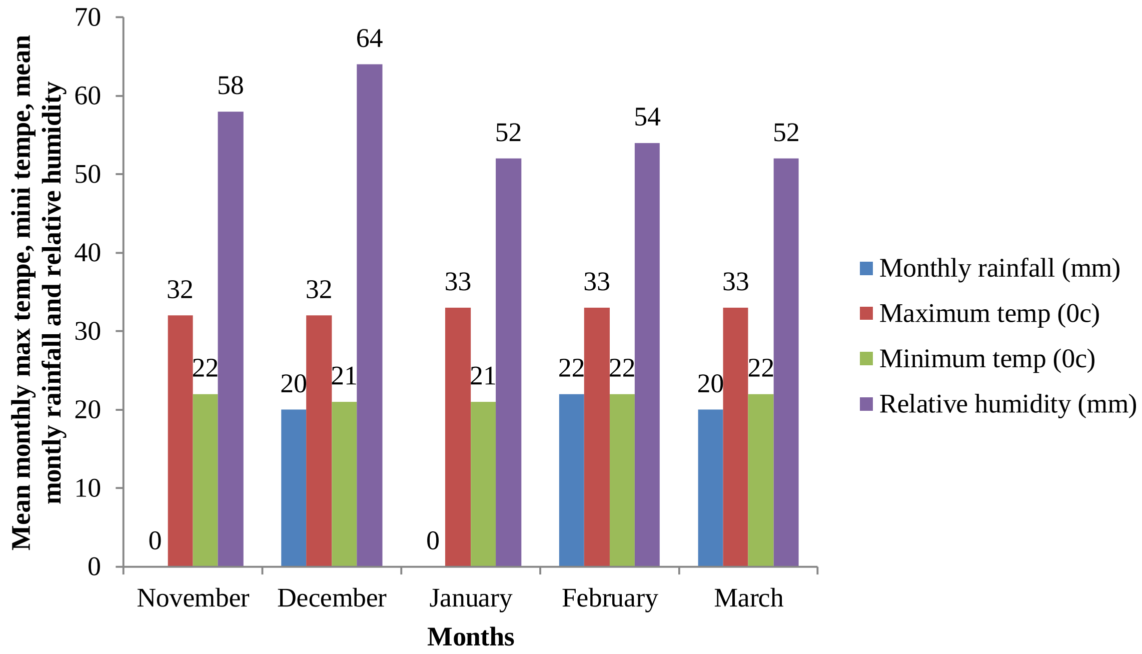

Figure 2: **Minimum and maximum temperatures, rainfall, and relative humidity recorded during the period of maize growth (November 2017 – March 2018)**

4.9 Days and Date to Different Crop Growth Stages

Days and date to various growth stages are indicated in Table 3 and were recorded as described by Hanway (1963). Days from planting to physiological maturity was 97 days. These are in agreement with Kitenge *et al.* (2004) who indicated similar findings for improved maize varieties in a survey conducted in northern Tanzania.

Table 3: **Days and date to different crop growth stages.**

Growth stage	Days	Date
Planting (V_0)	0	20/11/2017
Crop emergence (V_E)	7	26/11/2017
Fourth leaf (V_4)	21	10/12/2017
First tasseling (V_T)	51	9/1/2018
75% tasseling (V_T)	58	15/2/2018
Silking (R_1)	63	20/2/2018
Physiological maturity (R_6)	97	27/2/2018

4.10 Performanceof Maize Varieties Based on Growth and Development Characteristics Under Influence of N and P Fertilizers

4.10.1 Effect of maize varieties on days to 75% tasselling, days to silking and days to physiological maturity

Days to different growth stages are indicated (Table 4). There was no significant difference on days to 75% tasseling (P≤0.510), days to silking (P≤0.491) and days from emergence to physiological maturity (P≤0.491) among maize varieties as indicated in Table 4.

Table 4: Effect of maize varieties on days to 75% tasselling, days to silking and days to physiological maturity

Treatments	**DAT**	**DTS**	**EPM**
Situka M1	58.96 a	63.96 a	90.33 a
Meru HB513	58.19 a	63.19 a	97.08 a
Faru HB	58.15 a	63.12 a	97.29 a
Mean	58.40	63.42	94.9
SD	0.337	0.222	0.355
CV (%)	0.6	0.4	0.4
P value	0.510	0.491	0.679

Means followed by the same letters in the same column are not significantly different (P=0.05) according to Tukey's HSD test. Key: DAT (%) = Days to 75% tasselling DTS = Days to silking; EPM = Days from emergence to physiological maturity.

4.10.2 Effect of N, P fertilizers on days to 75% tasselling, days to silking and days to physiological maturity

Significant differences (P≤.001) were observed among N, and P containing fertilizers on days to 75% flowering of maize varieties at the site (Table 5). Early tasseling was recorded to the plots where DAP, *Minjingu Mazao* and NPK Cereal fertilizers were applied, while late tasselling was recorded from control (without fertilizers). Since

Minjingu Mazao contain N10%, P_2O_5 20%, S 5%, Zn 0.5%, B 0.1%, CaO 17.4%, MgO 1.9%), DAP contain DAP (N18%, P_2O_5 46%), and NPK cereal contain (23-10-5 + 2 MgO +3 S + 0.3 Zn). This might be attributed due to bumper growth of plants on account of more nitrogen availability and other nutrients such as P, K, Ca, Mg, S, Zn and B. Similar results were reported by Cock *et al*. (1992) that, sufficient nitrogen results in rapid growth and hastened tasseling, while too little or no N, resulted in slow growth and delayed tasseling.Interaction between maize varieties and fertilizers on days to 75% flowering were not significant ($P \leq 0.992$) (Table 6).

Similarly, response of maize to N and P applications on days to silking are presented in (Table 5). There are was significance difference ($P \leq .001$) on days to silking due to application of N and P containing fertilizers.Plots treated with DAP, *Minjingu Mazao* and NPK cereal gave minimum days (64.28, 63.61, 63.28 respectively) to silking compared to control that gave maximum (65.19). This might be due to succulent vegetative growth of the plant. These are in agreement with findings by Fageria*et al*.(2002) who reported Positive relations between N, P, K containing fertilizers for vigorous growth and improving crop yields and maturity.

Also, Response of maize to N and P applications on days to physiological maturity are presented in Table 5. There are was significance difference ($P \leq .001$) of maize varieties on days to physiological maturity due to application of N and P containing fertilizers as indicated in Table 5. These are in agreement with findings by Fageria *et al.* (2002) who reported Positive relations between N, P, K containing fertilizers for vigorous growth and improving crop yields and maturity.

Table 5: Effect of N, P fertilizers on days to 75% tasselling, days to silking and days to physiological maturity

Treatments	DAT	DTS	EPM
Control	59.19 b	65.19 b	98.81 b
DAP	58.28 ab	64.28 ab	95.25 a
Minjingu Mazao	58.64 a	63.61 a	95.44 a
NPK Cereal	58.28 a	63.28 a	95.44 a
Grand Mean	58.60	64.08	96.24
SD	0.838	0.828	0.607
CV (%)	1.6	1.5	0.6
P Value	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P=0.05) according to Tukey's HSD test. Key: DAT (%) = Days to 75% tasselling; DTS = Days to silking; EPM = Emergence to physiological maturity.

4.10.3 Effect of interaction between maize varieties and N, P fertilizers on days to 75% tasselling, days to silking and days to physiological maturity

The interaction results between maize varieties and N, P containing fertilizers are presented (Table 6). There was no significant differenceon days to 75% tasseling ($P \leq 0.993$), days to silking ($P \leq 0.992$) and days from emergence to physiological maturity ($P \leq 0.771$) as indicated in Table 6.

Table 6: Effect of interaction between maize varieties and N, P fertilizers on days to 75% tasselling, days to silking and days to physiological maturity

Treatments	**DAT**	**DTS**	**EPM**
Situka x Control	58.92 a	64.92 a	99.00 a
Situka x DAP	58.17 a	64.17 a	95.25 a
Situka x Minjingu Mazao	57.58 a	63.58 a	95.25 a
Situka x NPK Cereal	57.17 a	63.17 a	95.83 a
Meru 513 x Control	59.50 a	64.75 a	98.00 a
Meru x DAP	58.42 a	63.88 a	95.25 a
Meru x Minjingu Mazao	57.67 a	63.25 a	95.25 a
Meru x NPK Cereal	57.17 a	63.17 a	95.25 a
Faru x Control	59.17 a	65.17 a	98.83 a
Faru x DAP	58.25 a	64.25 a	95.25 a
Faru x Minjingu Mazao	57.67 a	63.58 a	95.83 a
Faru x NPK Cereal	57.50 a	63.50 a	95.25 a
Grand Mean	58.09	63.94	96.24
SD	3.531	3.529	1.313
CV (%)	6.6	6.3	3.3
P Value	0.993	0.992	0.771

Means followed by the same letters in the same column are not significantly different (P=0.05) according to Tukey's HSD test. Key: DAT (%) = Days to 75% tasselling; DTS = Days to silking EPM = Emergence to physiological maturity.

4.10.4 Effect of maize varieties on plant height

Effect of maize varieties on plant height are shown in (Table 7). There was siginificance difference ($P \leq .001$) of maize varieties on plant height. *Meru* HB 513, and *Faru* HB varieties gave higher plant height (174.0, 167.5 cm) than *Situka* M1 (151.5 cm). This variation might be due to genetic differences among the varieties (Hossain *et al*., 2011).

Table 7: Effect of maize varieties on Plant height (cm)

Treatments	Plant Height (cm)			
	V_4	V_T	R_4	R_6
Situka M1	46.60 a	151.5 a	151.5 a	151.5 a
Meru HB 513	62.67 b	174.0 b	174.0 b	174.0 b
Faru HB	56.17 b	167.5 b	167.5 b	167.5 b
Mean	55.1	164.3	164.3	164.3
SD	0.58	4.91	4.91	4.91
P Value	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P=0.05) according to Tukey's HSD test.

4.10.5 Effect of N, P fertilizers on plant height (cm) of maize varieties

Results on influence of N, P fertilizers on plant height of maize varieties is indicated in (Table 8). There was a significant differences ($P \leq .001$) of maize varieties on plant height due to application of N and P containing fertilizers at V4, VT, R4, R6, growth stages. However, the influence of nitrogen in combination of P and K greatly influenced the vegetative growth and plant height. Theseresults are in conformity with findings of Bishnu *et al*. (2010) indicated that tallest plant height was recorded when the crop was supplied with recommended dose of N, P, and K along with micronutrients (B, Ca, Mg, S and Zn). This characteristic (Plant height) may be important as always refers as indicator of crop growth in the field.

Table 8: Effect of N, P fertilizers on plant height (cm) of maize varieties

Treatments	**Plant Height (cm)**			
	$\mathbf{V_4}$	$\mathbf{V_T}$	$\mathbf{R_4}$	$\mathbf{R_6}$
Control	42.75 a	154.1 a	154.1 a	154.1 a
DAP	47.17 a	153.3 a	153.3 a	153.3 a
M. Mazao	63.83 b	173.5 b	173.5 b	173.5 b
NPK Cereal	66.83 b	176.5 b	176.5 b	176.5 b
Mean	55.1	164.3	164.3	164.3
SD	0.58	4.91	4.91	4.91
P value	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P=0.05) according to Tukey's HSD test

4.10.6 The effect of interaction between maize varieties and N, P fertilizers on plant height (cm)

Results for interaction between maize varieties and N, P fertilizers are indicated (Table 9). There was significant effect ($P \leq 0.042$) of plant height of maize varieties due to interaction at V_4 growth stage. This might be due to early utilization of N, P fertilizers that were applied during planting, promoted vigorous growth. However, there was no significant differences ($P \leq 0.233$) of plant height due to interaction at V_T, $R_{4,}$ R_6 maize growth stages.

Table 9: The effect of interaction between maize varieties and N, Pfertilizers on plant height (cm)

Treatments	Plant Height (cm)			
	V_4	V_T	R_4	R_6
Situka x Control	34.42 a	145.8 a	145.8 a	145.8 a
Situka x DAP	33.67 a	129.3 a	129.3 a	129.3 a
Situka x M. Mazao	57.67 bc	164.0 a	164.0 a	164.0 a
Situka x NPK Cereal	60.67 bcd	167.0 a	167.0 a	167.0 a
Meru 513 x Control	44.42 ab	155.8 a	155.8 a	155.8 a
Meru x DAP	54.42 b	165.8 a	165.8 a	165.8 a
Meru x M. Mazao	74.42 cd	185.8 a	185.8 a	185.8 a
Meru x NPK Cereal	77.42 d	188.8 a	188.8 a	188.8 a
Faru x Control	49.42 ab	160.8 a	160.8 a	160.8 a
Faru x DAP	53.42 b	164.8 a	164.8 a	164.8 a
Faru x M. Mazao	59.42 bcd	170.8 a	170.8 a	170.8 a
Faru x NPK Cereal	62.42 bcd	173.8 a	173.8 a	173.8 a
Mean	55.1	164.3	164.3	164.3
SD	0.58	4.91	4.91	4.91
CV (%)	1.0	3.0	3.0	3.0
P Value	0.042	0.233	0.233	0.233

Means followed by the same letters in the same column are not significantly different (P=0.05) according to Tukey's HSD test

4.10.7 Effect of maize varieties on total dry matter (g/m^2)

Results for the effects of maize varieties on total dry matter are presented in (Table 10). There was significant differences (P ≤ .001) of maize varieties on total dry matter. *Meru* HB 513, and *Faru* HB varieties gave maximum average total dry matter than *Situka* M1 as indicated in Table 10. This variation might be due to genetic differences among the varieties (Hossain *et al*., 2011).

Table 10: Effect of maize varieties on total dry matter (g/m^2)

Treatments	Total dry Matter (g/m^2)				
	V_4	V_T	R_4	R_6	Harvest
Situka M1	163.5 a	490.8 a	699.7 a	801 a	864 a
Meru HB 513	229.0 b	686.9 b	1030.3 b	1236 b	1360 b
Faru HB	228.3 b	684.8	1027.1 b	1233 b	1356 b
Mean	206.92	620.82	919.07	1090.14	1193.15
SD	13.479	38.504	56.464	67.330	74.443
CV (%)	6.5	6.2	6.1	6.2	6.2
P Value	<.001	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different ($P \leq 0.05$) according to Tukey's HSD test

4.10.8 Effect of N, P fertilizers on total dry matter (g/m^2) of maize varieties

The response of maize to N and P applications on total dry matter is presented in (Table 11). There was very highly significant ($P \leq .001$) increase in total dry matter due to the application of N and P compared with total dry matter obtained from the absolute control. This might be due to the supply of fertilizers which contain nutrients like N, P and K and other micronutrients which enhances the production of leaves, stem small roots and root hairs, which in turn facilitate the high absorbing capacity and increase photosynthetic efficiency per unit dry weight.Similar results were reported by Wadsworth (2002) who stated that, increased dry matter production with application of N, P containing fertilizers was due to role of nitrogen in determining the efficiency of sunshine by the increased biomas.The significant response of maize to the application of N and P indicates that these nutrients were deficient in the soils of the study area. The low total dry matter (436 g/m^2) obtained in the control plots (Table 11) reflects the inability of the study soils to supply adequate amounts of N and P, hence the low fertility status of these soils. Such results are in agreementwith Hussaini *et al.* (2008) who reported that minimum dry matter was recorded to the plots where N, P fertilizers were inadequate.

Table 11: Effect of N, Pfertilizers on total dry matter (g/m^2) of maize varieties

Treatments	Total Dry Matter (g/m^2)				
	V_4	V_T	R_4	R_6	Harvest
Control	73.9 a	221.1 a	331.0 a	397 a	436 a
DAP	182.5 b	547.5 b	818.7 b	982 b	1072 b
M. Mazao	275.4 c	827.7 c	1226.9 c	1455 c	1588 c
NPK-Cereal	295.9 c	886.9 c	1299.6	1526 c	1677 c
Mean	206.92	620.82	919.07	1090.14	1193.15
SD	13.479	38.504	56.464	67.330	74.443
CV(%)	6.5	6.2	6.1	6.2	6.2
P Value	<.001	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different ($P \leq 0.05$) according to Tukey's HSD test.

4.10.9 The effect of interaction between maize varieties and N,P fertilizers on dry matter (g/m^2)

Results for the effects of interaction between maize varieties and N, P fertilizers on total dry matter are presented (Table 12). There was no significant differences ($P \leq 0.542$, $P \leq 0.542$, $P \leq 0.542$, $P \leq 0.542$) of maize varieties on total dry matter at V_4, V_T, R_4, R_6 and harvest growth stages.

Table 12: The effect of interaction between maize varieties and N,Pfertilizers on dry matter (g/m^2)

Treatments	**Total Dry matter(g/m^2)**				
	V_4	**V_T**	**R_4**	**R_6**	**Harvest**
Situka x Control	75.4 a	224.9 a	335.4 a	403 a	441 a
Situka x DAP	152.9 a	458.6 a	680.2 a	816 a	872 a
Situka x M.Mazao	202.7 a	612.4 a	874.5 a	997 a	1 058 a
Situka x NPK Cereal	223.1 a	667.4 a	908.8 a	990 a	1 083 a
Meru 513 x Control	74.9 a	224.8 a	337.1 a	405 a	445 a
Meru x DAP	197.3 a	592.0 a	887.9 a	1 066 a	1 172 a
Meru x M. Mazao	311.4 a	934.1 a	1401.2 a	1 681 a	1 850 a
Meru x NPK Cereal	332.2 a	936.7 a	1 405.0 a	1 794 a	1 974 a
Faru x Control	71.2 a	213.7 a	320.5 a	385 a	423 a
Faru x DAP	197.3 a	592.0 a	887.9 a	1 066 a	1 172 a
Faru x M. Mazao	312.2 a	996.7 a	1 495.1 a	1 686 a	1 855 a
Faru x NPK Cereal	332.2 a	996.7 a	1 495.1 a	1 794 a	1 974 a
Mean	206.92	620.82	919.07	1090.14	1193.15
SD	13.479	38.504	56.464	67.330	74.443
CV (%)	6.5	6.2	6.1	6.2	6.2
P Value	0.542	0.551	0.345	0.184	0.166

Means followed by the same letters in the same column are not significantly different (P =0.05) according to Tukey's HSD test.

4.10.10 Effect of maize varieties on leaf area index (LAI)

Results for the effects of maize varieties on leaf area index are given in (Table 13). There was a significant (P≤.001) increase in LAI from V4 to VT for *Meru* HB and *Faru* HB as compared to *Situka* M1. This might be due to higher assimilatory surface of the hybridmaize varieties (*Meru* FB 513, *Faru* HB) due to expanded leaves had an added advantage in promoting vigorous vegetative growth of the leaves at early stages to tasselling stage. However, after tasselling a decline of LAI was observed until harvesting. This might be due to an interplant competition (for nutrient and space) within the community and ageing of leaves. Similar trend was also reported in maize and forage maize by Okpara *et al.* (1999).

Table 13: Effect of maize varieties on leaf area index

Treatments	Leaf area index			
	V_4	V_T	R_4	R_6
Situka M1	0.4115 a	1.674 a	1.421 a	1.210 a
Meru HB 513	0.6140 b	2.498 b	2.121 b	1.806 b
Faru HB	0.6116 b	2.488 b	2.113 b	1.799 b
Mean	0.546	2.22	1.89	1.61
SD	0.0058	0.024	0.020	0.017
CV (%)	1.1	1.1	1.1	0.017
P Value	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test

4.10.11 Effect of N, P fertilizers on leaf area index of maize varieties

The response of maize to N and P applications on LAI is presented in (Table 14). There was a significant ($P \leq .001$) increase in LA from V4 to VT due to the application of N and P containing fertilizers for *Meru* HB and *Faru* HB as compared to *Situka* M1. This is because the macro and micro nutrients especially found in *Minjingu Mazao* (N10%, P_2O_5 20%, S 5%, Zn 0.5%, B 0.1%, Cao 17.4%, MgO 1.9%) and NPK cereal (23-10-5 + 2 MgO +3 S + 0.3 Zn) promoted vigorous vegetative growth of the leaves at early stages to tasselling stage. Similar trend was also reported in maize and forage maize by Okpara *et al.* (1999).

Table 14: Effect of N, P fertilizers on leaf area index of maize varieties

Treatments	Leaf area index			
	V_4	V_T	R_4	R_6
Control	0.1890 a	0.769 a	0.653 a	0.556 a
DAP	0.4774 b	1.942 b	1.649 b	1.404 b
M. Mazao	0.7340 c	2.986 c	2.535 c	2.159 c
NPK Cereal	0.7824 c	3.183 c	2.703 c	2.302 c
Mean	0.546	2.22	1.89	1.61
SD	0.0230	0.093	0.079	0.068
CV (%)	4.2	4.2	4.2	4.2
P value	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test

4.10.12 The effect of interaction between maize varieties and N, P fertilizers on leaf area index

Effect of interaction between maize varieties and N, P fertilizers on leaf area index are presented in (Table 15). There was significant difference between interaction of maize varieties and N, P fertilizers on leaf area index. This is because the macro and micro nutrients especially found in *Minjingu Mazao* (N10%, P_2O_5 20%, S 5%, Zn 0.5%, B 0.1%, Cao 17.4%, MgO 1.9%) and NPK cereal (23-10-5 + 2 MgO +3 S + 0.3 Zn)and higher assimilatory surface of maize varieties promoted vigorous vegetative growth of the leaves. Similar trend was also reported in maize and forage maize by Okpara *et al.* (1999).

Table 15: The effect of interaction between maize varieties and N, P fertilizers on leaf area index

Treatments	Leaf area index			
	V_4	V_T	R_4	R_6
Situka x Control	0.1756 a	0.714 a	0.606 a	0.516 a
Situka x DAP	0.3748 abc	1.525 ab	1.295 ab	1.103 bc
Situka x M. Mazao	0.5287 bcd	2.151 b	1.826 b	1.555 c
Situka x NPK Cereal	0.5668 cde	2.306 b	1.958 b	1.667 c
Meru 513 x Control	0.2006 ab	0.816 a	0.693 a	0.590 ab
Meru x DAP	0.5287 bcd	2.151 b	1.826 b	1.555 c
Meru x M. Mazao	0.8366 de	3.404 c	2.890 c	2.461 d
Meru x NPK Cereal	0.8902 e	3.622 c	3.075 c	2.619 d
Faru x Control	0.1908 a	0.776 a	0.659 a	0.561 ab
Faru x DAP	0.5287 bcd	2.151 b	1.826 b	1.555 c
Faru x M. Mazao	0.8366 de	3.404 c	2.890 c	2.461 d
Faru x NPK Cereal	0.8902 e	3.622 c	3.075 c	2.619 d
Mean	0.546	2.22	1.89	1.61
SD	0.0496	0.202	0.171	0.146
CV (%)	9.1	9.1	9.1	9.1
PValue	0.0218	0.008	0.014	0.001

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test.

4.10.13 Effect of maize varieties on crop growth rate (g/m^2/day)

Results of the effects of maize varieties on crop growth rate are presented in (Table 16). There was a significance difference among maize varieties on crop growth rate. *Meru* HB and *Faru* HB recorded maximum crop growth rate as compared to Situka MI. This might be due to higher assimilatory surface of hybrid maize varieties as compared to open pollinated varieties which accerelated photosynthesis activity. Similar results were also reported by Jeffrey *et al.* (2005). The increase in crop growth rate up to tasselling stage is due to higher assimilatory surface at pre-silking period that support accumulation of dry matter in hybrid maize cultivars and hence maximum crop growth rate.

Table 16: Effect of maize varieties on crop growth rate (g/m^2/day)

Treatments	Crop growth rate (g/m^2/day)			
	V_4	**V_T**	**R_4**	**R_6**
Situka M1	6.460 a	7.862 a	5.564 a	3.870 a
Meru HB 513	8.829 b	10.461 b	8.012 b	6.419 b
Faru HB	9.008 b	10.544 b	8.052 b	6.401 b
Mean	8.10	9.62	7.21	5.56
SD	0.209	0.291	0.326	0.212
CV (%)	12.7	14.8	22.2	18.7
P Value	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test.

4.10.14 Effect of N, P fertilizers on crop growth rate (g/m^2/day) of maize varieties

The response of maize to N and P applications on CGR is presented in Tables 17. There was a significant ($P \leq .001$) increase in CGR from V4 to VT due to the application of N and P containing fertilizers for *Meru* HB and *Faru* HB as compared with *Situka* M1. This might be due to positive response of crop growth rate to N, P containing fertilizers and higher assimilatory surface of the hybrid maize varieties (*Meru* HB 513, *Faru* HB) due to expanded leaves, accelerated the photosynthesis activity. Similar results were also reported by Jeffrey *et al.* (2005). The increase in crop growth rate up to tasselling stage is due to higher assimilatory surface at pre-silking period that support accumulation of dry matter in hybrid maize cultivars and hence maximum crop growth rate. However, the decrease of CGR to the time of harvesting is due to senescence of leaves and decrease of leaf area index. Similar results were reported by Egly and Guffy (1997).

Table 17: Effect of N, Pfertilizers on Crop growth rate (g/m^2/day) of maize varieties

Treatments	Crop growth rate (g/m^2/day)			
	V_4	V_T	R_4	R_6
Control	2.678 a	4.001 a	3.015 a	2.448 a
DAP	7.561 b	9.006 b	6.221 b	4.212 b
M. Mazao	10.894 c	12.444 c	9.555 c	7.489 c
NPK	11.263 c	13.039 c	10.048 c	8.104 c
Mean	8.10	9.62	7.21	5.56
SD	0.242	0.336	0.377	0.245
CV (%)	12.7	14.8	22.2	18.7
P value	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P =0.05) according to Tukey's HSD test

4.10.15 The effect of interaction between maize varieties and N, P fertilizers on crop growth rate (g/m^2/day)

The effect of interaction between maize varieties and N, P fertilizers are presented in (Table 18). There was a significant (P≤.001) increase in CGR from V4 to VT due to the application of N and P containing fertilizers for *Meru* HB and *Faru* HB as compared with *Situka* M1. This might be due to positive response of crop growth rate to N, P containing fertilizers and higher assimilatory surface of the hybrid maize varieties (*Meru* HB 513, *Faru* HB) due to expanded leaves, accelerated the photosynthesis activity. Similar results were also reported by Jeffrey *et al.* (2005). The increase in crop growth rate up to tasselling stage is due to higher assimilatory surface at pre-silking period that support accumulation of dry matter in hybrid maize cultivars and hence maximum crop growth rate. However, the decrease of CGR to the time of harvesting is due to senescence of leaves and decrease of leaf area index. Similar results were reported by Egly and Guffy (1997).

Table 18: The effect of interaction between maize varieties and N, Pfertilizers on crop growth rate (g/m^2/day)

Treatments	Crop growth rate (g/m^2/day)			
	V_4	V_T	R_4	R_6
Situka x Control	2.658 a	3.931 a	3.093 a	2.344 a
Situka x DAP	6.228 b	7.465 b	4.888 ab	2.990 a
Situka x M. Mazao	8.228 c	9.777 c	6.888 bc	4.823 b
Situka x NPK Cereal	8.728 c	10.277 c	7.388 c	5.323 b
Meru 513 x Control	2.727 a	3.926 a	3.171 a	2.764 a
Meru x DAP	8.228 c	9.777 c	6.888 bc	4.823 b
Meru x M. Mazao	12.228 d	13.777 d	10.888 d	8.823 c
Meru x NPK Cereal	12.133 d	14.362 d	11.102 d	9.267 c
Faru x Control	2.650 a	4.146 a	2.780 a	2.235 a
Faru x DAP	8.228 c	9.777 c	6.888 bc	4.823 b
Faru x M.Mazao	12.228 d	13.777 d	10.888 d	8.823 c
Faru x NPK Cereal	12.928 d	14.477 d	11.654 d	9.722
Mean	8.10	9.62	7.21	5.56
SD	0.419	0.583	0.653	0.424
CV (%)	12.7	14.8	22.2	18.7
P Value	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test

4.10.16 Effect of maize varieties on relative growth rate (g/g/day)

Results of the effects of maize varieties on relative growth rate are presented in Table 19. There was a significance difference among maize varieties on relative growth rate. *Meru* HB and *Faru* HB recorded maximum relative growth rate as compared to Situka MI. This might be due to higher assimilatory surface of hybrid maize varieties as compared to open pollinated varieties which accerelated photosynthesis activity.

Table 19: Effect of maize varieties on Relative growth rate (g/g/day)

Treatments	**Relative growth rate (g/g/day)**			
	V_4	V_T	R_4	R_6
Situka M1	0.45 a	1.36 a	1.39 a	0.61 a
Meru HB 513	0.67 b	1.99 b	2.09 b	0.89 b
Faru HB	0.67 b	1.99 b	2.05 b	0.89 b
Mean	0.60	1.78	1.85	0.80
SD	0.045	0.136	0.161	0.061
CV (%)	7.5	7.6	8.7	7.6
P Value	0.008	<.001	0.002	0.004

Means followed by the same letters in the same column are not significantly different (P =0.05) according to Tukey's HSD test

4.10.17 Effect of N, P fertilizers on relative growth rate (g/g/day) of maize varieties

The response of maize to N and P applications on RGR is presented in Table 20. There was very highly significant ($P \leq .001$) increase in RGR from V4 to R4 due to the application of N and P containing fertilizers for *Meru* HB and *Faru* HB as compared to *Situka* M1. This might be due to positive response of relative growth rate to N, P containing fertilizers and higher assimilatory surface of the hybrid maize varieties due to expanded leaves, accelerated the photosynthesis activity. This observation is consistent with Tollenaar and Lee (2006), who observed that higher assimilatory surface at pre-silking period along with application of N, P, K, and other micronutrients such as S, Ca, Mg, Zn, B support accumulation of dry matter in hybrid maize cultivars and hence maximum relative growth rate. However, the decrease of RGR to the time of harvesting is due to senescence of leaves and decrease of leaf area index. Similar results were reported by Egly and Guffy (1997).

Table 20: Effect of N, P fertilizers on relative growth rate (g/g/day) of maize varieties

Treatments	Relative growth rate (g/g/day)			
	V_4	V_T	R_4	R_6
Control	0.19 a	0.59 a	0.63 a	0.27 a
DAP	0.52 b	1.57 b	1.64 b	0.71 b
M. Mazao	0.80 c	2.42 c	2.44 c	1.09 c
NPK	0.85 c	2.56 c	2.68 c	1.15 c
Mean	0.60	1.78	1.85	0.80
SD	0.045	0.136	0.161	0.061
CV(%)	7.5	7.6	8.7	7.6
P value	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSDtest

4.10.18 The effect of interaction between maize varieties and N, P fertilizers on relative growth rate (g/g/day)

The effect of interaction between maize varieties and N, P fertilizers are presented in (Table 21). There were significant difference between maize varieties and N, P fertilizers on relative growth rate of maize at V_T stage. This might be due to the fact that at this stage, the crop consumes a lot of energy at it changes from growth stage to development stage. However, there was no significant difference between maize varieties and N, P fertilizers on relative growth stage at V_4, R_4, and R_6 maize growth stages.

Table 21: The effect of interaction between maize varieties and N, P fertilizers on relative growth rate (g/g/day)

Treatments	Relative growth rate(g/g/day)			
	V_4	V_T	R_4	R_6
Situka x Control	0.1909 a	0.570 a	0.598 a	0.2571 a
Situka x DAP	0.4159 a	1.241 b	1.303 a	0.5601 a
Situka x M. Mazao	0.5687 a	1.758 bc	1.727 a	0.7929 a
Situka x NPK Cereal	0.6286 a	1.877 c	1.970 a	0.8466 a
Meru 513 x Control	0.1963 a	0.586 a	0.615 a	0.2643 a
Meru x DAP	0.5888 a	1.758 bc	1.845 a	0.7929 a
Meru x M.Mazao	0.9192 a	2.744 d	2.880 a	1.2379 a
Meru x NPK Cereal	0.9674 a	2.888 d	3.031 a	1.3028 a
Faru x Control	0.2115 a	0.631 a	0.663 a	0.2848 a
Faru x DAP	0.5695 a	1.700 bc	1.784 a	0.7670 a
Faru x M.Mazao	0.9185 a	2.751 d	2.701 a	1.2413 a
Faru x NPK Cereal	0.9674 a	2.888 d	3.031 a	1.3028 a
Mean	0.60	1.78	1.85	0.80
SD	0.045	0.136	0.161	0.061
CV (%)	7.5	7.6	8.7	7.6
PValue	0.656	<.001	0.502	0.579

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSDtest.

4.10.19 Effect of maize varieties on Net assimilation rate (g/m^2/day)

Results of the effects of maize varieties on net assimilation rate are presented in Table 22. There was a significance difference among maize varieties on net assimilation rate. *Meru* HB and *Faru* HB recorded maximum net assimilation rate as compared to Situka MI. This might be due to higher assimilatory surface of hybrid maize varieties as compared to open pollinated varieties which accerelated photosynthesis activity.

Table 22: Effect of maize varieties on Net assimilation rate (g/m^2/day)

Treatments	**Net assimilation rate (g/m^2/day)**			
	V_4	**V_T**	**R_4**	**R_6**
Situka M1	45.08 a	13.18 a	15.43 a	12.70 a
Meru HB 513	67.28 b	19.67 b	23.02 b	18.95 b
Faru HB	67.01 b	19.59 b	22.93 b	18.87 b
Mean	59.79	17.48	20.46	16.84
SD	0.639	0.187	0.219	0.219
CV (%)	1.1	1.1	1.1	1.1
P Value	0.009	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test

4.10.20 Effect of N, P fertilizers on net assimilation rate of maize varieties (g/m^2/day)

The response of maize to N and P applications on NAR is presented (Table 23). There was very highly significant (P≤.001) decrease of NAR from V4 to R6 due to the application of N and P containing fertilizers. Net assimilation rate (g/m^2/day) was higher at V4 growth stage. This might be due tocontribution of N, P, K and micronutrients such as S, Zn, B which promotes growth and accelerates the photosynthesis activity leading to accumulation of more dry matter at early stages. Similar results were reported by Moderras *et al.* (1998) that, application of N, P, K increase capture of solar radiation within the canopy and therefore increasing NAR. However, a decrease in NAR was observed as the crop advanced to maturity. This might be due to ageing and more competition of leaves to light within the canopy leading to low NAR as supported by Moderras *et al.* (1998).

Table 23: Effect of N, P fertilizers on Net assimilation rate of maize varieties ($g/m^2/day$)

Treatments	**Net assimilation rate ($g/m^2/day$)**			
	V_4	**V_T**	**R_4**	**R_6**
Control	20.71 a	6.05 a	7.09 a	5.83 a
DAP	52.31 b	15.29 b	17.90 b	14.73 b
M. Mazao	80.42 c	23.51 c	27.52 c	22.65 c
NPK	85.72 c	25.06 c	29.33 d	24.15 d
Mean	59.79	17.48	20.46	16.84
SD	0.639	0.735	0.861	0.708
CV(%)	1.1	4.2	4.2	4.2
P value	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test.

4.10.21 The effect of interaction between maize varieties and N, P fertilizers on net assimilation rate ($g/m^2/day$)

The effect of interaction between maize varieties and N, P fertilizers are presented in (Table 24). There were significant difference on the interaction between maize varieties and N, P fertilizers on net assimilation rate at V_4, V_T, R_4, and R_6 maize growth stages. This might be due to contribution of N, P, K and micronutrients such as S, Zn, B which promotes growth and accelerates the photosynthesis activity leading to accumulation of more dry matter at early stages. Similar results were reported by Moderras *et al.* (1998) that, application of N, P, K increase capture of solar radiation within the canopy and therefore increasing NAR. However, a decrease in NAR was observed as the crop advanced to maturity. This might be due to ageing and more competition of leaves to light within the canopy leading to low NAR as supported by Moderras *et al.* (1998).

Table 24: The effect of interaction between maize varieties and N, P fertilizers on net assimilation rate ($g/m^2/day$)

Treatments	Net assimilation rate($g/m^2/day$)			
	V_4	V_T	R_4	R_6
Situka x Control	19.24 a	5.62 a	6.58 a	5.42 a
Situka x DAP	41.06 ab	12.00 b	14.05 b	11.57 b
Situka x M. Mazao	57.93 abc	16.93 bc	19.82 c	16.32 c
Situka x NPK Cereal	62.10 abc	18.15 c	21.25 c	17.49 c
Meru 513 x Control	21.98 a	6.43 a	7.52 a	6.19 a
Meru x DAP	57.93 abc	16.93 bc	19.82 c	16.32 c
Meru x M. Mazao	91.66 bc	26.79 d	31.36 d	25.82 d
Meru x NPK Cereal	97.54 c	28.51 d	33.37 d	27.47 d
Faru x Control	20.91 a	6.11 a	7.15 a	5.89 a
Faru x DAP	57.93 abc	16.93 bc	19.82 c	16.32 c
Faru x M. Mazao	91.66 bc	26.79 d	31.36 d	25.82 d
Faru x NPK Cereal	97.54 c	28.51 d	33.37 d	27.47 d
Mean	59.79	17.48	20.46	16.84
SD	0.639	0.735	0.861	0.708
CV (%)	1.07	4.2	4.21	4.21
P Value	0.0717	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P =0.05) according to Tukey's HSD test

4.11 Effect of Maize Varieties on Yield and Yield Components

4.11.1 Plant Population (PP)

Response of maize varieties on plant population are presented in (Table 25). There was no significance difference ($P \leq 0.836$) in plant population among maize varieties.

4.11.2 Grains per Cob(GC)

The effect of maize varieties on number of grain per cob was highly significant ($P \leq .001$) as indicated in (Table 25). *Meru* HB 513 and *Faru* HB significantly ($P \leq .001$) produced higher number of grains per cob (508.7, 489.7) than the other one variety *Situka* M1-

388.5). This might be due to the fact that, hybrid maize varieties have higher grain yield potential .

4.11.3 1 000 grain weight (1 000 GW)

Response of maize varieties on 1000 grain weight was highly significant (P≤.001) as indicated in (Table 25). *Meru* HB 513 and *Faru* HB significantly (P≤.001) produced higher 1000 grain weight (456.8, 432.5g) than the other one variety *Situka* M1-303.8g) (Table 25).This might be due to the fact that, hybrid maize varieties have higher grain yield potential leading to maximum 1 000 grain weight.

4.11.4 Cob Length (CL)

Cob length wassignificant (P≤ 0.012) among maize varieties as indicated in (Table 25). Results show that *Meru* HB 513, *Faru* HB had higher cob length (27.90, 28.40) than *Situka* M1 (22.31). This might be due to the fact that, hybrid maize varieties have higher grain yield potential and nitrogen use efficiency leading to higher cob height.

4.11.5 Grain Weight (GW)

Response of grain weight of Maize varieties was highly significant(P≤.001). Results show that *Meru* HB 513 and *Faru* HB had higher grain weight (3.47 kg/plot, 3.59 kg/plot) than *Situka* M1 (2.63 kg/plot) as indicated in Table 25. These differences were attributed to differences in genetic potential of varieties. These are close related with results found by Hossain *et al.* (2011) who got the highest grain weight (350.6 g) as recorded from Pacific-984 hybrid variety, followed by (346.0 g) from BARI Hybrid maize-3 and the lowest grain weight (311.6 g) from BARI Hybrid maize-1.

4.11.6 Grain yield

Grain yield varies significantly (P≤.001) among maize varieties (*Situka* M1, *Meru* HB 513, *Faru* HB). Statistical results show that *Meru* HB 513 and *Faru* HB had higher grain yield (3.98t ha^{-1}, 4.12 t ha^{-1}) than *Situka* M1 (3.01t ha^{-1}) (Table 25). This might be due to the fact that, hybrid maize varieties have higher grain yield potential and nitrogen use efficiency leading to higher grain yield.This is consistent with the findings of Hossain *et al.* (2011) who reported the higher grain yield of 10.3 t ha -1 recorded from Pacific-984 variety, followed by 9.4 t ha-1 from BARI Hybrid maize 3 and the lowest grain yield of 7.7 t ha-1 from BARI Hybrid maize-1. Likewise Khan *et al.* (2008) reported that fruit production, grain yield and other yield components are usually influenced by genetic quality of individual variety.

Table 25: **Effect of maize varieties on yield and yield components**

Treatments	**PP/m^2**	**GC**	**CL(cm)**	**GW(kg)**	**1000 GW**	**Y (t ha^{-1})**
Situka M1	4.256 a	388.5 a	22.31 a	2.63 a	303.8 a	3.01 a
Meru HB 513	4.336 a	508.7 b	27.90 b	3.473 b	456.8 b	3.98 b
Faru HB	4.301a	489.7 b	28.40 b	3.590 b	432.5 b	4.12 b
Mean	4.30	462	26.20	3.230	397.69	3.70
SD	0.029	38.4	0.217	0.0729	39.337	0.083
CV (%)	0.7	8.3	0.8	2.3	48.5	2.2
P value	0.836	<.001	0.0120	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test. Key: PP/m^2 = Plant population per metre square; GC = Grain per cob; CL = Cob Length; GW = Grain weight; 1000 GW = One thousandgrain weight; Y (t ha^{-1}) = Yield ton per hactre.

4.12 Effect of N, P Fertilizers on Yield and Yield Components of Maize Varieties

4.12.1 Plant Population (PP)

Response of maize on N, P fertilizers on plant population are presented in Table 26. There was no significance difference (P≤ 0.440) in plant population among maize varieties due to application of N, P fertilizers. This shows that, fertilizers did not affect germination and there was consistent viability.

4.12.2 Grains per Cob(GC)

The effect of maize varieties on number of grain per cob was highly significant (P≤.001) with application of N, P containing fertilizer (Table 26). Maximum number of grains per cob was recorded from NPK Cereal – 581.1, followed by *Minjingu Mazao* – 578.8, then DAP – 428.9 and last was control – 260.5 (Table 26). The results are partly in agreement with those of Oktem *et al*. (2005) who reported that number of grains per cob was increased at N, P fertilization.

4.12.3 1 000 Grain Weight (1 000 GW)

Maximum 1 000 GW was recorded from NPK – 549g, followed by *Minjingu Mazao* – 546 g, then DAP – 355.1 g and last was control – 140.7 g (Table 26). This might be attributed to positive interaction between both macro and micro nutrients contained in these fertilizers (Oktem *et al*., 2005). The lowest (140.7 g) 1 000 GWrecorded from the control might be due to unavailability of nutrients required for growth and development.

4.12.4 Cob Length (CL)

The results indicated that there was a highly significant (P≤.001) increase of cob lengthfor *Minjingu Mazao* and NPK cereal– 30.97 cm, 30.94 cm than DAP (26.69 cm) respectively. The increase in cob length is due to increased photosynthetic formation and partitioning to stems that might have favourable impacts on plant and cob lengths of maize (Amanullah *et al*., 2009). These results are in conformity with findings of Bishnu *et al*. (2010) who reported that the tallest cob length (86.66 cm) and longest cob length (12.86 cm) was recorded in plots treated with the micronutrients (B, Mn, S and Zn) at the NPK level of 120:60:40 kg ha-1. However, the control plot had lower cob length of 22.86cm (Table 26). This might be due to low availability of essential nutrients required for plant growth.

4.12.5 Grain Weight (GW)

The results indicated that there was highly significant ($P \leq .001$) increase of grain weight for*Minjingu Mazao* and NPK Cereal as follows (3.72 kg, 3.86 kg respectively) than DAP - 3.83 kg. The increase in grain weight is due to increased photosynthetic formation and partitioning to stems that might have favourable impacts on plant and grain weight of maize (Amanullah *et al*., 2009). This result is in conformity with Bishnu *et al*. (2010) who found the highest grain weight of 412.66 g in the crop supplied with NPK level of 120:60:40 kg ha-1 and B, Zn, S and Mn. However, the control plot had lower grain weight of 1.52 kg. (Table 26). This showed the importance of supplying nutrients responsible for maize production.

4.12.6 Grain yield

The results indicated that there was a significant ($P \leq .001$) increase of grain yield for *Minjingu Mazao* and NPK Cereal (4.42 t ha^{-1}, 4.39 t ha^{-1} respectively) than DAP (4.26 t ha^{-}1). The increase in grain yield is due tosupplying all limiting nutrients (N, P, K) in maize production for yield increase.These results are in conformity with findings of Bishnu *et al*. (2010) who found highest grain yield (5.9 t ha^{-1}) produced when the crop was supplied with all micronutrients (B, Mo, Zn, Mn and S) along with NPK fertilizers at 120: 60:40 kg ha^{-1}.However, the control plot had lower grain yield of 1.74 t ha^{-1}. Table 26.This might be due to presence of limiting nutrients such as N, P required for maize growth.

Table 26: Effect of N, P fertilizers on yield and yield components of maize varieties

Treatments	PP/m^2	GC	CL(cm)	GW(kg)	1000 GW(g)	Y (t ha^{-1})
Control	4.397 a	260.5 a	22.86 a	1.52 a	140.7 a	1.74 a
DAP	4.151 a	428.9 b	26.69 b	3.72 b	355.1 b	4.26 b
M. Mazao	4.313 a	578.8 c	30.97 c	3.86 b	546.0 c	4.42 b
NPK Cereal	4.329 a	581.1 c	30.94 c	3.83 b	549.0 c	4.39 b
Mean	4.30	462	27.87	3.230	397.69	3.70
SD	0.029	13.2	0.217	0.0729	45.422	0.083
CV (%)	0.7	17.2	0.8	2.3	48.5	2.2
P value	0.440	<.001	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test. Key: PP/m^2 = Plant population per metre square; GC = Grain per cob; CL = Cob length; GW = Grain weight;1000 GW = One thousand grain weight; Y (t ha^{-1}) = Yield ton per hactre

4.13 The Effect of Interaction between Maize Varieties and N, P Fertilizers on Yield and Yield Components

4.13.1 Plant Population (PP)

The interaction betweenmaize and N, P fertilizers on plant population are presented in (Table 27). There was no significance difference (P≤ 1.00) in plant population due to interaction between maize varieties and N, P fertilizers. This shows that, the interaction between maize varieties and N, P fertilizers did not affect germination and there was consistent viability.

4.13.2 Grains per Cob (GC)

Interactive effect of maize varieties and N, P fertilizers on number of grain per cob was highly significant (P≤.001) (Table 27). This might be due to positive nutrients interaction between macro and micro nutrients. The results are partly in agreement with those of Oktem *et al*. (2005) who reported that number of grains per cob was increased due to interaction of both macro and micro nutrients.

4.13.3 1 000 Grain Weight (1 000 GW)

Interactive effect of maize varieties and N, P fertilizers on 1 000 grain weight was not significant ($P \leq 0.322$). (Table 27).This shows that the interaction of maize varieties and N, P fertilizers did not affect the 1 000 grain weight.

4.13.4 Cob Length (CL)

Interactive effect of maize varieties and N, P fertilizers on cob length was not significant ($P \leq 0.244$) (Table 27). This shows that the interaction of maize varieties and N, P fertilizers did not affect the cob length.

4.13.5 Grain Weight (GW)

Interactive effect of maize varieties and N, P fertilizers on cob length was significant ($P \leq 0.041$) (Table 27). The increase in grain weight is due to increased photosynthetic formation and partitioning to stems that might have favourable impacts on plant and grain weight of maize (Amanullah *et al*., 2009). This result is in conformity with Bishnu *et al*. (2010) who found the highest grain weight of 412.66 g in the crop supplied with NPK level of 120:60:40 kg ha-1 and B, Zn, S and Mn. However, the control plot had lower grain weight of 1.52 kg. (Table 26). This showed the importance of supplying nutrients responsible for maize production.

4.13.6 Grain yield

Interactive effect of maize varieties and N, P fertilizers on grain yield was significant ($P \leq 0.04$). (Table 27). The increase in grain yield is due tosupplying all limiting nutrients

(N, P, K) in maize production for yield increase.These results are in conformity with findings of Bishnu *et al*. (2010) who found highest grain yield (5.9 t ha^{-1}) produced when the crop was supplied with all micronutrients (B, Mo, Zn, Mn and S) along with NPK fertilizers at 120: 60:40 kg ha^{-1}. However, the control plot had lower grain yield of 1.74 t ha^{-1} (Table 26). This might be due to presence of limiting nutrients such as N, P required for maize growth.

Table 27: Interaction effect between maize varieties and N, P fertilizers on yield and yield components

Treatments	PP/m^2	GC	CL(cm)	GW(kg)	1000 GW(g)	Y (t ha^{-1})
Situka x Control	4.333 a	252.7 a	21.17 a	1.388 a	130.8 a	1.59 a
Situka x DAP	4.095 a	368.9 bc	27.33 a	2.971 b	278.8 a	3.41 b
Situka x M. Mazao	4.274 a	458.9 c	30.25 a	3.075 b	393.3 a	3.53 b
Situka x NPK Cere	4.321 a	473.7 c	30.50 a	3.075 b	412.2 a	3.53 b
Meru 513 x Control	4.429 a	267.2 ab	23.42 a	1.600 a	149.3 a	1.83 a
Meru x DAP	4.250 a	458.9 c	26.33 a	4.042 c	393.3 a	4.63 c
Meru x M. Mazao	4.333 a	638.7 d	30.83 a	4.167 c	622.3 a	4.78 c
Meru x NPK Cereal	4.333 a	670.0 d	31.00 a	4.083 c	662.2 a	4.68 c
Faru x Control	4.429 a	261.5 ab	24.00 a	1.558 a	142.0 a	1.79 a
Faru x DAP	4.107 a	458.9 c	26.42 a	4.142 c	393.3 a	4.75 c
Faru x M. Mazao	4.333 a	638.7 d	31.83 a	4.333 c	622.3 a	4.97 c
Faru x NPK Cereal	4.333 a	599.6 d	31.33 a	4.325 c	572.6 a	4.96 c
Mean	4.30	462	27.87	3.230	397.69	3.70
SD	0.029	38.4	0.217	0.0729	48.865	0.083
CV(%)	0.7	8.3	0.8	2.3	12.3	2.2
P Value	1.000	<.001	0.244	0.041	0.322	0.04

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test. Key: PP/m^2 = Plant population per metre square; GC = Grain per cob; CL = Cob length; GW = Grain weight; 1000 GW = One thousand grain weight; Y (t ha^{-1}) = Yield ton per hactre

4.14 Yield and Yield Components of Maize Varieties as Affected by N Levels

4.14.1 Plant Population (PP)

Nitrogen rates (N_0, $N_{37.5}$, N_{50}, $N_{62.5}$) significantly ($P \leq .001$) showed differences on plant population of maize varieties. Maximum plant populationwas recorded from $N_{62.5}$ - 4.369, followed by N_{50} – 4.341 , then $N_{37.5}$ – 4.044 and last was N_0 – 3.437 (Table 28). This might be due to the fact that increasing nitrogen levels in combination with P and K greatly influenced maize germination in maintaining plant population up to the harvest as the yield is concerned. This is in line with Gul *et al.* (2009) and Amanullah *et al*. (2009) who reported the increase of crop density and biological yield with increasing nitrogen levels. The lowest plant population per metre square was recorded from the control (3.437). This might be due to lack of adequate nitrogen in combination with P and K for influencing maize germination and maintaining plant density.

It was also observed that, the interaction between maize varieties and nitrogen rates were not significant ($P \leq 0.0581$). Results show thatall maize varieties (*Situka* MI, *Meru* HB and *Faru* HB) at nitrogen levels 50 – 62.5 kgNha^{-1} recorded maximum plant population (Table 29).

Further, the interaction between fertilizer types and nitrogen rates werenot significant ($P \leq 1.00$). Results indicate that all fertilizers (DAP, NPK Cereal and *Minjingu Mazao*) were effective when nitrogen levels were N_{50} and $N_{62.5}$ (Table 30).

Furthermore, the interaction between maize varieties, fertilizer types and nitrogen rates were not significant ($P \leq 0.931$). Results show that all maize varieties *Situka* MI, *Meru* HB 513 and *Faru* HB when treated with all fertilizers; DAP, *Minjingu Mazao* and NPK cereal fertilizers at nitrogen levels 50 – 62.5kgNha^{-1} gave maximum plant population (Table 31).

This indicates of positive interaction of nutrients contained in fertilizers which lead to good germination and maintaining plant population.

Table 28: **Effect of Nitrogen rates on yield and yield components of Maize varieties**

Treatments	**PP/m^2**	**CL(cm)**	**GC**	**GW (kg)**	**1000 GW(g)**	**Y (t ha^{-1})**
N_0	3.437 a	24.69 a	368.9 a	1.22 a	224.6 a	3.37 a
$N_{37.5}$	4.044 b	27.50 b	443.6 ab	1.49 a	261.7 a	4.13 a
N_{50}	4.341 c	29.19 bc	515.7 b	1.88 b	492.5 b	5.21 b
$N_{62.5}$	4.369 c	30.08 c	520.9 b	1.85 b	612.0 b	5.13 b
Mean	4.05	27.87	462	1.606	397.69	4.46
SD	0.029	0.900	35.3	0.1339	47.690	0.372
CV (%)	0.7	13.7	32.4	35.4	50.9	35.4
F value	<.001	<.001	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test. Key: PP/m^2 = Plant population per metre square; GC = Grain per cob; 1000 GW = One thousang grain weight; CL = Cob lenght; GW = Grain weight; Y (t ha^{-1}) = Yield ton per hactre

Table 29: Interaction effect between maize varieties and nitrogen rates on yield and yield components

Treatments	PP/m^2	CL(cm)	GC	GW(kg)	1000 GW(g)	Y (t ha^{-1})
Situka x N_0	3.405 a	22.92 a	317.2 a	1.983 a	171.6 a	2.274 a
Situka x $N_{37.5}$	3.917 b	27.17 ab	374.3 ab	2.292 a	199.9 ab	2.629 a
Situka x N_{50}	4.333 c	27.25 b	429.4 ab	3.142 ab	376.2 abcd	3.603 ab
Situka x $N_{62.5}$	4.369 c	27.92 b	433.3 ab	3.092 ab	467.4 bcde	3.541 ab
Meru 513 x N_0	3.464 a	25.33 ab	401.5 ab	2.717 ab	258.0 ab	3.116 ab
Meru x $N_{37.5}$	4.155 b	27.42 ab	487.2 ab	3.258 ab	300.6 abcd	3.737 ab
Meru x N_{50}	4.357 c	29.83 c	570.1 b	4.025 b	565.6 de	4.615 b
Meru x $N_{62.5}$	4.369 c	30.00 c	576.0 b	3.892 b	702.9 e	4.458 b
Faru x N_0	3.440 a	25.83 ab	388.1 ab	2.800 ab	244.3 ab	3.208 ab
Faru x $N_{37.5}$	4.060 b	27.92 ab	469.4 ab	3.367 ab	284.6 abc	3.862 ab
Faru x N_{50}	4.333 c	29.50 c	547.8 b	4.092 b	535.6 cde	4.692 b
Faru x $N_{62.5}$	4.369 c	30.33 c	553.4 b	4.100 b	665.6 e	4.696 b
Mean	4.05	27.61	462	3.230	397.69	3.70
SD	0.029	1.559	61.2	0.4558	82.602	0.523
CV (%)	0.7	13.7	32.4	34.6	50.9	34.6
F Value	0.05	<.001	0.0244	<.001	0.0322	0.041

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test. Key: PP/m^2 = Plant population per metre square; GC = Grain per cob; 1000 GW = One thousang grain weight; CL = Cob lenght; GW = Grain weight; Y (t ha^{-1}) = Yield per ton per hactre

Table 30: Interaction effect between N, P fertilizer and nitrogen rates on yield and yield components of Maize varieties

Treatments	PP	CL(cm)	GC	GW(kg)	1000 GW(g)	Y (t ha^{-1})
Control x N_{0}	3.317 a	21.11 a	227.4 a	1.372 a	79.4 a	1.572 a
Control x $N_{37.5}$	4.460 a	22.11 ab	253.9 a	1.478 a	92.6 a	1.695 a
Control x N_{50}	4.905 a	23.89 bc	279.4 a	1.589 a	174.2 ab	1.820 a
Control x $N_{62.5}$	4.905 a	24.33 bc	281.2 a	1.622 a	216.5 abc	1.858 a
DAP x N_{0}	3.444 a	23.33 ab	345.5 ab	2.861 b	200.6 abc	3.274 b
DAP x $N_{37.5}$	3.556 a	26.33 cd	412.2 bc	3.322 b	233.7 abc	3.813 b
DAP x N_{50}	4.346 a	28.44 de	476.6 cd	4.289 cd	439.8 de	4.923 cd
DAP x $N_{62.5}$	4.357 a	28.67 de	481.2 cd	4.270 cd	546.5 ef	4.951 cd
M.Mazao x N_{0}	3.476a	27.22 d	450.6 bcd	2.889 b	308.3 bcd	3.315 b
M.Mazao x $N_{37.5}$	4.063 a	30.67 ef	553.1 de	3.544 bc	359.3 cd	4.065 bc
M.Mazao x N_{50}	4.357 a	32.67 fgh	652.1 e	4.567 d	676.1 fg	5.235 d
M.Mazao x $N_{62.5}$	4.357 a	33.33 gh	659.2 e	4.433 cd	840.2 g	5.078 cd
NPK x N_{0}	3.208 a	27.11 d	452.2 bcd	2.878 b	310.0 bcd	3.302 b
NPK x $N_{37.5}$	4.095 a	30.89 efg	555.3 de	3.544 bc	361.2 cd	4.065 bc
NPK x N_{50}	4.357 a	31.78 fgh	654.9 e	4.567 d	679.8 fg	5.235 dd
NPK x $N_{62.5}$	4.357 a	34.00 h	662.0 e	4.422 cd	844.8 g	5.040 cd
Mean	4.05	27.87	462	4.30	397.69	3.70
SD	0.029	0.699	35.9	0.2598	48.892	0.298
CV (%)	0.7	5.3	16.5	17.1	26.1	17.1
F Value	1.000	0.02	0.006	0.01	0.01	0.01

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test. Key: PP/m^2 = Plant population per metre square; GC = Grain per cob; 1000 GW = One thousang grain weight; CL = Cob lenght; GW = Grain weight; Y (t ha-1) = Yield ton per hactre

Table 31: Interation effect between maize varieties, N, P fertilizer and Nitrogen rates on yield and yield components

Treatments	PP H	CL (cm)	GC	GW (kg)	1000GW	Y (t ha^{-1})
Situka x control x N_0	3.190 a	18.00 a	222.0 a	1.25 a	73.9 a	1.43 a
Situka x control x $N_{37.5}$	4.333a	19.33 ab	246.6 abc	1.37 ab	86.1 ab	1.57ab
Situka x control x N_{50}	4.305a	23.67 cd	270.3 abc	1.47 ab	162.0 abc	1.68ab
Situka x control x $N_{62.5}$	4.305a	23.67 cd	272.0 abc	1.47 ab	201.3 abcde	1.68ab
Situka x DAP X N_0	3.381 a	23.33 c	303.5 abcd	2.08 bcd	157.4 abc	2.38 bcd
Situka x DAP X $N_{37.5}$	3.429 a	27.33 defgh	355.8 bcde	2.60 de	183.4 abcd	2.99 de
Situka x DAP X N_{50}	4.314a	29.33ghijk	406.4 defg	3.50 fgh	345.2cdefgh	4.02fgh
Situka x DAP X $N_{62.5}$	4.357a	29.33ghijk	410.0 defg	3.70 fghi	429.0 ghi	4.24fghi
Situka x M.Mazao x N_0	3.476 a	25.67 cdefg	366.5 cdef	2.30 cd	222.1abcdef	2.64cd
Situka x M.Mazao x $N_{37.5}$	3.905a	30.67hijkl	440.4efgh	2.60 de	258.8abcdefg	2.98de
Situka x M.Mazao x N_{50}	4.257a	28.00 jkl	511.7ghij	3.80 fghi	487.0 hij	4.36fghi
Situka x M.Mazao x $N_{62.5}$	4.257a	28.67 kl	516.8ghij	3.60fgh	605.2 ijk	4.12fgh
Situka x NPK Cereal x N_0	3.571a	24.67 cde	376.9 cdef	2.30cd	232.8abcdef	2.64cd
Situka x NPK Cereal x $N_{37.5}$	4.000 a	31.33ijkl	454.3efgh	2.60 de	271.2abcdefg	2.98de
Situka x NPK Cereal x N_{50}	4.267 a	29.00 jkl	529.1 ghij	3.80 fghi	510.4 hij	4.36fghi
Situka x NPK Cereal x $N_{62.5}$	4.267a	29.00 l	534.4 ghij	3.60 fgh	634.3 jkl	4.12 fgh
Meru 513 x control x N_0	3.381 a	22.67 bc	232.2 ab	1.43ab	84.3 ab	1.64ab
Meru 513 x control x $N_{37.5}$	4.324a	23.00 bc	260.2 abc	1.57 abc	98.2 ab	1.79abc
Meru 513 x control x N_{50}	4.305 a	24.00 cd	287.3 abcd	1.67abc	184.8 abcd	1.91 abc
Meru 513 x control x $N_{62.5}$	4.305a	24.00 cd	289.2abcd	1.73abc	229.7abcdef	1.99 abc
Meru 513 x DAP x N_0	3.524 a	23.33 c	366.5 cdef	3.23efg	222.1 abcdef	3.71 efg
Meru 513 x DAP x $N_{37.5}$	3.810a	25.33cdef	440.4 efgh	3.60fgh	258.8abcdefg	4.13fgh
Meru 513 x DAP x N_{50}	4.310a	28.00efghi	511.7ghij	4.70jkl	487.0 hij	5.39 jkl
Meru 513 x DAP x $N_{62.5}$	4.357a	28.67fghij	516.8 ghij	4.63jkl	605.2 ijk	5.31 jkl
Meru 513 x M. Mazao x N_0	3.476 a	27.33 defgh	492.6 fghi	3.10ef	351.5 defgh	3.56 ef
Meru 513 x M. Mazaox $N_{37.5}$	4.143a	30.67hijkl	609.5ijkl	3.93ghij	409.5 fgh	4.51ghij
Meru 513 x M. Mazao x N_{50}	4.357 a	32.00jkl	722.3 lm	4.87 kl	770.6 klmn	5.58 kl
Meru 513 x M. Mazao x $N_{62.5}$	4.357a	33.33 l	730.4 lm	4.77kl	957.7 no	5.46kl
Meru 513 x NPK Cereal x N_0	3.476 a	28.00efghi	514.6ghij	3.10 ef	374.0efgh	3.56 ef
Meru 513 x NPK Cereal x $N_{37.5}$	4.143 a	30.67hijkl	638.9 jklm	3.93ghij	435.8 ghi	4.51ghij
Meru 513 x NPK Ceral x N_{50}	4.357 a	31.33ijkl	759.0 m	4.87 kl	820.0 lmn	5.58kl
Meru 513 x NPK Cereal x $N_{62.5}$	4.357 a	34.00 l	767.6 m	4.43ijkl	1019.0 o	5.08 ijkl
Faru x control x N_0	3.381 a	22.67 bc	228.2 ab	1.43 ab	80.2 a	1.64 ab
Faru x control x $N_{37.5}$	4.324 a	24.00 cd	254.8 abc	1.5 0ab	93.4 ab	1.72 ab
Faru x control x N_{50}	4.35a	24.00 cd	280.6 abcd	1.63abc	175.8 abcd	1.87abc

Faru x control x $N_{62.5}$	4.305a	25.33 cdef	282.4 abcd	1.67abc	218.5 abcde	1.91 abc
Faru x DAP x N_0	3.429 a	23.33 c	366.5cdef	3.27efg	222.1 abcdef	3.73 efg
Faru x DAPx $N_{37.5}$	3.429 a	26.33 cdefg	440.4 efgh	3.77fghi	258.8 abcdefg	4.33 fghi
Faru x DAPx N_{50}	4.314a	28.00efghi	511.7 ghij	4.67jkl	487.0 hij	5.36 jkl
Faru x DAP x $N_{62.5}$	4.357a	28.00efghi	516.8ghij	4.87kl	605.2 ijk	5.58 kl
Faru x M. Mazao x N_0	3.476 a	28.67fghij	492.6fghi	3.27efg	351.5defgh	3.75 efg
Faru x M.Mazao x $N_{37.5}$	4.143a	30.67 hijkl	609.5ijkl	4.10hijk	409.5 fgh	4.70hijk
Faru x M. Mazao x N_{50}	4.357a	34.00 l	722.3 lm	5.03 l	770.6 klmn	5.77 l
Faru x M. Mazao x $N_{62.5}$	4.357a	34.00 l	730.4 lm	4.93 l	957.7 no	5.65 l
Faru x NPK Cereal x N_0	3.476 a	28.67fghij	465.2 efgh	3.23 efg	323.4cdefgh	3.71 efg
Faru x NPK Cereal x $N_{37.5}$	4.143a	30.67hijkl	572.7hijk	4.10hijk	376.8b efgh	4.70 hijk
Faru x NPKCereal x N_{50}	4.357 a	32.00jkl	676.6 klm	5.03 l	709.0 klm	5.77 l
Faru x NPKCereal x $N_{62.5}$	4.357a	34.00 l	684.0 klm	4.93 l	881.1 mno	5.65l
Mean	4.02	27.87	462	3.23	397.69	3.70
SD	0.029	0.217	38.4	0.0729	48.865	0.083
CV (%)	0.7	0.8	8.3	2.3	12.3	2.2
F- Value	0.931	0.019	0.01	0.009	0.0074	0.0094

Means followed by the same letters in the same column are not significantly different ($P \leq 0.05$) according to Tukey's HSD test. Key: PP = Plant population; GC = Grain per cob ; 1000 GW = One thousang grain weight; CL = Cob lenght; GW = Grain weight; Y (t ha^{-1}) = Yield ton per hactre

4.14.2 Grains per Cob (GC)

Nitrogen rates (N_0, $N_{37.5}$, N_{50}, $N_{62.5}$) significantly (P≤.001) showed differences on grains per cob. Maximum grains per cob was recorded from $N_{62.5}$ –520.9, followed by N_{50} – 515.7, then $N_{37.5}$ – 443.6 and last was N_0 – 368.9 (Table 28). This might be due to the effect of nitrogen on growth of maize.These are in agreements with Ghulam *et al*. (2005) who reported that grains per cob increased with increased in nitrogen levels.

It was observed also that, the interaction between maize varieties and nitrogen rates were significant (P≤0.0244). Results indicated that *Meru* HB and *Faru* HB at 50 – 62.5 kg N ha^{-1} recorded maximum grains per cob as follows; (570.1 and 576, 547.8 and 553.4 respectively) (Table 29). This might be due to the fact that, hybrid maize varieties have higher grain yield potential and nitrogen use efficiency leading to maximum grains per cob.Lowest grains per cob was recorded in Situka M1 at 50 – 62.5 kg N ha^{-1}as follows; (429.4, 433.3). This might be due to low grain yield potential and nitrogen use efficiency leading to lower grains per cob.

Further, interaction between fertilizer types and nitrogen rates were significant (P≤0.006). Results indicate ndicate that *Minjingu Mazao* and NPK Cereal were effective in producing grains per cob when nitrogen levels were 50 – 62.5 $kgNha^{-1}$ (Table 30).

Furthermore, the interaction between maize varieties, fertilizer types and nitrogen rates were significant (P≤0.01). Results showed that *Meru* HB and *Faru* HB when treated with *Minjingu Mazao* and NPK cereal at nitrogen levels 50 – 62.5$kgNha^{-1}$ gave maximum grains per cobs (Table 31). These results are in line with Bhatt (2012) who reported that increasing nitrogen levels increases grains per cob.

4.14.3 1 000 grain weight

Nitrogen rates (N_0, $N_{37.5}$, N_{50}, $N_{62.5}$) significantly ($P \leq .001$) showed differences on 1 000 grain weight. Maximum 1 000 grain weight was recorded from $N_{62.5}$ –612, followed by N_{50} – 492.5, then $N_{37.5}$ – 261.7 and last was N_0 – 224.6 (Table 28). These results are in line with Bhatt (2012) who reported that increasing nitrogen levels increases 1 000 grains weight (g).

It was also observed that, the interaction between maize varieties and nitrogen rates were significant ($P \leq 0.0322$). Results showed that *Meru* HB and *Faru* HB at 50 – 62.5 kg N ha^{-1} recorded maximum 1 000 grain weight as follows; (4.025 kg, 3.892 kg, 4.092 kg, 4.100 kg) (Table 29). This might be due to the fact that, hybrid maize varieties have higher grain yield potential and nitrogen use efficiency leading to higher 1 000 grain weight.Lowest number of grains per cob was recorded in *Situka* M1 at 50 – 62.5kg N ha^{-1}as follows; (3.142 kg, 3.092 kg). This might be due to low grain yield potential and nitrogen use efficiency leading to lower 1 000 grain weight.

Further, the interaction between fertilizer types and nitrogen rates were significant ($P \leq 0.01$). Results indicated that *Minjingu Mazao*and NPK Cereal gave maximum 1 000 grain weight when nitrogen levels were N_{50} and $N_{62.5}$ (Table 30). This is also similar with the report of Amoruwa *et al*. (1987) who reported that thousand grains weight increased with increasing nitrogen rate.

Furthermore, the interaction between maize varieties, fertilizer types and nitrogen rates were significant ($P \leq 0.0074$). Results showed that *Meru* HB and *Faru* HB when treated with *Minjingu Mazao* and NPK cereal at nitrogen levels 50 – 62.5 kg N ha^{-1} gives maximum 1 000 grain weight (Table 31). Similar results were obtained by Ghulam *et al*. (2005) who reported that 1 000 grain weight increased with increased in nitrogen.

4.14.4 Coblength (CL)

Nitrogen rates (N_0, $N_{37.5}$, N_{50}, $N_{62.5}$) significantly (P≤.001) showed differences on cob lenght. Higher cob lenght was recorded from $N_{62.5}$ –30.08 cm, followed by N_{50} – 29.19 cm, then $N_{37.5}$ – 27.50 cm and last was N_0 – 24.69 cm (Table 28). These results are in line with Bhatt (2012) who reported that increasing nitrogen levels increases cob length (cm).

It was also observed that, the interaction between maize varieties and nitrogen rates were highly significant (P≤.001). Results showed that *Meru* HB and *Faru* HB at 50 – 62.5 kg Nha^{-1} recorded maximum cob lenght as follows; (28.83 cm, 30.00 cm, 29.50 cm, 30.33 cm). (Table 29). This might be due to the fact that, hybrid maize varieties have higher grain yield potential and nitrogen use efficiency leading to higher cob length.Lowest cob length was recorded in Situka M1 at 50 – 62.5kg N ha^{-1} as follows; (27.25 cm, 27.92 cm). This might be due to low grain yield potential and nitrogen use efficiency leading to lower cob length.

Further, the interaction between fertilizer types and nitrogen rates were significant (P≤0.02). Results indicate that *Minjingu Mazao*and NPK Cereal gave maximum cob length (32.67 cm, 33.33 cm and 31.78cm, 34.00 cm) when nitrogen levels were N_{50} and $N_{62.5}$ (Table 30). These results are similar with the results of Akram *et al.* (2010) who reported that cob length increases with increase in nitrogen levels.

Furthermore, the interaction between maize varieties, fertilizer types and nitrogen rates were significant (P≤0.019). Results showed that *Meru* HB and *Faru* HB when treated with

Minjingu Mazao and NPK cereal at nitrogen levels 50 – 62.5 kg N ha^{-1} gives maximum cob lenght (Table 31).

4.14.5 Grain Weight (GW)

Nitrogen rates (N_0, $N_{37.5}$, N_{50}, $N_{62.5}$) significantly (P≤.001) showed differences on grain weight. Maximum grain weight was recorded from N_{50}– 1.88 kg, followed by $N_{62.5}$ – 1.85 kg, then $N_{37.5}$ – 1.49 kg and last was N_0 – 1.22 kg (Table 28). These are in agreenment by Sharar *et al*. (2003) who indicated increse in N dose the grain weight showed increase.

It was also observed that, the interaction between maize varieties and nitrogen rates were highly significant (P≤.001). Results showed that *Meru* HB and *Faru* HB at 50 – 62.5 kg Nha^{-1} recorded maximum grain weight as follows; (4.025, 3.892 kg, 4.092 kg, 4.100 kg). (Table 29). This might be due to the fact that, hybrid maize varieties have higher grain yield potential and nitrogen use efficiency leading to highe grain weight. Lowest grain weight was recorded in *Situka* M1 at 50 – 62.5 $kgNha^{-1}$as follows; (3.142 kg, 3.092 kg). This might be due to low grain yield potential and nitrogen use efficiency leading to lower grain weight.

Further, the interaction between fertilizer types and nitrogen rates were significant (P≤.001). Results indicated that *Minjingu Mazao* and NPK Cereal gave maximum grain weight when nitrogen levels were N_{50} and $N_{62.5}$ (Table 30). These results are similar with the results of Akram *et al.* (2010) who reported that grain weight increases with increase in nitrogen levels. The results are partly in agreement with those of Oktem *et al*. (2005) who reported that higher 1 000 grain weight was increased at certain levels of fertilization. Furthermore, the interaction between maize varieties, fertilizer types and nitrogen rates were significant (P≤0.009). Results showed that *Meru* HB and *Faru* HB when treated with

Minjingu Mazao and NPK cereal at nitrogen levels 50 – 62.5 kgNha^{-1} gives higher grain weight (Table 31).

4.14.6 Grain yield

Data for grain yield is given in (Table 28). The results indicated significant (P≤.001) enhancement in maize yield due to application of different levels of nitrogen. The yield in the control was 3.37 t ha^{-1}and maximum yield of 5.21 t ha^{-1} from the plots treated with 50kg N ha^{-1}. This demonstrated the importance of supplying nitrogen in maize production for yield increase. Grain yield from plot where 37.5 kg Nha^{-1} was applied, grain yield was 4.13 t ha^{-1}, The results above showed that Nitrogen at 0 and 37.5 kg N ha^{-1} had low grain yield per hectare compared with other plots treated with 50 and 62.5 kg N ha $^{-1}$ (Table 28) It was also observed that, the interaction between maize varieties and nitrogen rates were significant (P≤0.041). Results showed that *Meru* HB and *Faru* HB at 50 – 62.5 kg Nha^{-1} recorded maximum grain yield as follows; (4.615 t ha^{-1}, 4.458 t ha^{-1}, 4.692 t ha^{-1}, 4.696 t ha^{-1}) (Table 29). This might be due to the fact that, hybrid maize varieties have higher grain yield potential and nitrogen use efficiency leading to higher grain yield. Lowest grain yield was recorded in Situka M1 at 50 – 62.5 kgNha^{-1}as follows; (3.603 t ha^{-1}, 3.541 t ha^{-1}). This might be due to low grain yield potential and nitrogen use efficiency leading to lower grainyield.

Further, the interaction between fertilizer types and nitrogen rates were significant (P≤0.01). The results indicated that *Minjingu Mazao* and NPK Cereal fertilizers gave maximum grain yield when nitrogen levels were N_{50} and $N_{62.5}$ (Table 30). Similar pattern of response to mixed fertilizers in maize was also given by Lana *et al*. (2007). This yield was contributed by vital nutrients supplied such as N, P, K, S and Zn and may have enhanced photosynthesis, early growth and better partitioning of assimilates to grain and final yield. These results are similar with the results of Akram *et al.* (2010) who reported that grain yield increases with increase in nitrogen levels.

Furthermore, the interaction between maize varieties, fertilizer types and nitrogen rates were significant ($P \leq 0.0094$). Results showed that *Meru* HB and *Faru* HB when treated with *Minjingu Mazao* and NPK cereal fertilizers at nitrogen levels 50 – 62.5kg N ha^{-1} gives higher grain yield (Table 31).

4.15 Correlation Between Yieldcomponents and Grain Yield

Correlation analysis results are indicated in (Table 34). Significant ($P<0.0001$) and positive correlationwere observed between grains per cob (r =0.84, $P<0.0001$), cob length(r= 0.759, $P<0.0001$), grain weight (r = 0.81, $P<0.0001$) and 1 000 grain weight (r =0.81, $P<0.0001$)to grain yield. All correlations between yield components and yield were found to be of high values as indicated above. Similar results were reported in Egypt by Shoa *et al.* (2009) in his study on correlation results between grain per cob (r = 0.808), cob length (r= 0.963), grain weight (r= 0.581) and 1 000 grain weight (r = 0.489).

Similar results from Tanzania such as those reported by Odongoand Bilaro (1980, 2008) indicate that maize yields are positively correlated with grains per cob, cob length and 1 000 grain weight. According to Panwar *et al.* (2006), working in Ethiopia, application of N and P fertilizers induce the uptake ability of the roots to nutrients and positive increase in the yield parameters because of improving the root system as a source-sink relationship to the reproductive part (shoot).

Table 32: **Correlation between yield components and grain yield of maize**

	GY	**GW**	**GC**	**1000GW**	**CL**
GY	-	P <0.0001	P <0.0001	P <0.0001	P <0.0001
GW	P <0.0001	-	P <0.0001	P <0.0001	P <0.0001
GC	P <0.0001	P <0.0001	-	P <0.0001	P <0.0001
1 000GW	P <0.0001	P <0.0001	P <0.0001	-	P <0.0001
CL	P <0.0001	P <0.0001	P <0.0001	P <0.0001	-

KEY: GY = Grain yield; GW = Grain weight; GC = Grains per cob; 1 000GW = One thousand grain weight; CL= Cob Length, **Highly significant at (P ≤0.01)

4.16 Results on Effect of Different Nutrients Uptake

4.16.1 Nitrogen

Data on nutrient uptake is presented in (Tables 33, 34, 35, 36). Results show that, nitrogen uptake was significantly (P≤0.008) affected by the treatments applied among maize varieties. M*eru* HB 513 and *Faru* HB recorded the highest N uptake (2.68%, 2.67% respectively) compared with Situka M1 (2.56%). Further, *Minjingu Mazao* and NPK cereal top dressed with nitrogen levels 50 – 62.5 kgNha^{-1} resulted intohighlysiginificant (P≤.001) N uptake (3.11%, 3.11%, 3.3% , 3.35%, 3.11%, 3.14%, 3.3%, 3.29% respectively) compared with DAP (2.96%, 2.99%, 2.97%, 3.01%respectively). According to Campbell and Plank (2000, the critical nitrogen range for maize crop is between 2.8 – 4.0%. The lowest N uptake by the crop (1.91%) as expected was recorded from the control (with no fertilizers). This could have been due to low initial soil nitrogen content as indicated in (Table 2) which was 0.04% (0.88 kg N ha^{-1}). Similar results were reported in Southern Malawi by Akinnifesi *et al.* (2007) on effect of N fertilizers in *dorke* maize variety, that recorded higher nitrogen uptake of 3.3% and was within the sufficient range for maize crop (Campbell and Plank, 2000). According to Hussaini *et al*. (2008) reported that total N uptake by the maize crop was significantly affected by nitrogen fertilizerapplication. Uptake of N by the maize crop increased significantly with increasing in N application. For example, application of 180 kg N ha^{-1} increased N uptake by 217.1%.

Table 33: Effect of maize varieties on N and P uptake

Treatments	N (%)	P (%)
Situka M1	2.56 a	0.23 a
Meru HB 513	2.68 b	0.23 a
Faru HB	2.67 b	0.23 a
Mean	2.67	0.23
SD	0.05	0.011
CV (%)	2.1	5.6
P- Value	0.008	0.95

Means followed by the same letters in the same column are not significantly different (P =0.05) according to Tukey's HSD test

Table 34: Effect of N, P fertilizers on N and P uptake

Treatments	N (%)	P (%)
Control	1.91 a	0.06 a
DAP	2.87 b	0.26 b
Minjingu Mazao	2.88 b	0.30 c
NPK Cereal	3.01 b	0.29 c
Mean	2.67	0.23
SD	0.04	0.01
CV (%)	3.5	7.5
P value	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test.

Table 35: Effect of different nitrogen levels on N and P uptake

Treatments	N (%)	P (%)
N_0	2.23 a	0.17 a
$N_{37.5}$	2.69 b	0.22 b
N_{50}	2.86 c	0.26 c
$N_{62.5}$	2.89 c	0.27 c
Mean	2.67	0.23
SD	0.04	0.01
CV (%)	6.2	15.8
P value	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test.

Table 36: Interaction effects between maize varieties, N, P fertilizers and Nitrogen levels on N and P uptake

Treatments	**N (%)**	**P (%)**
Situka x control x $N_{37.5}$	1.92 a	0.04 a
Situka x control x N_0	1.48 a	0.04 a
Situka x control x N_{50}	1.95 a	0.06 a
Situka x control x $N_{62.5}$	2.03 a	0.06 a
Situka x DAP x $N_{62.5}$	2.89 a	0.29 a
Situka x DAP x $N_{37.5}$	3.02 a	0.27 a
Situka x DAP x N_{50}	2.80 a	0.29 a
Situka x DAP x N_0	2.14 a	0.19 a
Situka x MM x $N_{62.5}$	2.97 a	0.39 a
Situka x MM x $N_{37.5}$	2.87 a	0.26 a
Situka x MM x N_0	2.65 a	0.19 a
Situka x MM x N_{50}	2.98 a	0.36 a
Situka x NPK x $N_{62.5}$	3.15 a	0.35 a
Situka x NPK x N_{50}	3.12 a	0.35 a
Situka x NPK x N_0	2.49 a	0.21 a
Situka x NPK x $N_{37.5}$	3.02 a	0.25 a
Meru 513 x control x $N_{62.5}$	2.18 a	0.06 a
Meru 513 x control x N_0	1.54 a	0.04 a
Meru 513 x control x N_{50}	2.1 a	0.06 a
Meru 513 x control x $N_{37.5}$	2.06 a	0.05 a
Meru 513 x DAP x $N_{37.5}$	2.96 a	0.24 a
Meru 513 x DAP x N_0	2.28 a	0.21 a
Meru 513 x DAP x N_{50}	2.96 a	0.28 a
Meru 513 x DAP x $N_{62.5}$	2.99 a	0.28 a
Meru 513 x MM x N_{50}	3.11 a	0.36 a
Meru 513 x MM x $N_{37.5}$	2.93 a	0.27 a
Meru 513 x MM x N_0	2.66 a	0.18 a

Meru 513 x MM x $N_{62.5}$	3.11 a	0.36 a
Meru 513 x NPK x $N_{37.5}$	2.95 a	0.26 a
Meru 513 x NPK x N_{50}	3.3 a	0.38 a
Meru 513 x NPK x $N_{62.5}$	3.35 a	0.37a
Meru 513 x NPK x N_{0}	2.42 a	0.24 a
Faru x control x N_{50}	2.04 a	0.06 a
Faru x control x $N_{62.5}$	2.12 a	0.07 a
Faru x control x $N_{37.5}$	2.0 a	0.05 a
Faru x control x N_{0}	1.53 a	0.04 a
Faru x DAP x $N_{62.5}$	3.01 a	0.29 a
Faru x DAP x $N_{37.5}$	3.02 a	0.25 a
Faru x DAP x N_{50}	2.97a	0.28 a
Faru x DAP x N_{0}	2.28 a	0.21 a
Faru x MM x $N_{62.5}$	3.14 a	0.34 a
Faru x MM x $N_{37.5}$	2.84 a	0.32 a
Faru x MM x N_{50}	3.11 a	0.35 a
Faru x MM x N_{0}	2.68 a	0.22 a
Faru x NPK x N_{0}	2.57 a	0.23a
Faru x NPK x $N_{37.5}$	2.74 a	0.27a
Faru x NPK x N_{50}	3.3 a	0.31 a
Faru x NPK x $N_{62.5}$	3.29 a	0.31 a
Mean	2.67	0.23
SD	0.115	0.025
CV (%)	4.4	11.5
P value	0.896	0.796

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test

4.16.2 Phosphorus

Results on nutrient uptake is presented in (Tables 33, 34, 35, 36). Data show that, phosphorus uptake was not significantly ($P \leq 0.95$) affected by the type of fertilizers appliedamong maize varieties. All maize varieties used in this study *Situka* MI, M*eru* HB 513 and *Faru* HB recorded the P uptake of (0.23%, 0.23% , 0.23% respectively). Further, *Minjingu Mazao* and NPK cereal top dressed with nitrogen levels 50 – 62.5 kgNha^{-1} recorded highest P uptake (0.36%, 0.36%, 0.38%, 0.37%, 0.35%, 0.34%, 0.31%, 0.31% respectively) compared with DAP (0.29%,0.29%, 0.28%, 0.29% respectively). According to Tandon (1995), the critical range of P in maize crop is 0.31 – 0.40 %. Similar results were reported in Southern Malawi by Akinnifesi *et al.* (2007) on effect of P fertilizers in DORKE maize variety, that resulted higher phosphorus uptake of 0.31 – 0.40 % which was within the sufficient range for maize crop (Tandon, 1995). The lowest P uptake (0.06% = 1.3 kg P/ha) as expected was recorded from the control (with no fertilizers). This is because, there was no P fertilizer that was applied.These results are in agreement by Panwar *et al*. (2006) that application of P fertilizers induced the uptake ability of the roots to scavange formore nutrients and therefore higher nutrient uptake.

4.16.3 Ca, Mg, S, Zn, B

Results on nutrient uptake is presented in Appendix 1, 2, 3, 4. Data show that, Ca, Mg, S, Zn, and B uptake were highly significant ($P \leq .001$) among maize varieties and N, P fertilizers and were within sufficient range according to Campbell and Plank (2000). The high uptake may have been influence by the type of fertilizer applied. For example *Minjingu Mazao*which contains (N10%, P_2O_5 20%, S 5%, Zn 0.5%, B 0.1%, Cao 17.4%, MgO 1.9%) resulted into uptake of 0.58% Ca, 0.31% Mg, 0.21% = S, 26.72mg/kg, 9.29 ppm. NPK Ceral which contains (23-10-5 + 2 MgO +3 S + 0.3 Zn) resulted to uptake of 0.62% Ca, 0.33% Mg, 0.22% S, 28.33Mg, 9.79ppm Boron respectively. According to

Campbell and Plank (2000), these values are within sufficient range for maize crop. Similar results were reported in Southern Malawi by Akinnifesi *et al.* (2007) oneffect of N, P fertilizers in DORKEmaize variety, that recorded higher micronutrients uptake of 20 – 70 mg kg^{-1} for Zn, 0.1 – 0.24% for S, 0.6% for Ca, 0.33% for Mg, and 30.4 ppm for B.

Application of N, P fertilizers could be accounted for by the increased maize root growth hence increased ability of the maize plants to scavenge for more of these nutrients.The uptake of Ca, Mg, S, Zn and Bin DAP (N18%, P_2O_5 46%) applied treatments were low(0.39% Ca, 0.16% Mg, 0.17%S, 17.38 mg/kg Zn, 6.0 ppm B because does not contain micronutrients . Control plots showed the lowest (0.33% Ca, 0.18% Mg, 0.15% S, 14.87 mg/kg Zn, 5.14 ppm B levels in maize crops. These levels are inadequate according to Campbell and Plank (2000). Therefore, there is a need to apply fertilizers containing these nutrients to obtain optimum yield of maize.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The soils of Miwaleni are sandy clay soils with a ph of 6.1 characterized by low organicmatter as well as low fertility status with respect to N, P, K, S, Ca, Mg, Zn and B. Results show that best crop performance was observed in *Faru* HB (4.12 t ha^{-1}), followed by *Meru* HB 513(3.98 t ha^{-1}), and the last was *Situka* M1(3.01t ha^{-1}) maize variety. Such results are four times higher than those commonly obtained by small scale farmers which are 0.7 – 1.2 t ha $^{-1}$.The Maize crop performance was best when supplied with *Minjingu Mazao*at kg 71 kg P ha^{-1} (N10%, P_2O_5 20%, S 5%, Zn 0.5%, B 0.1%, Cao 17.4%, MgO 1.9%), and NPKCereal at 124 kg P ha^{-1}(23-10-5 + 2 MgO +3 S + 0.3 Zn), fertilizers.

Further, Maize Varieties had significant effect on grain yield and yield components as *Situka*M1 recorded 3.01t ha^{-1}, *Meru* HB 513, *Faru* HB recorded 3.98t ha^{-1}, 4.12t ha^{-1} respectively. However, all yield components were consistently highly correlated to maize grain yield ($P<.001$). It was also noted that fertilizers such as *Minjingu Mazao at* 71 kg P ha^{-1} (N10%, P_2O_5 20%, S 5%, Zn 0.5%, B 0.1%, Cao 17.4%, MgO 1.9%), and NPK Cereal at 124 kg P ha^{-1}(23-10-5 + 2 MgO +3 S + 0.3 Zn) had significant effect on grain yield and yield components.

Furthermore, current results indicate that nitrogen levels had significant effect ($P<.001$) on yield and yield components of maize varieties. The highest nutrient uptake was recorded under the *Minjingu Mazao* and NPK Cereal fertilizers at the level of 50-62.5 kg N ha^{-1} that resulted to 3.11%N, 0.36%P, and 3.11%N, 0.36%P), (3.3%N, 0.38%N, and 3.35%N, 0.37%P), (3.11%N, 0.35%P, and 3.14%N, 0.34%P), (3.3%N, 0.31%P, and

3.29%N, 0.31%P). Also, such uptake by *Meru* HB 513 and *Faru* HB supplied with *Minjingu Mazao* and NPK cereal fertilizers, at the same rates mentioned above resulted intosignificantly high yield and yield components as mentioned above.

5.2 Recommendations

Although farmers are advised to use Situka MI in the study area, from this study it is recommended that much as most maize famers use *Situka* MI, it is advised that, the extension officers (government, NGO, CBO) should encourage maize growers in the study area to use *Meru* and *Faru* maize varieties.

Basing on the results from this study, in order to optimize maize yield, it is strongly advised that, *Minjingu Mazao* and NPK Cereal should be applied then top dressed with nitrogen at 50kg N ha^{-1} and 62.5 kg Nha^{-1} when maize crop is grown under conditions indicated and when the crop is irrigated whenever necessary.

Since the soil chemical analysis at Miwaleni indicated low micro nutrients, it is advised that field studies on influences of micronutrients on maize yield be initiated in the area as such studies have not been conducted. Further, it is advised that the relevant authority should conduct more research on the use of the locally available fertilizer (*Minjingu Mazao*) in order to increase its use in various areas of maize growers in Tanzania as the present study indicates promising results on its use on the crop.

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APPENDICES

Appendix 1: Effect of maize varieties on uptake of S, Zn, Mg, Ca, B

Treatments	**S**	**Zn**	**Mg**	**Ca**	**B**
	….%....	**Mg/kg**	**….%....**	**….%....**	**ppm**
Situka M1	0.15 a	14.87 a	0.18 a	0.33 a	5.14 a
Meru HB 513	0.18 b	22.36 b	0.23 b	0.49 b	7.72 b
Faru HB	0.18 b	22.27 b	0.23 b	0.49 b	7.69 b
Mean	0.17	19.83	0.22	0.44	6.85
SD	0.006	0.25	0.01	0.01	0.09
CV (%)	4.7	1.5	3.1	1.6	1.5
P- Value	0.019	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P = 0.05) according to Tukey's HSD test.

Appendix 2: Effect of N, P fertilizer types on uptake of S, Zn, Mg, Ca, B

Treatments	**S**	**Zn**	**Mg**	**Ca**	**B**
	….%....	**Mg/kg**	**….%....**	**….%....**	**ppm**
Control	0.07 a	6.89 a	0.06 a	0.16 a	2.38 a
DAP	0.17 b	17.38 b	0.16 b	0.39 b	6.00 b
Minjingu	0.21 c	26.72 c	0.31 c	0.58 c	9.23 c
NPK	0.22 c	28.33 d	0.33 c	0.62 d	9.79 d
Mean	0.17	19.83	0.22	0.44	6.85
SD	0.007	0.392	0.014	0.011	0.136
CV (%)	8.9	4.2	13.9	5.1	4.2
P value	<.001	<.001	<.001	<.001	<.001

Means followed by the same letters in the same column are not significantly different (P =0.05) according to Tukey's HSD test.

Appendix 3: Effect of nitrogen levels on uptake of S, Zn, Mg, Ca, B

Treatments	S ….%....	Zn Mg/kg	Mg ….%....	Ca ….%....	B ppm
N_0	0.17 b	16.43 a	0.14 a	0.47 b	7.09 c
$N_{37.5}$	0.19 bc	21.65 c	0.24 b	0.19 a	7.56 d
N_{50}	0.13 a	23.35 d	0.23 b	0.54 c	6.14 a
$N_{62.5}$	0.19 c	17.90 b	0.26 b	0.54 c	6.61 b
Mean	0.17	19.83	0.22	0.44	6.85
SD	0.01	0.37	0.02	0.02	0.07
CV (%)	18.1	8.0	41.4	18.2	4.4
P value	<.001	<.001	<.001	<.001	<.001

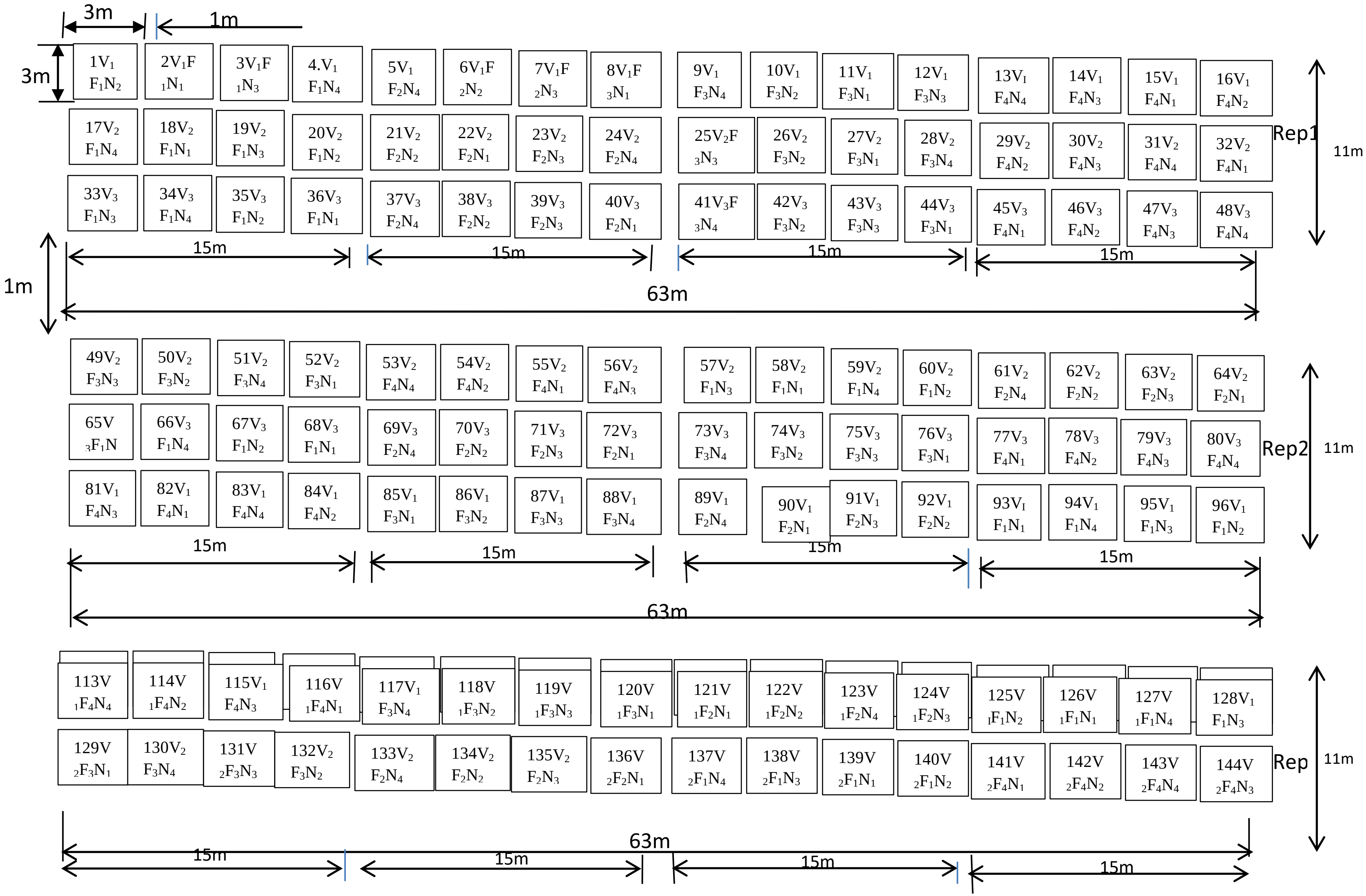
Means followed by the same letters in the same column are not significantly different (P =0.05) according to Tukey's HSD test.

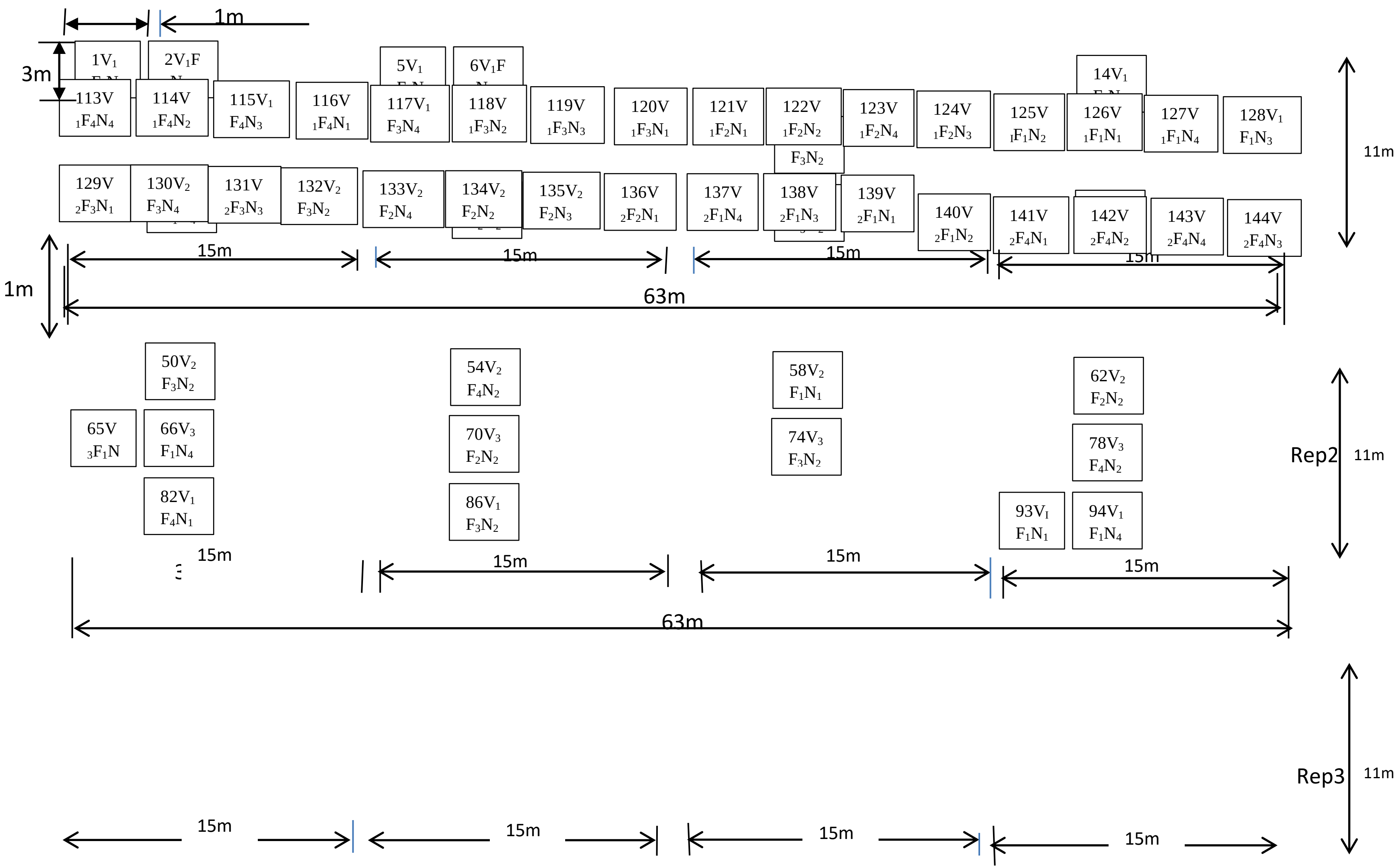
Appendix 4: Interaction between, maize varieties, N-P fertilizers and Nitrogen levels on uptake of S, Zn, Mg, Ca, and B

Treatments	S ….%....	Zn Mg/kg	Mg ….%....	Ca ….%....	B ppm
Situka x control x $N_{37.5}$	0.08 a	6.99 ab	0.09 a	0.06 a	2.44 abc
Situka x control x N_0	0.06 a	5.31 a	0.05 a	0.15 a	2.28 ab
Situka x control x N_{50}	0.04 a	7.54 ab	0.02 a	0.18 abc	1.98 a
Situka x control x $N_{62.5}$	0.09 a	5.78 a	0.05 a	0.18 abc	2.13 a
Situka x DAP x $N_{62.5}$	0.19 a	12.31 bc	0.10 a	0.39 def	4.55 de
Situka x DAP x $N_{37.5}$	0.17 a	14.89 cd	0.2102 a	0.13 a	5.20 defg
Situka x DAP x N_{50}	0.08 a	16.07 cde	0.06 a	0.39 def	4.22 bcd
Situka x DAP x N_0	0.12 a	10.67 abc	0.1252a	0.30 bcd	4.60 cdef
Situka x MM x $N_{62.5}$	0.22 a	16.68 cdef	0.35 a	0.44 defg	6.16 defgh
Situka x MM x $N_{37.5}$	0.21 a	21.01 efgh	0.22 a	0.16 ab	7.33 h
Situka x MM x N_0	0.18 a	15.95 cde	0.1394 a	0.45 efg	6.87 gh
Situka x MM x N_{50}	0.12 a	22.66 fh	0.33 a	0.55 eg	5.96 defgh
Situka x NPK x $N_{62.5}$	0.23 a	18.21 defgh	0.38 a	0.57 g	6.72 fgh
Situka x NPK x N_{50}	0.12 a	23.75 h	0.36 a	0.57 g	6.24 efgh
Situka x NPK x N_0	0.19 a	16.72 cdefg	0.14 a	0.48 efg	7.20 h
Situka x NPK x $N_{37.5}$	0.23 a	22.02 fgh	0.25 a	0.19 abc	7.68 h
Meru 513 x control x $N_{62.5}$	0.10 a	6.59 a	0.05 a	0.20 bcd	2.43 a
Meru 513 x control x N_0	0.06 a	6.05 a	0.06 a	0.17 ab	2.61 a
Meru 513 x control x N_{50}	0.04 a	8.60 a	0.03 a	0.20 bcd	2.26 a

Meru 513 x control x $N_{37.5}$	0.09 a	7.97 a	0.11 a	0.06 a	2.78 a
Meru 513 x DAP x $N_{37.5}$	0.22 a	21.01 bcd	0.29 a	0.18 abc	7.33 b
Meru 513 x DAP x N_0	0.1834a	15.95 b	0.15 a	0.45 e	6.87 b
Meru 513 x DAP x N_{50}	0.12 a	22.66 cde	0.08 a	0.55 e	5.96 b
Meru 513 x DAP x $N_{62.5}$	0.22 a	17.37 bc	0.15 a	0.55 e	6.41 b
Meru 513 x MM x N_{50}	0.1935a	35.86 h	0.46 a	0.81 fg	9.43 c
Meru 513 x MM x $N_{37.5}$	0.15a	33.25 gh	0.28 a	0.29 cd	11.60 de
Meru 513 x MM x N_0	0.23 a	25.24 def	0.173 a	0.72 f	10.88 cde
Meru 513 x MM x $N_{62.5}$	0.24 a	27.49 efg	0.47 a	0.82 fg	10.15 cd
Meru 513 x NPK x $N_{37.5}$	0.23 a	35.38 h	0.38 a	0.30 d	12.35 e
Meru 513 x NPK x N_{50}	0.20 a	38.16 h	0.36 a	0.83 fg	10.03 cd
Meru 513 x NPK x $N_{62.5}$	0.23 a	29.25 fg	0.40 a	0.84 g	10.80 cde
Meru 513 x NPK x N_0	0.25 a	26.86 def	0.22 a	0.77 fg	11.58 de
Faru x control x N_{50}	0.04 a	8.18 a	0.03 a	0.19 bcd	2.15 a
Faru x control x $N_{62.5}$	0.09 a	6.27 a	0.05 a	0.19 bcd	2.31 a
Faru x control x $N_{37.5}$	0.08 a	7.58 a	0.10 a	0.06 a	2.64 a
Faru x control x N_0	0.06 a	5.76 a	0.05 a	0.16 ab	2.48 a
Faru x DAP x $N_{62.5}$	0.22 a	17.37 bc	0.15 a	0.55 e	6.41 b
Faru x DAP x $N_{37.5}$	0.21 a	21.01 bcd	0.29 a	0.18 bc	7.33 b
Faru x DAP x N_{50}	0.12 a	22.66 cde	0.08 a	0.55 e	5.96 b
Faru x DAP x N_0	0.18 a	15.95 b	0.15 a	0.45 e	6.87 b
Faru x MM x $N_{62.5}$	0.23 a	27.49 efg	0.44 a	0.81 fg	10.15 cd
Faru x MM x $N_{37.5}$	0.27 a	33.25 gh	0.27 a	0.29 cd	11.60 de
Faru x MM x N_{50}	0.19 a	35.86 h	0.45 a	0.80 fg	9.43 c
Faru x MM x N_0	0.22 a	25.24 def	0.17 a	0.72 f	10.88 cde
Faru x NPK x N_0	0.22 a	26.86 def	0.19 a	0.77 fg	11.58 de
Faru x NPK x $N_{37.5}$	0.23 a	35.38 h	0.30 a	0.30 d	12.35 e
Faru x NPK x N_{50}	0.20 a	38.16 h	0.44 a	0.87 g	10.03 cd
Faru x NPK x $N_{62.5}$	0.23 a	29.25 fg	0.46 a	0.86 g	10.80 cde
Mean	0.17	19.83	0.22	0.44	6.85
SD	0.023	0.675	0.042	0.024	0.224
CV (%)	15.8	1.6	23.9	5.6	0.9
P value	0.057	<.001	0.693	0.002	<.001

Appendix 5: Experimental layout from study area

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2V1F
5V1
6V1F
14V1
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114V 1F4N2
115V1 F4N3
116V 1F4N1
117V1 F3N4
118V 1F3N2
119V 1F3N3
120V 1F3N1
121V 1F2N1
122V 1F2N2
F3N2
123V 1F2N4
124V 1F2N3
125V 1F1N2
126V 1F1N1
127V 1F1N4
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129V 2F3N1
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142V 2F4N2
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144V 2F4N3
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1m
15m
15m
15m
15m
63m
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54V2 F4N2
58V2 F1N1
62V2 F2N2
65V 3F1N
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70V3 F2N2
74V3 F3N2
78V3 F4N2
82V1 F4N1
86V1 F3N2
93V1 F1N1
94V1 F1N4
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15m
15m
15m
15m
63m
Rep3
11m
15m
15m
15m
15m