LOCALIZING ETHIOSIS FERTILITY MAP BASED FERTILIZER TYPE RECOMMENDATION FOR MAIZE (*ZEA mays* L.) IN COFFEE AND SPICE PRODUCTION BELT IN YEKI DISTRICT, SOUTHWEST OF ETHIOPIA

M.Sc. THESIS

BY:

MULISA WEDAJO ABDI

November 2019

JIMMA, ETHIOPIA

LOCALIZING ETHIOSIS FERTILITY MAP BASED FERTILIZER TYPE RECOMMENDATION FOR MAIZE (*ZEA mays* L.) IN COFFEE AND SPICE PRODUCTION BELT IN YEKI DISTRICT, SOUTHWEST OF ETHIOPIA

`

BY

MULISA WEDAJO ABDI

November 2019

JIMMA, ETHIOPIA

DEDICATION

This thesis is dedicated to my father Mr. Wedajo Abdi and my mother Mrs. Gadise Gonfa for their dedicated partnership in the success of my life.

STATEMENT OF THE AUTHOR

First of all, I declare that this is my work and that all sources of the materials used for writing have been properly acknowledged. I have submitted this thesis to Jimma University, College of Agriculture and Veterinary Medicine in partial fulfillment of the requirements of Master of Science in Soil science. This thesis is deposited at the University Library to be made available to borrowers under the rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Brief quotations from this thesis are allowable without special permission provided that accurate acknowledgment of the source is made. Request for permission for extended quotation from or reproduction of this manuscript in the whole or any part may be granted by the Dean or Coordination of the School of Graduate Studies or Head of the Department of Natural Resource management when the proposed use of the material is in the interest of scholarship. In all other cases, however, permission must be obtained from the author.

Name: Mulisa Wedajo Abdi signature______________________________

Place: Jimma University, Jimma

Date of submission ______________________________

BIOGRAPHICAL SKETCH

The author, Mulisa Wedajo was born on July 25, 1998, at Beke town, West Showa, Oromia regional state from his father Mr. Wedajo Abdi and mother Mrs. Gadise Gonfa. He attended his primary education at Beke Abbo from 1996-2004 and Secondary and preparatory School from 2005 to 2009 at Ginchi. He joined Jimma University in the 2010 academic year and graduated with a Bachelor Science degree in Agriculture (Plant Science) in June 2012. Then, after his graduation, he was employed by Ethiopia Institute of Agriculture Research, in Tepi Agricultural Research Center, South Nation Nationality People Regional state and worked being junior researcher on soil fertility and health management from July 2014 to September 2017. Then, he joined Jimma University College of Agriculture and Veterinary Medicine, School of Graduate Studies in October 2017 to attend his Master of Science degree in Soil Science.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude and appreciation to my advisor Dr. Selamyihun Kidanu and Dr. Alemaheyu Reggasa for their excellent guidance and support throughout my research.

I would like to acknowledge Ethiopia Institutes of Agricultural Research for budget funded for my experiment input. I also wish to express my thanks to Tepi Agricultural Research Center and its staff for their cooperation during fieldwork. I do not have enough words to express my gratitude and sincere thanks to Mr. Guta Amante who supported me not only from the beginning, but actually lived this dream with me. Very special thanks to Mr. Tesfaney Ejegu for his support of my work from field experiment to completion. My thanks are extended also to Mr. Adena Teshoma for his support during field data collection. I express my thanks to Jimma Agricultural Research Center Soil and Plant Analysis Research Laboratory and its staff for their kindness to plant tissue analysis.

I would like my special thanks to my parents; my father and mother for their endless prayers and wishes. I would like to thank my sisters and brothers for their support in all possible ways to help me to achieve this goal.

Last but not least, thank you to Mr. Reta Ajema, Shemil Alo and Mr. Fekedu Mekonnen for their friendship and sharing of knowledge and experiences, constant support and encouragement throughout my study.

LIST OF ACRONYMS AND ABBREVIATIONS

Acronyms

AAS	Atomic Absorbance Spectrophotometer
AEZ	Agro-ecological Zones
ANOVA	Analysis of Variance
ATA	Agricultural Transformation Agency
CEC	Cation Exchange Capacity
CIMMYT	International Maize and Wheat Improvement Center
CSA	Central Statically Agency
DAP	Diammonium Phosphate
DTPA	diethylenetriamine penta-acetic acid
ETB kg^{-1}	Ethiopian Birr kilogram per hector
EthioSIS	Ethiopian Soil Information system
FAO	Food and Agricultural Organization
FCU	farmer corporative union
GDP	Gross Domestic Product
GTP	Growth and Transformation Plan
IAA	Idole-acetic acid
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
IITA	International Institute for Tropical Agriculture
KCl	Potassium chloride
kg ha^{-1} yr^{-1}	kilogram per hector per year
LSD	List significant difference
MARR	Minimum acceptable rate of return
MoA	Minister of Agriculture
MRR	Marginal rate of return
PIF	Public investment fund
RNA	Ribonucleic acid
SAS	Statically analysis software

SG2000	Sasakawa Global
SNNPRS	South Nation Nationality People Regional State
SSA	Sub-Saharan Africa
t/ha	Tone per hector
TSP	Triple Super Phosphate

Abbreviations

B	Boron
Ca	Calcium
Cu	Copper
Fe	Iron
H_2SO_4	Sulfuric acid
K	Potassium
KCl	Potassium chloride
L	Litter
Mg	Magnesium
N	Nitrogen
NaCl	Sodium chloride
NaOH	Sodium hydroxide
NH3	Ammonia
P	Phosphorous
pH	Power of Hydrogen
S	Sulfur
US$	United state Dollar
Zn	Zink

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF TABLE IN APPENDIX

FIGURE IN APPENDIX

Localizing EthioSIS Fertility Map Based Fertilizer Type Recommendation for Maize (*Zea mays* L.) in Coffee and Spice Production Belt in Yeki District, Southwest of Ethiopia

ABSTRACT

Maize (Zea mays L) is an important smallholder crop in Ethiopia. However Yields are low because of low soil fertility and little fertilizer use. This field experiment was conducted to evaluate the effectiveness of NPS and NPSB, fertilizer types recommended by EthioSIS for the study domain during the 2018 main cropping season. The treatments were laid out in a randomized complete block design with four replications. Treatments were consisting of the two new fertilizer types (NPS and NPSB) kg ha^{-1} applied at rate of 150, 200, 250 each combined with two rates of urea kg ha^{-1} (100 and 150) and recommendation NP kg ha^{-1} (92N and 69 P_2O_5) and control. Data on selected soil physicochemical properties and maize nutrient uptake, use efficiency and profitability of fertilizer were taken. Yield and yield components of maize subjected to statistical analysis using SAS; mean treatment difference was compared using LSD. The results of the soils in the study area were slightly acidic (6.27 pH), Clay texture with moderate in TN (0.24%), available sulfur (13.14 ppm) and boron (0.99 ppm), high in K (550.80 ppm), OC (2.64 %) and CEC (30.89 cmol (+) kg^{-1}), low in available P Olsen (5ppm). Maize plants in NPS and NPSB fertilizers treated plots had larger ear length (37.55cm)and cob length (18.05cm) and higher thousand grain weight (425.31gm), grain yield (8828.20 kg ha^{-1}), straw yield (8760 kg ha^{-1}), cob weight (1266.67 kg ha^{-1}), biological yield (18521.5 kg ha^{-1}), harvest index(0.47) and shelling percentage (0.88) compared to control and the recommended NP and the differences were highly significant ($p<0.01$). The number of ear per plant and number of grain rows per cob were none significantly ($p>0.05$) different, while number of grains per row were significant ($p<0.05$). Maize grain yield were highly significantly ($p<0.01$) and positively correlated with plant height, ear length, thousand seed weight, straw yield, biological yield, harvest index, shelling percentage and significantly ($p<0.05$) and positive correlation with number of grain per cob and none significantly ($p>0.05$) and positively correlated with ear height. Fertilizer NPS and NPSB along with urea and potassium had improved nutrient concentration, uptake, agronomic efficiency and apparent recovery as compared to recommended NP fertilizer, but it did not influence physiological P use efficiency. Application of NPSB at a rate of 250 with 100 urea and 100 KCl kg ha^{-1} had minimum acceptable marginal rate of return, highest net benefit and relatively small total cost of production was recommended for maize production in Yeki District. NPS applied at a rate of 250 kg ha^{-1} with a similar rate of urea and KCl as above can be considered as the second alternative. The result indicates the site-specific fertilizer type recommendations reformed better than the recommended NP both in agronomic and economic sense at Yeki District. However, further validation and demonstrations across multiple environments will be necessary to make a conclusive recommendation.

Keywords: *grain yield, blanket fertilizer recommendation, nutrient uptake, soil pH*

1. INTRODUCTION

The decline in soil fertility is severe problem in tropical soils (Sanchez, 1976; Stocking, 2003 and FAO, 2015). This is due to inappropriate cropping systems, mono-cropping, nutrient mining, unbalanced nutrient application, removal of crop residues from the fields and inadequate resupplies of nutrients. Many African soils are affected by multiple nutrient deficiencies including the macronutrients (N, P and K), secondary macronutrients (S, Ca and Mg) and micronutrients (Zn, Fe, Cu, Mn and B) (Vanlauwe *et al*., 2015).

Crop productivity in the developing world faces several constraints. One of the major crop productivity constraints in the third world is the unavailability of crop nutrients in the appropriate amount and form to crops (Hussain *et al.,* 2006). Plants require a specific amount of certain nutrients in some specific form at appropriate times, for their growth and development. The roles of both macro and micronutrients are crucial in crop nutrition and thus important for achieving higher yields (Arif *et al.,* 2006). The drive for higher agricultural production without balanced use of fertilizers created problems of soil fertility exhaustion and plant nutrient imbalances not only of major but also of secondary macronutrient and micronutrients. The deficiencies of secondary macronutrient and micronutrient will arise if they are not replenished timely under intensive agriculture (Fageria and Baligar, 2008a; Fageria *et al*., 2012 and Singh, 2008).

Land degradation also among the major causes of low and in many places declining agricultural productivity and continuing food insecurity and rural poverty in Ethiopia (Taddese, 2001 and IFPRI, 2005). Locally available organic matter inputs have become more limiting due to increasing demand for fuel and fodder, as well as lower biomass production driven by declining soil fertility and competing uses (Selamyihun *et al*., 2005 and Nigussie *et al.,* 2007).

Fertilizer based green revolution has been attempted to improve crop yield at the beginning of the 1990s in some African countries, including Ethiopia (Quinones *et al*., 1997). Although the fertilizer based green revolution seemed successful in the first five years of its inception in Ethiopia, crop yields started to decline despite the continued fertilizer use. Continuous cultivation without appropriate farming practices has resulted in severe depletion of nutrients and soil organic matter, seriously threatening agricultural production (Zingore, 2011 and ATA, 2016). Thus, the decline in soil fertility is one of the major challenges to crop production and food security in Ethiopia (Sanchez, 2002).

Maize (*Zea mays* L.) is one of the major food crops in Ethiopia leading in volume of production and productivity (3.67 tons per hectare) (CSA, 2017). Yet, the national crop productivity remained low compared to the 4.7 t ha^{-1} reported from on-farm trials (IFPRI, 2010) and lower than the world average yield which is about 5.21 t ha^{-1} (FAO, 2011). Poor soil fertility is one of the bottlenecks for sustaining maize production and productivity in Ethiopia in general (Tolessa *et al.*, 1994 and Abebayehu *et al*., 2011).

Deficiencies of micronutrients have emerged as a new problem to crop productivity in Ethiopia (Yifru and Sofia, 2017). Different research reports indicate that nutrients like K, S, Ca, Mg and all micronutrients are becoming depleted and deficiency symptoms are being observed on major crops in different areas of the country (Abiye *et al.*, 2003 and Wassie *et al.*, 2011).

The Ethiopian soil information system (EthioSIS), a project launched by the Ethiopian Government's Agricultural Transformation Agency (ATA) in 2012, is a detailed soil map providing up-to-date soil fertility data. The result informs revealed that in addition to nitrogen and phosphorus, sulfur, boron and zinc deficiencies are widespread in Ethiopian soils, while some soils are also deficient in potassium, copper, manganese and iron ((EthioSIS, 2013, 2014, 2015 and Lelago *et al*., 2016), which all potentially hold back crop productivity despite continued use of N and P fertilizers as per the blanket recommendation. Therefore, fertilizer recommendation for crops in the country has until recently focused on Nitrogen and Phosphorus macronutrients only, but future gains in food grain production will be more difficult and expensive considering the increasing problem of multi soil nutrient deficiencies

After the soil fertility map is developed by Agricultural Transformation Agency (ATA) in 2016, 13 blended fertilizers containing N, P, K, S, B, Zn and Cu in different mix forms have been recommended for South Nation Nationalities and People Regional State (EthioSIS, 2016).

Instead of Urea and DAP, the fertilizer shall be distributed to smallholder farmers which own farmlands with a deficiency in some important nutrients. Here, the right rate of recommended type of fertilizer for the specific soil, ecology and crop type is important. Therefore, this study was initiated with the following objectives.

General objective;

- To evaluate site-specific fertilizer type recommendation of EthioSIS (NPS and NPSB)

Specific objectives;

- To determine optimum NPS and NPSB fertilizer application rates and economic feasibility for Maize
- To assess the differential response of Maize to NPS, NPSB and recommended NP fertilizer in terms of nutrient uptake and nutrient use efficiency
- To validate fertilizer type recommendation of EthoSIS

2. LITERATURE REVIEW

2.1 Importance of Fertilizer in Crop Production

A rapidly increasing world population demands ever-increasing food production. One of the major problems limiting crop production worldwide is nutrient deficiency. As much as 50% of the increase in crop yields worldwide during the twentieth century was due to the adoption of chemical fertilizers (Fageria and Baligar, 2005a and Fageria, 2009). In the twenty-first century, chemical fertilizers will play a major role in increasing crop yields, mainly due to limited land and water resources available for crop production and declining trends in crop yields globally (Fageria *et al.*, 2008a).

Low levels of essential crop nutrients can limit crop production. As a result, all plant nutrients that can limit crop growth must be determined for specific locations to enable the choice of proper fertilizers and the determination of appropriate rates of application. The use of manufactured P, K, S and micronutrient fertilizers in conjunction with N fertilizers in a balanced fertilization program is a key part of a total crop production system that enhances crop yields and sustains soil productivity (Alley and Vanlauwe, 2009). Nitrogen and phosphorus are the most limiting nutrients for crop production in sub-Saharan Africa (Sanchez, 1976; Bationo *et al.*, 2003 and Gikonyo and Smithson, 2003).

2.2 Concept of Soil Nutrient Balance

Effective nutrient management requires an accurate accounting of nutrients removed from soils in the harvested portion of a crop. From the agricultural sustainable point of view, nutrient management ideally should provide a balance between nutrient inputs and outputs over the long term (Bacon *et al*., 1990 and Heckman *et al*., 2003). In the establishment of a sustainable system, soil nutrient levels that are built up to levels that will support economic crop yields. To sustain soil fertility levels, nutrients that are removed by crop harvest or other losses from the system must be replaced annually or at least within the longer crop rotation cycle. When nutrient inputs as fertilizer, manure or waste materials exceed crop removal over the years, the soil becomes oversupplied and nutrient leaching and runoff become an environmental concern (Sims *et al*., 1998).

Accurate values for crop nutrient removal are an important component of nutrient management planning and crop production. A maize crop producing 9.5 tons of grain per hectare under North American conditions can remove the following amounts of nutrients through grain plus stover (IFA, 1992); macronutrients (kg ha^{-1}) N 191, P_2O_5 89, K_2O 235, MgO 73, CaO 57 and S 21 and micronutrients (gm ha^{-1}) Fe 130, Zn 380, Mn 340, B 240, Cu 110, Mo 9 and also 81 kg Cl. Study in Mid-Atlantic a maize grain harvest of 11 Mg ha^{-1} on average 3.3 harvest years would remove (N 120.8, P 36.7, K 44.7, S 9.9, Mg 14.4, Ca 2.6, Fe 0.33, Zn 0.25, B 0.055, Mn 0.045 and Cu 0.03) kg ha^{-1} (Heckman et al., 2003).

Soil nutrient balance studies in Africa show evidence of widespread nutrient mining (Sanchez, 2009). Amount of nutrients annually removed in the form of harvested crops, crop residues transferred out of fields or lost through leaching, erosion and volatilization are higher than the amount of nutrient inputs through chemical fertilizers and any other methods (Omotayo and Chukwuka, 2009). For example, soil nutrient mining has been estimated to average 660 kg of nitrogen, 75 kg of phosphorus and 450 kg of potassium per hectare per year during the last 30 years from about 200 million hectares of cultivated land in 37 countries in Africa (Sanchez, *et al*., 2009).

Continuous nutrient depletion and low soil fertility had not only led to the development of integrated soil fertility management technologies that offer potential for improving soil fertility in Africa (Tilahun, 2003) but almost simultaneously caused extensive studies on nutrient balance in various African farming systems. Low and declining soil fertility arises from continuous cultivation where levels of soil fertility replenishment, by whatever means are too low to mitigate the process of soil nutrient mining, whereby the soil fertility is to restore by new inputs. Intensively cultivated highlands in East Africa lose an estimated 36 kg N, 5 P and 25 K kg ha^{-1} yr^{-1} (Bekunda *et al*., 2010).

2.3 Soil Nutrient Depletion of Ethiopia

Soil fertility is critical to an agricultural economy in Ethiopia. The fertility status of Ethiopian soils has also declined and continued to decline to pose a challenge to crop production. Several studies both in and outside Ethiopia, have been carried out on the subject of soil nutrient depletion (Mesfin,1998; Haileselassie *et al*., 2005; Zingore, 2011; Amare *et al*., 2013 and Van Beek *et al*., 2016) did a study on the economics of improving household food security through targeting the nutrient depleted soils of Ethiopia. This is due to, continuous cropping (abandoning of fallowing), reduced manure application, removal of crop residues and animal dung for fuel wood and erosion coupled with low inherent fertility of the soils (Tilahun *et al.,* 2007). Due to their low organic matter content, most of the soils in Ethiopian have low total N content and there is a high crop response to N fertilizers in these areas (Attah, 2010).

On account of rapid nitrification, most of the N added as fertilizer containing NH4 is subject to leaching or de-nitrification soon after application. Ammonia fixation also affects fertilizer efficiency (Girma *et al.,* 2012). Most Ethiopian soils are deficient in P when analyzed by chemical methods, yet, with the addition of P fertilizers, field crop P responses on these soils, particularly in the central highlands are low, even under improved drainage conditions (Tekalign *et al*., 2002) owing to unbalanced fertilization.

Different studies conducted in Ethiopia in the past few years by various researchers have demonstrated that most Ethiopian soils have a very low level of P due to depletion or P fixation (Lalisa *et al.,* 2010). They considered a soil fertility replenishment product specifically designed to ameliorate nutrients depleted in different crop fields. Fertilizer is considered the most important input for the achievement of increased agricultural productivity and food security status of farm households in Ethiopia (Fufa and Hassan, 2006). Integrated application of lime with organic and blended fertilizer were given higher grain yield and economical feasible of barley as compared to no application of any input (Woubshet *et al*., 2017).

A Greenhouse assessment of micronutrient deficiency (Fe, Cu, Zn, B and Mo) in some Nitisols of Western Ethiopia on maize shows a significant yield reduction (Teklu *et al*., 2005). The research conclusion of Murphy (1968) stated that Ethiopian soils are rich in K and there was no need for K application, but nowadays since many crop responses to K have been reported from recent studies (Asgelil *et al*., 2007 and Admassu, 2015). Wassie and Shiferaw, (2011) also reported that the application of potassium has significantly and positively increased the tuber yield of potato at Chencha suggesting a low level of soil K and there is a need for application of K fertilizer.

2.4 Maize Production in Ethiopia

Maize is one of the most important cereal crops in Ethiopia, ranking second in area coverage and first in total production (CSA, 2017). Although it is one of the strategic crops for the achievement of food security in the country, more than 90% of the production is handled by small scale farmers under rain fed growing conditions (CSA, 2008). About 40% of the total maize growing area is also located in low moisture stress areas, where it contributes less than 20% to the total annual production (Mandefro *et al.*, 2002). The low yield in these areas, like other Sub-Saharan African countries, is mainly attributed to recurrent drought, low levels of fertilizer use and low adoption of improved varieties (CIMMYT and IITA, 2010).

In Ethiopia, maize grows from moisture stress areas to high rainfall areas and from lowlands to the highlands (Kebede *et al*., 1993). It is one of the important cereal crops grown in the country. The total annual production and productivity exceed all other cereal crops, though it is surpassed by teff in area coverage (Benti *et al*., 1997). Therefore, considering its importance in terms of wide adaptation, total production and productivity, maize is one of the high priority crops to feed the increasing population of the country.

On the half-hectare demonstration plots of Sasakawa Global 2000 (SG-2000) and the similar government extension program, hybrids gave an average yield of 5-6 t ha^{-1} in potential areas. This represents a 250% increment over the average yield obtained by traditional practices in the country (Benti *et al*., 1997 and Simons *et al*., 2014). Increased the average productivity of maize from 34.3 Quintals per hector in 2015 to 50 Quintals per hector in 2020 and increased the total volume of produce from 72.3 million quintals in 2015 to 109 million quintal by the year 2020 (MoA, 2016).

2.5 Nutrient Requirement of Maize

Nutrient requirements of crops depend on yield level, crop species, cultivar or genotypes within species, soil type, climatic conditions and soil biology. Hence soil, plant and climatic factors and their interactions are involved in determining plant nutrient requirements. In addition to this, the economic value of a crop and the socioeconomic conditions of the farmer also are important factors in determining the nutrient requirements of a crop. Diagnostic techniques for nutritional disorders are the methods for identifying nutrient deficiencies, toxicities or imbalances in the soil-plant system (Fageria *et al.*, 2011).

2.5.1 Nitrogen requirement

Nitrogen (N) is one of the most yield limiting nutrients for crop production in the world. It is also the nutrient element applied in the largest quantity for most annual crops (Huber and Thompson, 2007). Nitrogen is called a basic constituent of life because it is required for all stages of plant growth and development since it is the essential element of both structural (cell membranes) and nonstructural (amino acids, enzymes, protein, nucleic acids and chlorophyll) components of plant (Seilsepour and Rashidi, 2011). Nitrogen is a vital plant nutrient and a major yield determining factor required for maize production (Adediran, 1995 and Shanti *et al.*, 1997). It is very essential for plant growth and makes up 1 to 4 percent of dry matter of the plants (Anonymous, 2000).

To produce one ton of maize grains, the plant removes 24 kg N, 3 kg P, 23 kg K, 5 kg Ca and 4 kg Mg from the soil (Fageria *et al.*, 2011). Application of nitrogen at the rate of 210 kg ha^{-1} produced maximum maize grain yield of 2673 kg ha^{-1} which is statistically at par with 180 and 150 kg N ha^{-1} with grain yield of 2475 and 2461 kg ha^{-1} respectively and minimum grain yield of 1803 kg ha^{-1} was recorded from no application of N (Imran *et al.*, 2015).

According to Demissew *et al*. (2002), 150 kg DAP ha^{-1} and 200 kg ha^{-1} of urea is recommended for the Southwest of Ethiopia. Significant response of maize grain yield up to the rate of 75 kg N ha^{-1} and 75 kg P_2O_5 ha^{-1} in west Wollega (Tolessa *et al.*, 2002), application of 184 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} gave the highest grain yield (5497.5 kg ha^{-1}) in Nedjo (Geremew *et al.*, 2015) and 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} recommended for maize on Nitisols of Jimma area (Wakene *et al.*, 2011).

2.5.2 Phosphorus requirement

Phosphorus (P) is one of the most important essential plant nutrients in crop production. Ozanne (1980) reported that P is indispensable for all forms of life because of its genetic role in ribonucleic acid and function in energy transfers via adenosine tri-phosphate. After nitrogen; P has a more widespread influence on both natural and agricultural ecosystems than any other essential plant element (Brady and Weil, 2002 and Fageria, 2009). Phosphorus is another essential nutrient required to increase maize yield. Consequently, the lack of phosphorus is as important as the lack of nitrogen in limiting maize performance.

2.5.3 Potassium requirement

Potassium (K) plays an important role in the formation of protein and chlorophyll and it provides much of an osmotic pull that draws water into plant roots. Potassium produces strong stiff straw and reduces lodging in maize. Potassium regulates the leaf stomata opening and subsequently the rate of transpiration and gas exchange. Plants also need K for the formation of sugars and starches, for the synthesis of proteins and cell division. It increases the oil content of pistachios and contributes to its cold hardiness (Beede *et al.*, 2011). A Study in Pakistan on hybrid maize SB-92K97 revealed that the application of 120 kg K ha^{-1} increase grain yield 4694 kg ha^{-1} when compared with no application of K which grain yield of 3779 kg ha^{-1} (Muhammad *et al*., 2018). Young maize plants take more K by heavy K application, but this uptake does not reflect in terms of grain yield (Rehm and lamb, 2004; Kaiser *et al*., 2005). Maize takes up to 38% of the total K for the whole growing season, from 38 to 52 days after sowing (Rehman *et al*., 2008).

2.5.4 Sulfur requirement

Sulfur (S) is a constituent of the amino acids cysteine and methionine and hence, part of proteins that play an important role in the synthesis of vitamins and chlorophyll in the cell. Deficiency of either nitrogen or sulfur limits protein production of the plant. Sulfur fertilization is most critical for oil, protein synthesis and improvement of quality of produce by their enzymatic and metabolic efforts (Singh *et a*l., 1981).

2.5.5 Calcium requirement

Calcium (Ca) is also an essential secondary plant macronutrient. It is a key element required in structural roles in cell walls and membranes. It plays a critical role in carbohydrate removal and neutralizes cell acids. Calcium also affects the membrane stability and respiratory rate of a tissue and its resistance to fungal infections (Hepler, 2005)

2.5.6 Magnesium requirement

Magnesium (Mg) is considered as a secondary essential nutrient required by the crops and, is absorbed by crops as Mg^{+2} from the soil solution. The functions of Mg in crops are mainly related to its capacity to interact with strongly nucleophilic ligands (for example phosphoryl groups) through ionic bonding and to act as a bridging element and or form complexes of different stabilities (Marschner, 2011). Most reactions involving phosphate transfer from adenosine triphosphate (ATP) require Mg.

Nitrogen metabolism is strictly related to the presence of magnesium in the chlorophyll and its role as a cofactor of the activity of enzymes responsible for the remobilization and transportation of metabolites (nitrogen among others) from the vegetative plant parts to the developing kernels. Moreover, since magnesium activates a large number of enzymes in the plant, its simultaneous supply increases the rate of mineral nitrogen transformation into proteins (Pessarakli, 2002).

2.5.7 Boron Requirement

Boron (B) is an essential element for the normal growth and development of higher plants (Camacho *et al.* 2008). Many physiological and biochemical processes such as sugar transport, cell wall synthesis, lignifications of cell wall structure, membrane integrity, carbohydrate, RNA, IAA and phenol metabolisms, in plants are directly or indirectly regulated by the boron (Cakmak and Romheld 1997). Boron deficiency is one of the most widespread micronutrient deficiencies in crops in the world and leads to heavy losses in yield. In soil deficiency of boron is most prevailed due to its easily leachable property under high rainfall conditions (Camacho *et al.* 2008).

Boron deficiency has been reported to result in considerable yield reduction in maize (Rashid, 2005). Rashid (2006) estimated a substantial potential net economic benefit from the use of B fertilizers in B deficient crops. Boron requirement is generally higher for reproductive development than for vegetative growth in plants (Dell and Huang 1997). Agarwala *et al.* (1981) showed delayed emergence of tassels and lack of sporogenous tissue and formation of staminodes in place of stamens in B deficient maize. Requirement of B for pollen fertility has been demonstrated because poor *in vitro* germination of pollen grains in the absence of B has been observed in maize (Agarwala *et al.* 1981).

2.5.8 Zink requirement

Zink (Z) is a vital micronutrient necessary for plant growth. It affects the synthesis of protein in plants as such it is considered to be the most critical micronutrients (Cakmak *et al*., 1998). It is important in taking part in plant development due to the catalytic action it performs in metabolism in maize. Zinc deficiency has been reported in maize (Rashid *et al*., 1979 and 2004 and Singh *et al*., 2008). Deficiency of Zn in maize affects young leaves, in addition, to delay in silking and tasseling (Kakade, 2009 and Saddiq *et al.,* 2013). Zink activates several enzymes that regulate plant response to water stress. Also, as a structural constituent, Zn is involved in the maintenance of the integrity of biological membranes, which is especially critical for water absorption and utilization under drought stress (Osakabe *et al*., 2014).

A study in Pakistan indicates that the mean grain yield of maize was significantly increased by adding 2.75 kg Zn ha^{-1} to the soil resulted in an additional 720 kg ha^{-1} (25%) of grain. Total dry matter, the number of cobs ha^{-1} and cob weight ha^{-1} were all significantly increased following application of 2.75 kg Zn ha^{-1} whereas the response to adding 5.5 kg Zn ha^{-1} was the same as (for total dry matter and cob yield) or worse than (for cob number and grain yield) adding 2.75 kg Zn ha^{-1} (Harris *et al*., 2007).

2.6 Source of Balanced Fertilization

2.6.1 NPK and other nutrients

A complex fertilizer refers to a compound fertilizer formed by combining ingredients to react chemically. Intensive and multiple cropping, cultivations of crop varieties with heavy nutrient requirement and unbalanced use of chemical fertilizers especially nitrogen and phosphorus fertilizers reduced the quality of grain production and the appearance of micronutrient deficiency in crops (Habib, 2009).

Application of secondary and micronutrients can have significant effects on crop yields in Sub-Saharan Africa (IFDC, 2012), but has received less attention than the macronutrients N, P and K as illustrated by the fact that most fertilizer subsidy programs primarily focus on

NPK fertilizers. This may be due in part to a commonly expressed belief that there is no need to address other nutrients while the continent is still struggling to adopt micronutrient fertilizers. But indeed the reverse is more likely to be true where secondary and micronutrient deficiencies exist; they can limit response to NPK fertilizers. Because Secondary and micronutrients are required in small quantities, addressing these deficiencies can offer farmers an increased return on fertilizer investment, which is a major factor in increasing farmer adoption.

Fertilizer use efficiency for different crops can be increased by the application of micronutrients to NPK fertilizer and also increase grain yield for different cereal crops (John *et al*., 2000; Malakouti, 2000; Malakouti, 2008 and Asefa *et al*., 2014). Another important of micronutrient combination with macronutrients NPK fertilizers is to improve nutrient concentration and uptake and enhanced yield (Asefa *et al*., 2014). A study of NPK fertilizers combination with Micronutrients (Zn and B) improving nutrient concentration and uptake and enhancing yield of teff under the application of 200 kg ha^{-1} (14N + 21 P_2O_5 + 15 K_2O + 6.5 S + 1.3 Zn + 0.5B) blended + 23 kg N ha^{-1} fertilizer brought higher yield (2147.7 kg ha^{-1}), compared to 1886.10 kg ha^{-1} of grain yield under the application of NPK (69N + 55 P_2O_5 + 75 K_2O) kg ha^{-1} (Fayera *et al*., 2014).

2.7 Bulk Blended Fertilizer

Bulk blend fertilizers are a mixture of different kinds of fertilizers to obtain a predicted NPK chemical composition. With some raw materials containing different nutritive substances; it is possible to obtain a new compound fertilizer better adapted to the requirements of a plant. This process is economical and offers great flexibility. In general, the raw materials used for the bulk blends are solid granulates.

The blended fertilizer that contains balanced nutrients with recommended amounts of N and P produced significantly higher teff yield compared to the recommended N and P alone (Asefa *et al*., 2014 and Ayalew and Habte, 2017). Ayalew and Habte (2017) noted that bulk blends with a proper proportion of N and P give the highest marginal rate of return as compared to the equivalent application of Urea and DAP applications. Grain yield increases up to 100 percent when compared to conventional fertilizer application DAP and UREA quantities alone while other trials have suggested that special fertilizer blends can raise maize and wheat yields by 20% to 30% respectively (MoA, 2014). The study showed that previously existing NP fertilizers and blended fertilizer on maize yield blended fertilizer showed significantly increases maize productivity (Dagne, 2016).

Blended fertilizer amended with enough amount of nitrogen and phosphorous gave highest yield, nutritional content and economic return of sorghum under irrigation Raya rift valley of Northern Ethiopia (Gebrekorkos *et al*., 2017). Blended fertilizer can be recommended for teff production particularly in Dedessa District of southwest of Ethiopia it greatly benefit farmers where deficiencies of micronutrients in the soil significantly reduce the productivity of the crops (Asefa *et al*., 2014).

2.8 Factor that Affecting the Quality of Blended Fertilizer

Fertilizers are applied to fields to attain desired soil fertility levels for crops grown emphasized the importance of uniform fertilizer application for crops to maintain optimum yields. Blended fertilizers offer several advantages over homogenous fertilizers (Lance, 1996). They can be specifically mixed to meet required soil conditions and crop needs. Also, multiple passes for spreading individual products can be replaced by a single pass.

Since bulk blends are a physical mixture a potential problem is the segregation of the components during handling or spreading (Hofstee and Huisman, 1990). Though; fertilizer segregation occurs when the granules of different blends separate due to differences in physical characteristics. The most common variables causing segregation of blended fertilizers are particle size, density and shape. Several researchers have reported that the size of fertilizer granules is the most important factor responsible for segregation (Bridle *et al*., 2004). Major particle parameters affecting the spread pattern for spinner spreaders are particle size and density while particle shape had little influence (Miserque *et al*., 2008). The uniformity of particle size distribution and content of granular fertilizers was significantly different but no significant difference existed in the chemical content of the constituents. For granulated blended fertilizers, it has been assumed that nutrients are equally distributed with mass; however, particle size variability as related to nutrient distribution remains unknown (Smith *et al*., 2005).

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location

The experiment was conducted at Sheka Zone in Yeki District, on-farm in Beko village during the 2018 cropping season. Yeki District located in Southwest of Ethiopia in SNNP Regional State at an elevation of 1200 m.a.s.l and it is located at Latitude of $7^0 10^{'} 54.5''$ and with a Longitude of 35^0 25' 04.3'' East of Ethiopia and is situated approximately 611 km Southwest of Addis Ababa.

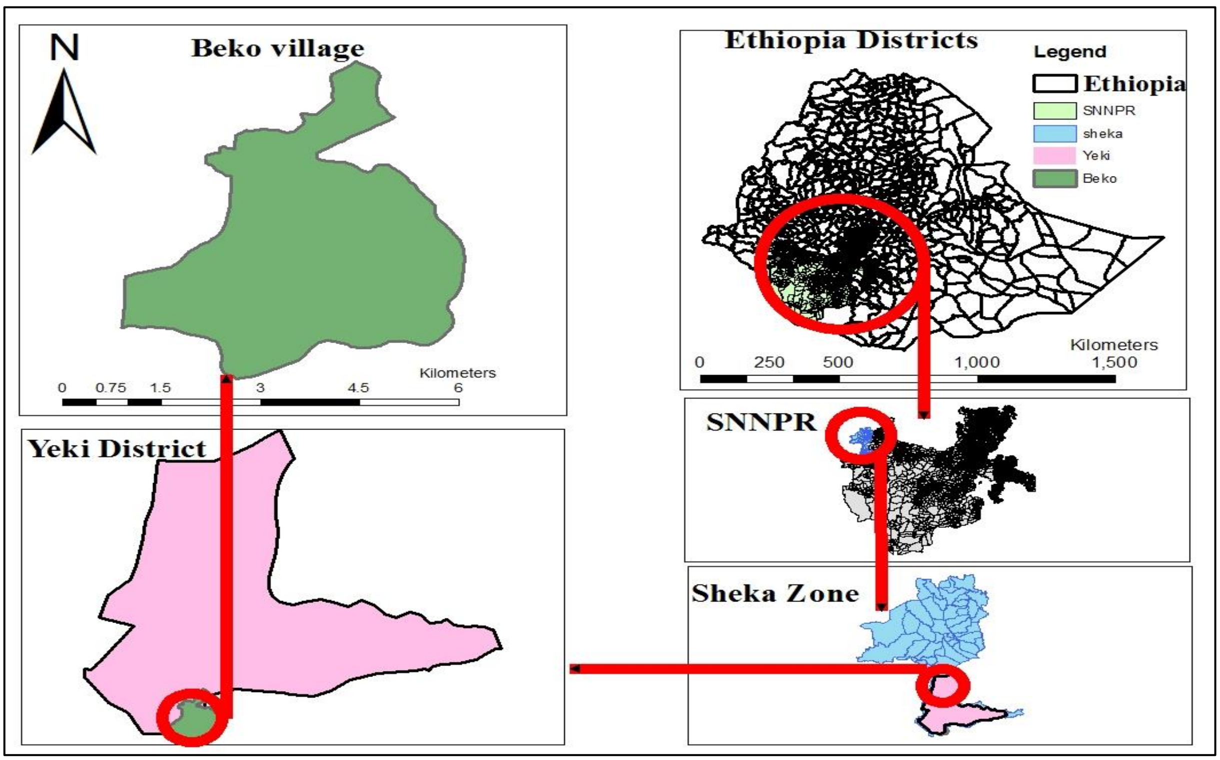


Figure 1.Map of study District.

3.1.2 Climate and soil type

The climatic condition of the area is a warm humid low land condition with a relatively medium growing season. Rainfall in the area was uni-modal distribution with an annual average of 1559 mm with maximum and minimum temperatures of 29.7^{o}C and15.5^{o}C, respectively (National Meteorological Services Agency, 2008). The soils of the study District are dominated by Nitisols (FAO, 1988).

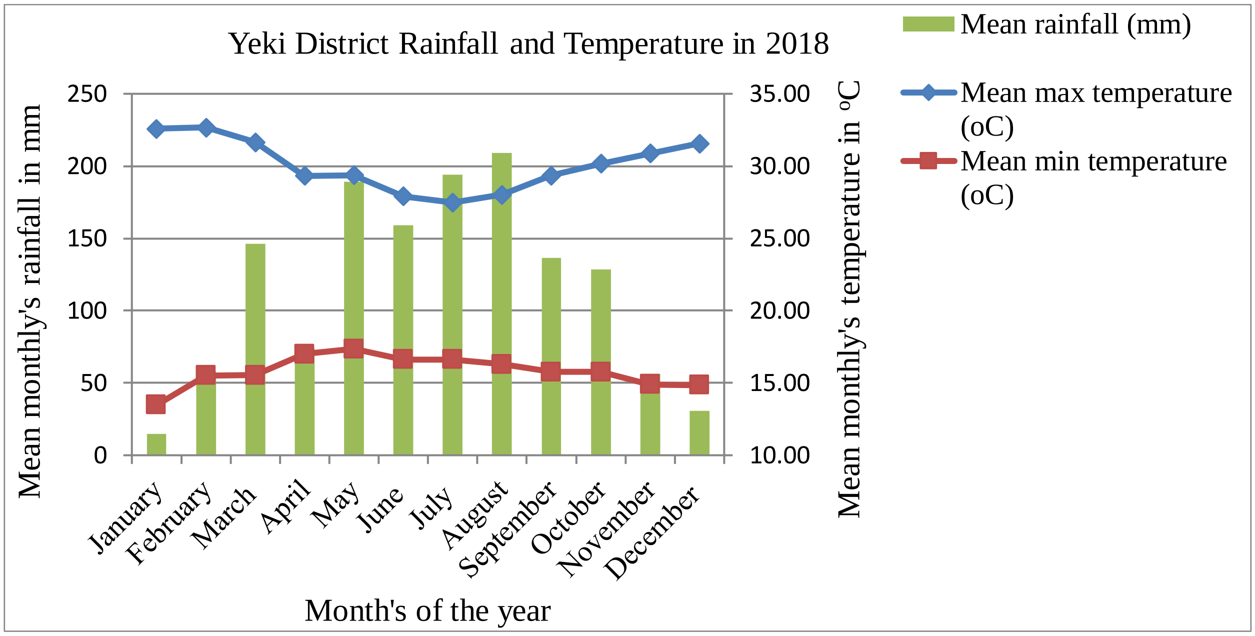


Figure 2. The annual rainfall, maximum and minimum temperature of experimental District during 2018

3.1.3 Land use and vegetation

A mixed crop-livestock system is the main land-use system in the studied area. The majority of smallholder farmers in the study District mainly depend on coffee and spices, cereals and livestock production. Coffee and lowland spices compose the major share of cash income while maize, sorghum and false banana are mainly produced for home consumption. The major cereal crop grown in the area are Maize (*Zea mays* L,), Teff (*Eragrostic tef Zucc. Trotter*), Wheat (*Triticum aestivum* L.) and Sorghum (*Sorghum biocolor* L.). The major pulse crops are Faba beans (*Vicia faba*), Field peas (*Pisum stivum*) and Horticultural crop like False banana (*Ensete ventricosum*), Coffee (*Coffee arabic L.*). Among the spice Ginger (*Zingiber officinale*) and Turmeric *(Curcuma longa)* are widely grown in the Disitrict. The main food crop in the area includes maize, Taro and Enset, Sorghum, Teff, Wheat and Barley. Cash crops included fruits (Bananas, Pineapples and Oranges) and spices (Turmeric and Ginger), however, Coffee is the primary cash crop.

Other important agricultural sources of income include selling milk and vegetables (SNNPR, website).

3.2 Experimental Materials

A high yielding medium maturing hybrid maize variety (BH140) was used as a test crop. It was released by Bako Agricultural Research Centre through the National Maize Research Program, (1988). It performs well in agro-ecology of 1000-1800 m.a.s.l with rainfall of 1000-1200 mm. It can give (7.5-8.5 and 4.7-6) t ha^{-1} grain yields on-station and on-farm experiments respectively with maturity date of 145 and 25 kg ha^{-1} seed rate. For this experiment, the seed of BH140 maize variety and fertilizer (NPS, NPSB, TSP, KCl and urea) were obtained from Tepi Agricultural Research Center.

3.3 Experimental Design

The treatments were laid out in a randomized complete block design with four replications. The recommended fertilizer type for Yeki specific area was obtained from the EthioSIS map which was released by ATA (Appendix Figure1). Two fertilizer types (NPS and NPSB) recommended for the study area (EthioSIS, 2016) with three rates of applications for each type (150, 200 and 250) kg ha^{-1}combined with two rates of urea (100 and 150) kg ha^{-1}.

Nitrogen was adjusted for the compound NPS and blended NPSB fertilizer from the urea source. Based on the soil information data of EthioSIS for each limiting nutrient identified compared among each other and against the recommended NP from TSP and urea fertilizers respectively. The compound NPS (19N-38P_2O_5-0K-7S) and blended NPSB (18.1 N - 36.1 P_2O_5 - 0.0 k_2O - 6.7 S - 0.0 Zn - 0.71 B) fertilizer grade rates were set based on N and P_2O_5 (92 N and 69 P_2O_5) kg ha^{-1} recommended for maize on Nitisols of Jimma area (Wakene *et al*., 2011). The recommended NP (92 N and 69 P_2O_5) kg ha^{-1} and one control plot (without any input) were added in each replication. Therefore, there were a total of fourteen treatments per replication (Table1).

Fertilizers' TSP, NPS and NPSB were applied at planting and while urea was applied in twice equal split half at knee height and the remaining half at flag leaf emergence (Tolessa *et al*., 1994). The first side dressing was 30 days after emergence (knee height stage) just after the first weeding and again 60 days after emergence just after the second weeding or before tasseling and Potassium (100 kg ha^{-1}) fertilizer was applied at the intermediate of the first and second nitrogen application.

The area of each plot was 3.5 m x 3.75 m (13.125 m^2) length and width respectively and the total experimental area of 18 m x 55.5 m (999 m^2) then the fourteen treatments were randomly assigned to each experimental unity followed (Gomez and Gomez, 1984) procedure, so as to allocate in each block and plant space 75 cm x 25 cm between row and between plants were used for plating of the maize respectively. A footpath of 1m and 0.5m were left between blocks and plots respectively.

Table 1. Details of treatment arrangements

Treatment code	Description of the treatments		
T1	Control (no fertilize)		
T2	Recommended NP (92N + 69 P_2O_5) kg ha^{-1}		
		Urea kg ha^{-1}	KCl kg ha^{-1}
T3	150 kg NPS ha^{-1}	100	100
T4	200 kg NPS ha^{-1}	100	100
T5	250 kg NPS ha^{-1}	100	100
T6	150 kg NPS ha^{-1}	150	100
T7	200 kg NPS ha^{-1}	150	100
T8	250 kg NPS ha^{-1}	150	100
T9	150 kg NPSB ha^{-1}	100	100
T10	200 kg NPSB ha^{-1}	100	100
T11	250 kg NPSB ha^{-1}	100	100
T12	150 kg NPSB ha^{-1}	150	100
T13	200 kg NPSB ha^{-1}	150	100
T14	250 kg NPSB ha^{-1}	150	100

3.4 Experimental Procedures and Field Management

The land was plowed two times by ox and leveled by hand. Maize seed-sowing was done by hand on the 25th of April 2018 after rainfall to provide moisture for better germination. Two seeds were planted per hill to ensure the desired stand in each treatment and thinned to one plant with a plant population of 53,333 plants per hector. Thinning was done at two to three leave stages after germination. The outermost rows at both sides of plots were considered as borders.

The fall army warm pest was controlled through both manual collections and by chemical during cropping season. The chemical was applied one times before the crop starts tasseling. No disease was observed throughout the trial. At physiological maturity of maize harvesting and shelling were done by hand.

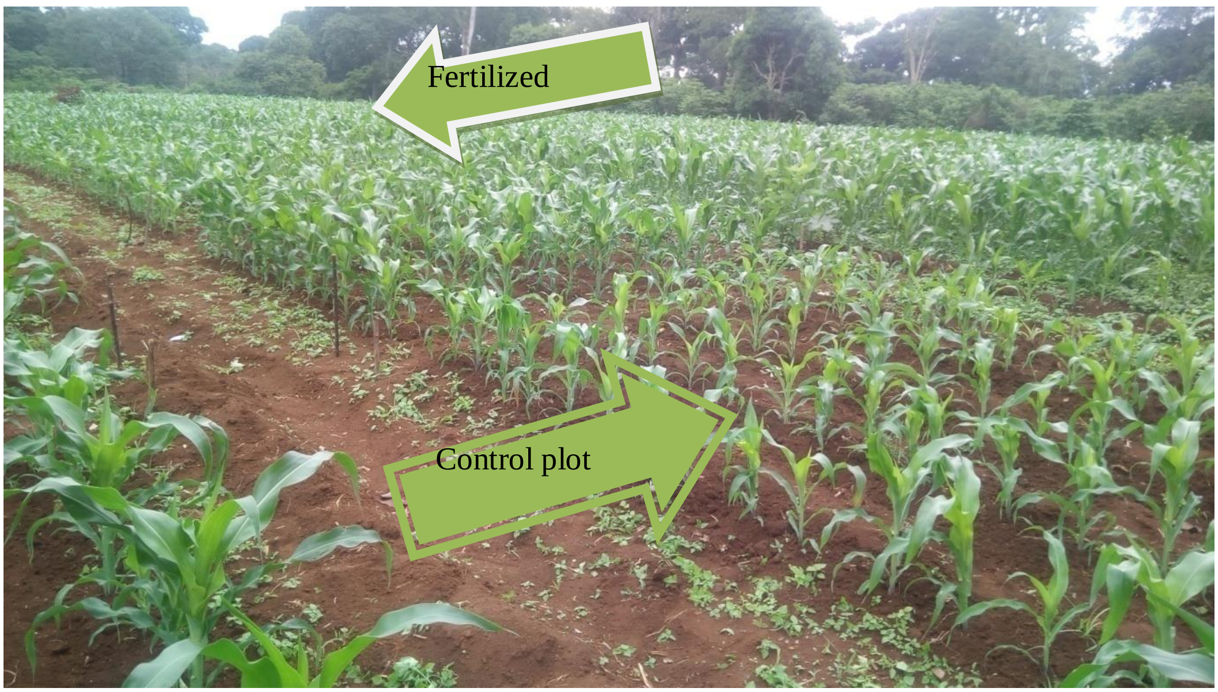


Figure 3. Early growth of maize physiological response to fertilizer

3.5 Data Collection and Measurements

3.5.1 Soil sampling

Composite top soil samples were collected in a zigzag method by Auguring from (0-20 cm) depth pre-planting from the experimental site to understand soil fertility status. The composited soil sample was analyzed in Horticoop Ethiopia (Horticulture) PLC Soil and Water Analysis laboratory. The soil samples were air-dried at room temperature (25^{o}c-30^{o}c) and sieved (<2 mm) sieve size before laboratory analysis.

3.5.2 Soil Analysis methods

Soil texture was determined by Bouyoucos hydrometer method (Day, 1965). Percentages of sand, silt and clay were identified, a textural class was determined using the USDA triangular guideline for classifying soil textures (FAO, 1990). Soil pH was determined in a 1:2.5 soil water suspension using a glass electrode pH meter (Van Reeuwijk, 1992).

Total Nitrogen was determined by the modified Kjeldahl method (Bremner, 1965) procedure. Available Phosphorus was determined in Olsen methods (Olsen *et al.* (1954). Available Potassium was determined by ammonium acetate extracts flame photometer (Morgan, 1941). Available sulfur and Boron were determined by Mehlich-3 method (Mehlich, 1984).

Cation exchange capacity (CEC) of the soil was determined with the ammonium acetate (Chapman, 1965). Organic carbon Walkley and Black method (1934) and Organic matter was estimated as organic carbon multiplied by 1.724 assuming average Carbon concentration of organic matter of 58 % (Black, 1934).

3.5.3 Maize Agronomic data

Plant height (cm): - It was measured as the height from the soil surface to the base of the tassel of six randomly taken maize plants from the net plot area (3.5 mx3.75 m) at plant physiological maturity.

Ear height (cm): - It was measured from ground level to the node bearing the top useful ear.

Ear length (cm): - It was measured from the point where the ear attaches to the stem to the tip of the ear before the husk removed.

Cob length (cm): - It was measured from the point where the grain rows start to the tip of the grain rows end after the husk removed.

Number of grain rows per cob: - It was computed as the average numbers of grain of six randomly taken cobs from the center of each net plot and the means taken as number of grain rows per cob.

Number of grains per row: -It was computed as the average number of grains from a single row of six randomly taken cobs from the center of each net plot and the means taken as the number of grains per row.

Thousand grain weight (g): - It was determined from 1000 randomly taken grains from each plot and weighed using sensitive balance.

Grain yield (kg ha^{-1}): - From each internal three rows of net plot, four maize plants were randomly harvested by hand. The grains were shelled manually and their weights by electronic balance and seed moisture content by seed moisture tester was recorded. After drying the grain yield adjusted downward to 12.5% moisture content, the final dry weight was determined and recorded and then convert to a hector basis.

Biological yield (kg ha^{-1}): - Total above ground of four maize plants from each internal three rows of net plot were randomly harvested at physiological maturity by hand. It was measured from a plant harvested from the net plot and weighed after uniformly sun-dried until it had constant weight and then weighed and converted to a hector basis.

Harvest index: - Harvest index is the physiological ability of maize to convert total dry matter into grain yield. It was calculated as the ratio of grain yield to total aboveground biomass.

Shelling percentage: - it was measured as the ratio of the weights of shelled grain and unshelled ear expressed in percentage.

3.5.4 Plant tissue analysis

Maize grain and straw representative samples at physiological maturity were collected from each treatment. The samples were oven-dried and grounded for laboratory analysis of Nitrogen, Phosphorus, Potassium, Sulfur and Boron concentration in both grain and straw in Jimma Agricultural Research Center Soil and Plant Analysis Research Laboratory.

The measurement of grain and straw N was carried out according to the Kjeldahl procedure (Chapman, 1965). The measurement of P, K, B and S concentration of grain and straw was carried out dry ashing as described by Chapman (1965).

The grain and straw concentrations of N, P, K, S and B were used to estimate the N, P, K, S and B uptake which was calculated by multiplying grain and straw yields on a hector basis with the respective N, P, K, S and B percentage. Apparent fertilizer N and P recovery were calculated following the formula as [(UN - UO)/N] x 100; where UN stands for nutrient uptake (grain + straw) of fertilized plot, UO stands for nutrient uptake (grain + straw) of control (no fertilized plot) and N stands for amount of nutrient applied. Agronomic and physiological N and P use efficiencies were calculated by using procedures described by Fageria and Baligar, (2005a) as: (GN – GO)/N for agronomic efficiency and (YN - YO / (UN - UO) for physiological efficiency; where GN and GO stand for grain yield of fertilized plot and grain yield of unfertilized plot respectively, YN - YO stand for grain yield of fertilized plot and unfertilized plot respectively and UN and UN stand for nutrient uptake (grain + straw) of fertilized plot and nutrient uptake (grain + straw) of control (no fertilized plot), respectively.

3.5.5 Economic data

Economic analysis was performed to investigate the economic feasibility of the treatments (fertilizer). A partial budget, dominance and marginal analysis were used. Partial budget and Marginal analysis of economic concepts were used to analyze the economic data. Partial budget is a method of organizing experimental data and information about the costs and benefits of various alternative treatments. Marginal analysis is a method for comparing the costs that vary with the net benefits for selecting the best technology for recommendations from the experiment. The market cost of maize was taken from local market prices in Ethiopian Birr (ETB) kg^{-1}. Prices for fertilizer taken as fixed price.

The average yield was adjusted downward by 10% and was used to reflect the difference between the experimental field and the expected yield from farmers' fields with farmers' practices from the same treatments (Getachew and Rezene, 2006). Analysis of marginal rate of return (MRR) was carried out for non dominated treatments and the MRRs are compared to a minimum acceptable rate of return (MARR) of 100% to select the optimum treatment (CIMMTY, 1988).

3.6 Statistical Analysis

Data Analysis of variances for different yields and was first checked for all assumptions of ANOVA. Then the data were subjected to Analysis of Variance (ANOVA) and simple correlation analysis was performed using SAS PROC CORR (SAS Institute, 2008) by SAS version 9.0). The data collected were statistically analyzed using the Analysis of Variance (ANOVA) procedures (Gomez and Gomez, 1984). Means were separated using the LSD test to signify the treatment differences at a 5% level of probability (Steel and Torrie, 1980).

4. RESULTS AND DISCUSSION

4.1 Pre-Plant Soil Physiochemical Properties

Pre-plant soil physical and chemical properties of the experimental area were presented in (Table2). The soil textural class of the experimental area was clay with the percentage of Clay (60%), Silt (26%) and Sand (14%) content at the depth of 0-20 cm soil sampled from the experimental site. The soil texture controls water contents, water intake rates, aeration, root penetration and soil fertility. Therefore, the soil textural class of the experimental area was suitable for maize production.

Table 2. Pre-plant-soil physicochemical properties of experimental site

Soil properties	Values	Rating	Reference(s)
pH	6.27	Slightly acid	Landon, 1991
Total N (%)	0.24	Moderate	Tekalign, 1991
Olsen available P (mg kg^{-1})	5.00	Low	Landon, 1991
Available K (ppm)	550.80	High	Horneck *et al*. (2011)
Available S (ppm)	13.14	Medium	Horneck *et al*. (2011)
Available B (ppm)	0.99	Moderate	Horneck *et al*. (2011)
CEC cmol (+) kg^{-1} of soil	30.89	High	Landon, 1991
Organic C (%)	2.64	High	Hazelton and Murphy, 2007
Clay (%)	60		
Silt (%)	26		
Sand (%)	14		FAO, 1977
Textural class	Clay		

The soil pH of the experimental site was 6.27 and rated as slightly acidic (Landon, 1991). The most favorable soil pH for the availability of most plant nutrients corresponds roughly with the optimum range of 6 to 7. According to Havlin *et al*. (1999) the soil pH range of 5.5-7 is optimum for maize production. Therefore, the soil pH of the experimental site was ideal for maize production.

The soil total N (0.24%) of the experimental area was recorded (Table 2). According to Tekalign, (1991) rated soil total N availability of <0.1% as very low, 0.1-0.2% low, 0.2-0.5% as moderate, 0.5-1% high and >1% as very high. Thus, the soil of the experimental site has moderate and requires nitrogen application as maize is a highly exhaustive crop for nitrogen and the production potential of it is highly affected by N deficiency. Total nitrogen analysis measures N in all organic and inorganic forms. Total nitrogen does not indicate plant available N and is not the sum of NH_4-N + NO_3-N. Therefore, total N is not used for fertilizer recommendations. Studies in sub-Saharan Africa (SSA) showed that the application of N alone, with P, K, Ca, Zn and B gave the largest yield increase for highly fertile soil as compared to low fertile soil (Zingore, 2011).

Available soil phosphorous of the experimental area was 5 mg kg^{-1}. According to Landon (1991), available (Olsen extractable) soil P level of less than 5 mg kg^{-1} was rated as low, 6-15 mg kg^{-1} as medium and greater than 15 mg kg^{-1} was rated as high. According to this worker, the available (Olsen extractable) P in the experimental area was low. Therefore, P content fertilizer might be important to obtain optimum maize production in the experimental site. Tekalign and Hague (1991) have shown the critical Olsen P values to be 8 mg kg^{-1} for Ethiopian soils. Taye *et al*. (2000) reported that 10 mg kg^{-1} to be the critical Olsen P level for wheat in soils of Hitosa Woreda, Ethiopia. Very recently, Yihenew (2016) reported that the soil P critical level measured by the Bray II extraction method for maize was 14.6 mg kg^{-1} soil in Alfisols of Northwestern Ethiopia. Similarly, Getachew and Berhane (2015) also reported that the critical level of extractable P using the Bray II method for malt barley was 12 mg kg^{-1} in the Nitisols of Ethiopian highlands.

Available soil Potassium of the experimental area was 550.80 ppm. Horneck *et al*. (2011) reported that soils with potassium content of <150 ppm low, 150-250 ppm medium, 250-800 ppm high and >800 ppm excessive. Thus, the soil of the experimental site has rated as high. This high K in experimental site was contradicting with that of EthioSIS **(**Appendix Figure 1) recommended potash fertilizer for the District. Murphy (1968) stated that Ethiopian soils are rich in K and there was no need for K application, but crop responses to K have been reported (Asgelil *et al*., 2007 and Admassu, 2015). Wassie and Shiferaw, (2011) also reported that the application of potassium fertilizer application increased the tuber yield of potato at Chencha suggesting a low level of soil K and there is a need for application of K fertilizer.

The soil available sulfur of the experimental area was 13.14 ppm. Horneck *et al*. (2011) reported that soils with Sulfur content of very low < 2 ppm, low 2-5 ppm, medium 5-20 ppm and >20 ppm high. Thus, the soil of the experimental site has rated as medium.

The soil available boron 0.99 ppm of the experimental area was recorded. According to Horneck *et al*. (2011) rated soil availability of <0.2 ppm as very low, 0.2-0.5 ppm low, 0.5-1 ppm medium, 1-2 ppm high and >2 ppm excessive. Thus, the soil of the experimental site has moderate and requires boron application for the production potential of maize.

The Cation exchangeable capacity of the exponential area was 30.89 cmol (+) kg^{-1} of soil. According to Landon (1991), CEC of the soils greater than 40 cmol (+) kg^{-1} were rated as very high and 25- 40 cmol (+) kg^{-1} as high and CEC of soil from 15-25 medium, 5-15 low and < 5 cmol (+) kg^{-1} of soil were rated as very low. Therefore the CEC soil of the experimental area was high. This high CEC may be due to the relatively high organic matter in the experimental area that implying good for agricultural purposes. Furthermore, such high CEC value provides the soil with high buffering capacity so that one can apply the required amount of fertilizer dosage without any immediate negative effects on the soils. The cation exchange capacity of soil could then relate to the organic matter content of a soil (Brady and Weil, 2002).

The results of the soil analysis of the experimental site showed the soil organic carbon content was 2.64%. Hazelton and Murphy, (2007) rated soil organic carbon percentage of very low <0.60, 0.6-1 low, 1-1.8 medium, 1.80-3 high and >3 very high. Therefore the amounts of organic carbon content of the experimental area rated as high (2.64%). The high organic carbon content of surface soil could be related to organic matter content due to litter fall and crop residue of the soil surface.

Soil organic carbon was determined to estimate the amount of organic matter in the soil. Organic matter has an important influence on soil physical and chemical properties, soil fertility status, plant nutrient and biological activity in the soil (Brady and Weil, 2002). The organic matter content (4.55%) was estimated from soil organic carbon of the experimental area. On the other hand; the higher the clay content a soil has, the higher the % OC it contains due to the stability of clay colloids. Results in the work of Feller and Beare, (1997) support the argument and reported that organic carbon generally increased with the clay content.

4.2 Effect of Fertilizer on Growth Parameters of Maize

4.2.1 Plant height

The difference in plant height among treatments that received application of NPS and NPSB or recommended NP was none significantly (P>0.05) different. However, plant height on the control plots were significantly (P<0.05) lower than plant height on plot received 250 kg NPSB ha^{-1} combined urea and potassium (Table 3). Numerically the longest plant height (268.55cm) was recorded from the application of 250 NPSB + 100 urea + 100 KCl kg ha^{-1}; while the shortest plant height (244.45cm) was recorded from the control treatment (Table 3).

This result similar to Dagne, (2016) found that the application of blended fertilizer was none significant when compared with the application of recommended NP fertilizer, but a significant difference from the control treatment. Also, the highest plant height was obtained from the application of compound NPS and blended NPSB fertilizer and it showed a significant difference when compared to the control treatment (Shiferaw, 2018).

4.2.3 Ear height

The application of fertilizer was none significantly (p>0.05) different among the treatments except control treatment which was significantly (p<0.05) different from the recommended NP and treatment that received 250 NPSB + 150 Urea + 100 KCl kg ha^{-1} fertilizer (Appendix Table2). Numerically the longest ear height (144.95cm) was recorded from the application of 250 NPSB + 150 urea + 100 KCl kg ha^{-1}; while the shortest ear height (126.70cm) was recorded from the control treatment.

Table 3. Effects of balanced fertilizer on plant height, Ear height and Ear length of maize

Treatments (Fertilizer rates kg ha^{-1})	Plant height (cm)	Ear height (cm)	Ear length (cm)
T1= control	244.45^{b}	126.70^{b}	30.00^{c}
T2=(92N + $69P_2O_5$)	256.55^{ab}	141.70^{a}	32.95^{bc}
T3=150 NPS + 100 Urea + 100 KCl	259.15^{ab}	137.85^{ab}	34.85^{ab}
T4=200 NPS + 100 Urea + 100 KCl	254.00^{ab}	134.50^{ab}	36.05^{ab}
T5=250 NPS + 100 Urea + 100 KCl	263.55^{ab}	136.85^{ab}	33.85^{b}
T6=150 NPS + 150 Urea + 100 KCl	253.65^{ab}	130.95^{ab}	34.80^{ab}
T7=200 NPS + 150 Urea + 100 KCl	254.60^{ab}	135.60^{ab}	35.90^{ab}
T8=250 NPS + 150 Urea + 100 KCl	258.10^{ab}	137.20^{ab}	35.40^{ab}
T9=150 NPSB + 100 Urea +100 KCl	256.90^{ab}	137.55^{ab}	33.30^{bc}
T10=200 NPSB + 100 Urea +100 KCl	263.30^{ab}	138.50^{ab}	34.40^{ab}
T11=250 NPSB + 100 Urea +100 KCl	268.55^{a}	140.25^{ab}	37.55^{a}
T12=150 NPSB + 150 Urea + 100 KCl	262.30^{ab}	138.75^{ab}	35.80^{ab}
T13=200 NPSB +150 Urea +100 KCl	258.40^{ab}	136.45ab	34.60^{ab}
T14=250 NPSB +150 Urea +100 KCl	266.20^{a}	144.95a	35.85^{ab}
LSD	19.65	14.45	3.30
CV%	5.32	7.37	6.66

LSD =Least Significant Difference ($p<0.05$), cm=centimeter, CV=Coefficient of Variation, Means values followed by the same letter(s) within the column were not significantly different at 0.05 probability level.

4.2.4 Ear length

The balanced fertilizer application was highly significantly ($P<0.01$) affected ear length (Appendix Table2). Numerically the maximum ear length (37.55cm) was recorded on plots received 250 NPSB + 100 urea + 100 KCl kg ha^{-1} fertilizer; while the minimum ear length (30cm) was recorded on the control plots (Table 3). The ear length development at a balanced fertilizer application was due to nutrient application at the optimum rate. Nitrogen was also an essential requirement of ear growth. An increase in ear length at higher N and P could be due to good photo-assimilates supply which facilitates photosynthesis and S aids in seed formation

Dagne (2016) reported that the application of blended fertilizer was showed significant differences in ear length when compared to the control treatment. Increase in photosynthesis activities account for plant growth under an adequate supply of nitrogen and phosphorous (Jan *et al.*, 2002). The maximum assimilate supply should be available during maize grain filling with a split application of Nitrogen (Arif *et al*., 2010). These results were in agreement with that of Rajeshwari *et al*. (2010) who reported a significant increase in ear length with increased rates of nitrogen fertilizer application from different sources. Moraditochaee *et al.* (2012) also reported that increasing the nitrogen level from 50 to 200 kg ha^{-1} significantly increased the ear length of maize from 10.17 to 15.69 cm.

4.3 Effect of Balanced Fertilizer on Yield and Yield Component of Maize

4.3.1 Number of ear per plant

The number of ear per plant was none significantly ($P > 0.05$) affected by the application of fertilizer (Table 4).

4.3.2 Cob length

The balanced fertilizer application was highly significantly ($p < 0.01$) affected cob length (Appendix Table 2). Numerically the maximum cob length (18.05 cm) was recorded at the application of 200 NPS + 100 urea + 100 KCl kg ha^{-1} fertilizers; while the minimum cob length (13.55 cm) was recorded from the control treatment (Table 4).

This result disagrees with the Shifera (2018) finding which showed that the application of NPS and NPSB fertilizer had no significant effect on cob length comparing with the control treatment, but the study by Ahmad *et al*. (2018) reported increase in nitrogen levels positively influence cob length of maize. Cob length increases with the increasing nitrogen level. The maximum cob length (17.18 cm) was recorded in the application of treatment with 180 kg N ha^{-1} and minimum ear length (14.29) was recorded in the control plot. At favorable environmental optimum utilization of solar light, higher assimilated production and its conversion to starches resulted in higher cob length as reported by Derby *et al*. (2004).

Table 4. Effect of balanced fertilizer on yield and yield component parameters of maize

Treatments (Fertilizer rates kg ha^{-1})	NEP	CL	NRC	NGR	TW
T1= control	1.00	13.55^{d}	14.40^{ab}	36.15^{bc}	300.78^{c}
T2=(92N + 69P_2O_5)	1.05	15.65^{c}	14.30^{ab}	35.45^{c}	364.80^{b}
T3=150 NPS + 100 Urea + 100 KCl	1.05	17.05^{abc}	13.88^{ab}	40.30^{abc}	379.53^{b}
T4=200 NPS + 100 Urea + 100 KCl	1.00	18.05^{a}	13.45^{b}	42.45^{a}	381.15^{b}
T5=250 NPS + 100 Urea + 100 KCl	1.05	16.85^{abc}	13.83^{ab}	40.78^{abc}	372.89^{b}
T6=150 NPS + 150 Urea + 100 KCl	1.00	17.40^{ab}	13.50^{b}	37.45^{abc}	384.43^{ab}
T7=200 NPS + 150 Urea + 100 KCl	1.10	17.00^{abc}	13.75^{ab}	39.13^{abc}	387.03^{ab}
T8=250 NPS + 150 Urea + 100 KCl	1.05	17.55^{ab}	13.85^{ab}	40.60^{abc}	425.31^{a}
T9=150 NPSB + 100 Urea +100 KCl	1.05	16.80^{abc}	14.10^{ab}	38.53^{abc}	385.24^{ab}
T10=200 NPSB + 100 Urea +100 KCl	1.00	17.00^{abc}	13.65^{b}	41.05^{ab}	407.50^{ab}
T11=250 NPSB + 100 Urea +100 KCl	1.05	17.30^{ab}	15.18^{a}	38.83^{abc}	406.46^{ab}
T12=150 NPSB + 150 Urea + 100 KCl	1.00	16.45^{bc}	13.95^{ab}	40.90^{ab}	384.42^{ab}
T13=200 NPSB +150 Urea +100 KCl	1.00	16.95^{abc}	12.95^{b}	37.60^{abc}	395.62^{ab}
T14=250 NPSB +150 Urea +100 KCl	1.00	17.00^{abc}	14.20^{ab}	39.65^{abc}	387.41^{ab}
LSD	ns	1.50	1.48	5.37	42.92
CV%	6.81	6.24	7.44	9.58	7.83

LSD=List significant difference, CV%=coefficient variation, ns=none significant, NEP= number of ear per plant, CL=cob length in cm, NRC=number of grain row per cob, NGR=*number of grain per row, TW =thousand grain weight (gm), Means values followed by the same letter(s) within the column are not significantly different at 0.05 probability level.*

4.3.3 Number of grain rows per cob

The balanced fertilizer application was none significantly ($P>0.05$) affected the number of rows per cob (Appendix Table 2).

4.3.4 Number of grains per row

Comparing with the control treatment and recommended NP fertilizer the number of grains per row of some treatment was significantly ($p<0.05$) affected by the application of fertilizer types (NPS and NPSB) along with urea and KCl fertilizer rate (Appendix Table 2).

Numerically the highest number of grains per row (42.45) was recorded from the application of 200 NPS + 100 urea + 100 KCl kg ha^{-1}; whereas, the lowest number of grains per row (35.450) was recorded from the recommended NP fertilized treatment (Table 4). The possible reason for the higher number of grains per row at the highest nitrogen rate could be due to increased biomass production and then more translocation to the sink resulting in more numbers of grains per row.

Similar results have been reported by Ali and Raouf, (2012) and Muhammad *et al*. (2010) who obtained a higher number of grains per row of maize at higher nitrogen rates. Similarly, Ayman and Samier (2015) reported that the highest number of grains per row (45.92) was recorded at 140 kg N ha^{-1}

4.3.5 Thousand grain weight

Thousand grain weight was highly significantly ($P<0.01$) affected by the application of fertilizer (Appendix Table 3). The highest (425.31 gm) thousand grain weights were recorded from the application of 250 NPS + 150 urea + 100 KCl kg ha^{-1} which were not statistically significant from the other treatment (Table 4) while the lower (300.78 gm) thousand grain weights were recorded from the control treatment. An increase in thousand grain weights were due to the effects of N for grain filling and increases the plumpness of grains, P for cell division, seed formation and development, S for seed production helps for heavier grain weight of maize. Availability of sufficient light and moisture to an individual plant at higher nutrient proportion leads to enhanced plant growth and might have led to better grain development which ultimately increased grain weight. At sufficient NPS fertilizer grains providing sufficient development of an individual grain, leading to higher thousand grain weight.

The weight of grains depends on the flabbiness of grains and the transport of assimilates to the seed (Siam *et al*., 2008). Also, the sufficient availability of nutrients from inorganic source at critical growth stages; especially at grain filling and development (Mohsin *et al*., 2012) and thus resulted in properly filled grains. This result also were in line with the report of Onasanya *et al*. (2009) who reported that higher values of thousand grain weight with higher doses of inorganic fertilizers application.

4.4 Influence of NPS and NPSB Fertilizer on Yield and yield Components of Maize

4.4.1 Grain yield

The analysis of variance among fertilizer rates, types and recommended NP on grain yield revealed highly significantly ($P<0.01$) difference (Appendix Table 3). Numerically the highest grain yield (8828.20 kg ha^{-1}) was recorded from the application of 250 NPSB + 100 urea + 100 KCl kg ha^{-1}, while the lowest grain yield (2968.90 kg ha^{-1}) was recorded from the control plot (Table 5). The low yield of maize under the application of recommended NP might be due to the absence of macronutrients like K and S and other micronutrients (B). The more grain yield increment from the plot that treated with balanced fertilizer might be the contribution of balanced nutrient (macro and micronutrient) present in blended fertilizer as compared to recommended NP and control.

Ali *et* al. (2002) reported combined application of nitrogen and phosphorous increase maize yield (3424.95 kg ha^{-1}) by 112.05% as compared to the control plot when applied at the rate of 150 + 120 N and P_2O_5 kg ha^{-1} respectively. Muhammad *et al*. (2018) reported application of 120 kg K ha^{-1} fertilizer to improve maize yield by 24.21% as compared to the control. A similar study indicated that maximum grain yield was obtained by applying blended fertilizer, whereas the lowest grain yield was recorded from the control treatments (Dagne, 2016 and Shiferaw *et al*., 2018). Asfa *et al*. (2014) and Ayalew and Habte, (2017) reported blended fertilize with the recommended amount of N and P increased teff yield as compared to the control. Similar achievements from the application blended fertilizer increased bread wheat yield (Mulugeta and Abay, 2017 and Abebaw and Hirpha, 2018) reported combination application of macronutrient and micronutrients increases dry matter, grain yield, yield component and straw of wheat over control.

Table 5. Influence of fertilizer on grain yield, straw yield and cob weight of maize

Treatments (Fertilizer rates kg ha^{-1})	GYL kg ha^{-1}	SW kg ha^{-1}	CW kg ha^{-1}
T1= control	2968.90^{g}	3813.30^{f}	893.33^{f}
T2=(92 N + 69 P_2O_5)	5166.60^{f}	5600.00^{e}	1000.00^{ef}
T3=150 NPS + 100 Urea + 100 KCl	5682.70^{f}	5920.00^{e}	1106.67^{bcd}
T4=200 NPS + 100 Urea + 100 KCl	7567.90^{de}	8106.70^{c}	1133.33^{bcd}
T5=250 NPS + 100 Urea + 100 KCl	8390.10^{ab}	8746.70^{ab}	1040.00^{de}
T6=150 NPS + 150 Urea + 100 KCl	7789.60^{bcd}	8386.70^{abc}	1226.67^{abc}
T7=200 NPS + 150 Urea + 100 KCl	7015.60^{e}	7440.00^{d}	1186.67^{abc}
T8=250 NPS + 150 Urea + 100 KCl	8387.60^{ab}	8666.70^{ab}	1240.00^{ab}
T9=150 NPSB + 100 Urea +100 KCl	7033.40^{e}	7280.00^{d}	1200.00^{abc}
T10=200 NPSB + 100 Urea +100 KCl	8291.20^{abc}	8760.00^{a}	1253.33^{ab}
T11=250 NPSB + 100 Urea +100 KCl	8828.20^{a}	8680.00^{ab}	1013.33^{def}
T12=150 NPSB + 150 Urea + 100 KCl	8082.90^{bcd}	8453.30^{abc}	1266.67^{a}
T13=200 NPSB +150 Urea +100 KCl	7547.10^{de}	8213.30^{bc}	1173.33^{abc}
T14=250 NPSB +150 Urea +100 KCl	7605.30^{cde}	8106.70^{c}	1213.33^{abc}
LSD	720.40	541.29	131.56
CV%	7.03	4.99	8.08

LSD =List significant difference, CV%= coefficient variation, GYL= grain yield, SW= Straw weight, CW=Cob weight), Means values followed by the same letter(s) within the column are not significantly different at 0.05 probability level.

4.4.2 Straw yield

Straw yield was highly significantly ($P<0.01$) affected by the application of fertilizer (Appendix Table 3). The maximum maize straw yield (8760 kg ha^{-1}) was recorded from the application of 200 NPSB + 100 urea + 100 KCl kg ha^{-1}, while minimum value (3813.3 kg ha^{-1}) was recorded from the control treatment (Table 5).

Nitrogen increases shoot dry matter, which was positively associated with grain yield in cereals and legumes (Fageria, 2008b). A similar study indicated that maximum maize straw was obtained by applying blended fertilizer, whereas the lowest straw was recorded from the control treatments (Dagne, 2016 and Shiferaw *et al*., 2018).

4.4.3 Cob weight

The analysis of variance among fertilizer rates, types and recommended NP on cob weight was highly significantly (P<0.01) difference (Appendix Table 3). Numerically the highest cob weight (8828.2 kg ha^{-1}) was recorded from application of 150 NPSB + 150 urea + 100 KCl kg ha^{-1} and the lightest cob weight (893.33 kg ha^{-1}) was recorded from the control treatment (Table 5).

4.4.4 Biological yield

The analysis of variance among fertilizer types and rates on biological yield revealed was highly significant (P<0.01) differences. The two types of fertilizer had significantly improved biological yield over recommended N and P and control treatment. The maximum amount of biological yield (18521.50 kg ha^{-1}) was obtained under the application of 250 NPSB + 100 kg urea + 100 KCl kg ha^{-1} and the minimum biological yield (7675.4 kg ha^{-1}) was obtained from control treatment (Table 6). Biological yield increment of maize with the application of balanced fertilizer over the control and recommended NP might be due to the balanced nutrient (macro and micronutrient) present in the blended fertilizer. This was might be due to the split application of nitrogen fertilizer in addition to the balanced fertilizers and also it might be attributed to the additional availability of nutrients.

These results conformed to found of Sharma *et al.* (2012) those stated that the application of micronutrients combinations with macronutrients gave the highest biological yield. Dagne, 2016 and Shiferaw *et al*., 2018 reported a similar study indicated that maximum maize biological yield was obtained by applying blended fertilizer, whereas the lowest biological yield was recorded from the control treatments

Table 6. Influence of Fertilizer types and rates on biological yield, harvest index and shelling percentage of Maize

Treatments (Fertilizer rates kg ha^{-1})	BY	HI	Shell
T1= control	7675.4^{e}	38.614^{c}	73.79^{f}
T2=(92N + 69 P_2O_5)	11766.6^{d}	43.90^{b}	80.56^{e}
T3=150 NPS + 100 Urea + 100 KCl	12709.3^{d}	44.67^{b}	81.46^{de}
T4=200 NPS + 100 Urea + 100 KCl	16807.9^{b}	44.973^{b}	84.01^{cd}
T5=250 NPS + 100 Urea + 100 KCl	18176.8^{a}	46.12^{ab}	87.67^{ab}
T6=150 NPS + 150 Urea + 100 KCl	17402.9^{ab}	44.71^{b}	83.85^{cd}
T7=200 NPS + 150 Urea + 100 KCl	15642.2^{c}	44.79^{b}	83.27^{cde}
T8=250 NPS + 150 Urea + 100 KCl	18294.3^{a}	45.86^{ab}	85.15^{bc}
T9=150 NPSB + 100 Urea +100 KCl	15513.4^{c}	45.31^{b}	84.01^{cd}
T10=200 NPSB + 100 Urea +100 KCl	18304.60^{a}	45.29^{b}	84.96^{bc}
T11=250 NPSB + 100 Urea +100 KCl	18521.50^{a}	47.65^{a}	88.51^{a}
T12=150 NPSB + 150 Urea + 100 KCl	17802.90^{ab}	45.47^{ab}	84.56^{c}
T13=200 NPSB +150 Urea +100 KCl	16933.80^{b}	44.53^{b}	83.92^{cd}
T14=250 NPSB +150 Urea +100 KCl	16925.30^{b}	44.91^{b}	83.99^{cd}
LSD	1121.10	2.27	2.8714
CV%	4.93	3.55	2.40

LSD =List significant difference, CV%= coefficient variation, BY= biological yield (kg ha^{-1}), HI =harvest index in percent (%), shell =shelling percentage in percent (%), Means values followed by the same letter(s) within the column were not significantly different at 0.05 probability level.

4.4.5 Harvest index

Harvest index was highly significantly (P<0.01) different (Appendix Table3). The maximum harvest index (47%) was obtained at the application of 250 NPSB + 100 urea + 100 KCl kg ha^{-1} and the minimum harvest index (38%) was recorded under control treatment. The increase in the harvest index due to micronutrients may be attributed to its influences in enhancing the photosynthesis process and translocation of photosynthetic products to the economic part. The higher harvest index expressed was for the reason of the physiological potential for converting dry matter into grain yield.

4.4.6 Maize Shelling percentage

The analysis of variance among fertilizer types and rates on shelling percentage of maize revealed a highly significant (P<0.01) difference. The highest shelling percentage (88%) was obtained from the application of 250 NPSB + 100 urea + 100 KCl kg $ha^{-1}$and the lowest (73%) was obtained from the control treatment (Table 6).

Application of N and P alone or in various combinations had increase shelling percentage of maize (Ali *et al*., 2002). Similarly, a positive correlation was observed between shelling percentage and various levels of N. Application of N and P in combination of 150 + 120 kg ha^{-1} resulted in higher shelling percentage (68.80%) while minimum shelling percentage was recorded in control plots (60.62%) respectively (Ali *et al*., 2002).

4.5 Correlation Analysis

4.5.1Correlation analysis of maize yield and yield component

Grain yield were highly significantly (P<0.01) and positively correlated with plant height (r=0.34), ear length (r=0.51), thousand seed weight (r=0.61), straw weight (r=0.97), biological yield (r=0.99), harvest index (r=0.81), shelling percentage (r=0.89) and significant (p<0.05) and positive correlation with number of grains per cob (r=0.27) and non significant (p>0.05) and positively correlated with ear height (r=0.16), but grain yield were none significant and negative correlation with number of ear per plant (r=-0.02) and number of rows per cob (r=-0.01). This indicated the fertilizer application had no significant effect on the number of ear per plant. The above ground biomass was highly significantly (p<0.01) and positively correlated with ear length (r=0.48), cob length (r=0.59), thousand grain weight (r=0.40), straw weight (0.99) and cob weight (r=0.51) and none significant (p>0.05) and positively correlated with ear height (r=0.15), but none significant (p>0.05) and negatively correlated with number of ear per plant (r=-0.04) and number of row per cob (r=-0.12).

Similar findings were reported by Yihenew (2015) and Habtamu *et al*. (2015) that grain yield of maize was positively and significantly correlated with yield components. Generally, Pearson’s moment correlation coefficients between grain yield and fourteen other agronomic traits considered in the study were shown (Appendix Table 4). The current investigation was in line with the previous studies made by Pearl**,** (2012) that certain plant characters such as thousand kernel weight and cob length highly significant and positively correlated with grain yield.

4.6 Effect of Fertilizer on Nutrient Content and Uptake of Maize

4.6.1 Nitrogen nutrient concentration and nutrient uptake of maize

The maximum N concentration in grain (1.44%) was obtained from the application of 250 NPSB + 100 urea +100 KCl kg ha^{-1} and the maximum N concentration in straw (1.37%) was from the application of 250 NPS + 150 urea +100 KCl kg ha^{-1}, while the minimum N concentration grain and straw was recorded from the control treatment (Table 7).

The maximum grain N uptake (126.83 kg ha^{-1}) was obtained from the application of 250 NPSB + 100 urea +100 KCl kg ha^{-1} and the maximum straw N uptake (114.63 kg ha^{-1}) and total biomass N uptake were obtained from the application of 250 NPS + 150 urea + 100 KCl kg ha^{-1}, while the minimum N in grain, straw and total biomass was recorded from the control treatment (Table 7). The improvement of N uptake and concentration of maize over the control and the recommended NP could be due to improved efficiency of N attributed to macro and micronutrient present in types of fertilizer applied. The application of compound NPS and blended NPSB along with urea and K and recommended NP had influenced the grain and straw N uptake.

These results conformed to the finding of Dagne (2016) who stated that the application of micronutrients combinations with macronutrients gave the highest N concentration and uptake both in grain and straw. N uptake in grain has positive significant associations with grain yield (Fageria and Baligar, 2001). Hence, improving N uptake in grain may lead to improved grain yield. Also, combined the application of nitrogen and phosphorus to increase the N uptake of maize was reported by Ali *et al*. (2002) as the level of phosphorous increase the N uptake increased. The combined application of NP (150 + 120) kg ha^{-1} noted that maximum N uptake (119.13 kg ha^{-1}) reported. Split application of N also increases the nitrogen uptake through the growing season. Lelei *et al*. (2009) reported that N was taken up by maize throughout the growing season with maximum uptake recorded at 10 days before to 25 to 30 days after tasselling.

Table 7. Maize grain and straw nutrient concentration and uptake

Treatment	Nitrogen concentration %		Nitrogen Uptake kg ha^{-1}			Phosphorous concentration %		Phosphorous Uptake kg ha^{-1}			Potassium concentration %		Potassium Uptake Kg ha^{-1}		
	Grain	Straw	Grain	Straw	TB	Grain	Straw	Grain	Straw	TB	Grain	Straw	Grain	Straw	TB
T1	0.42	0.35	12.37	13.35	25.72	0.27	0.12	8.02	4.58	12.59	0.55	1.54	16.33	58.72	75.05
T2	0.76	0.59	39.27	33.04	72.31	0.36	0.21	18.60	11.76	30.36	0.66	1.87	34.1	104.72	138.82
T3	1.03	0.70	58.53	41.44	99.97	0.54	0.27	30.69	15.98	46.67	1.13	2.43	64.21	143.86	208.07
T4	1.13	0.75	85.77	60.80	146.57	0.67	0.28	50.70	22.70	73.40	1.15	2.13	87.03	172.67	259.7
T5	1.07	0.79	89.77	69.10	158.87	0.55	0.27	46.15	23.62	69.76	1.10	2.17	92.29	189.8	282.09
T6	1.37	1.00	106.97	83.87	190.84	0.53	0.28	41.28	23.48	64.77	1.10	2.36	85.69	197.93	283.61
T7	1.42	0.97	99.62	72.17	171.79	0.86	0.24	60.33	17.86	78.19	0.81	2.54	56.83	188.98	245.8
T8	1.42	1.37	119.10	118.73	237.83	0.50	0.26	41.94	22.53	64.47	1.10	2.21	92.26	191.53	283.8
T9	1.00	0.91	70.10	66.25	136.35	0.54	0.25	37.98	18.20	56.18	1.14	2.36	80.18	171.81	251.99
T10	1.36	0.78	112.76	68.33	181.09	0.61	0.25	50.58	21.90	72.48	1.17	2.73	97.01	239.15	336.16
T11	1.44	1.20	126.83	104.16	230.99	0.73	0.28	64.45	24.30	88.75	1.02	2.69	90.05	233.49	323.54
T12	1.06	1.05	85.95	88.76	174.71	0.54	0.25	43.65	21.13	64.78	1.14	2.24	92.15	189.35	281.5
T13	1.40	0.82	105.66	67.35	173.01	0.67	0.28	50.57	23.00	73.56	0.95	2.69	71.70	220.94	292.64
T14	1.24	0.97	94.31	78.63	172.94	0.76	0.33	57.80	26.75	84.55	0.90	2.61	68.45	211.58	280.03

TB=Total biomass, *T1=control, kg* ha^{-1} *(T2=92N + 69* P_2O_5 *, T3=150 NPS + 100 Urea + 100 KCl , T4=200 NPS + 100 Urea + 100 KCl, T5=250 NPS + 100 Urea + 100 KCl, T6=150 NPS + 150 Urea + 100 KCl , T7=200 NPS+ 150 Urea + 100 KCl, T8=250 NPS + 150 Urea + 100 KCl, T9=150 NPSB + 100 Urea +100 KCl, T10=200 NPSB + 100 urea +100 KCl, T11=250 NPSB + 100 Urea +100 KCl, T12=150 NPSB + 150 Urea + 100 KCl, T13=200 NPSB +150 Urea +100 KCl, T14=250 NPSB +150 Urea +100 KCl).*

On the other hand; N content in the straw was lower as compared to that in the grain. Below *et, al*. (1981) indicated the main reason as why N content in grain was higher than straw nitrogen; this was due to nitrogen was lost from the leaves and straws immediately following silking, corresponding to the time of greatest increase in ear N content by remobilization of N. Nitrogen in the grain at harvest came partly from uptake after anthesis and straw. Accordingly, 48% of N in the grain was taken up after anthesis and about 52 % was transferred from the vegetative parts (Russel, et al., 1988).

4.6.2 Phosphorous nutrient concentration and nutrient uptake of maize

The highest P concentration of grain (0.86%) was observed at fertilizer rate of 200 NPS + 150 urea + 100 KCl kg ha^{-1} and P concentration of straw (0.33%) was observed at fertilizer rate of 250 NPSB + 150 urea + 100 KCl kg ha^{-1} respectively. The maximum and minimum P grain uptake (64.45 and 8.02) kg ha^{-1} were obtained at the application of 250 NPSB + 100 urea + 100 KCl kg ha^{-1} and control treatment respectively (Table 7). This improvement might be the synergic effect of micronutrient combined with macronutrient fertilizer improved uptake of phosphorous over recommended NP fertilizer. Also, the positive strong and highly significant association of P uptake with K grain uptake, N grain uptake, P recovery and S grain uptake were observed; consequently improve the grain P uptake over recommended NP.

This result was line with (Dagne, 2016), who reported blended fertilizer with Cu and Zn the highest grain uptake and contents of P were observed. Generally, the highest removal of P was observed more toward the grain as compared to the straw. These results were in line with the funding of (Waldren and Flower, 1979), who reported that the quantity of P in grain at harvest ranged from 78% to 90% of the total P content. The nutrient uptake increased through the application of lime and compost with blended macronutrients and micronutrients in the appropriate form of fertilizer to nutrient-deficient soil (Woubshet *et al.*, 2017).

4.6.3 Potassium nutrient concentration and nutrient uptake of maize

The highest concentration of K in grain (1.17%) and straw (2.73%), were recorded at 200 NPSB + 100 urea + 100 KCl kg ha^{-1}, whereas the minimum value in grain (0.55% and straw (1.54%) were recorded from control treatment (Table 7). The highest K uptake in grain, straw and total biomass kg ha^{-1} (97.01, 239.15 and 336.16) was obtained from the application of 200

NPSB + 100 urea +100 KCl kg ha^{-1} (Table 7). These increments might be the optimum supply of nitrogen with blended fertilizer ensures optimum uptake of potassium as well as phosphorus.

This result was line with (Malkouti, 2008 and Asefa *et al*., 2014), who reported fertilizer use efficiency for different crops increased by the application of suitable micronutrients combination with NPK fertilizer. Maize takes up to 38% of the total K for the whole growing season, from 38 to 52 days after sowing (Rehman *et al*., 2008).

4.7 Apparent Fertilizer Recovery, Agronomic and Physiological Use Efficiency of Maize

4.7.1 Apparent N and P fertilizer recovery

The highest apparent fertilize recovery of N recorded was 230.47% from 250 NPSB + 100 urea + 100 KCl kg ha^{-1} and P was 96.38% from 150 NPSB + 150 urea + 100 KCl kg ha^{-1} (Table 8). Application of compound NPS and blended NPSB fertilizer along with urea and K fertilizer improved the apparent N and P fertilizer recovery as compared to the recommended NP fertilizer. The apparent N and P recovery decreased with increasing rate of fertilizer application were inconsistently. The fertilizer had improved the N and P recovery over recommended N and P might be the contribution of macronutrient (S) and micronutrient (B) present in compound NPS and blended NPSB fertilizer increased the availability of macronutrients.

Table 8. Apparent fertilizer recovery, agronomic and physiological use efficiency of maize

Treatments (Fertilizer rates kg ha-1)	AR %		AE kg ha^{-1}		PE kg ha^{-1}	
	N	P	N	P	N	P
T1= control	-	-	-	-	-	-
T2=(92N + P_2O_5)	50.89	25.75	23.89	31.85	46.94	230.23
T3=150 NPS + 100 Urea + 100 KCl	101.41	59.79	36.43	47.61	35.92	147.71
T4=200 NPS + 100 Urea + 100 KCl	142.87	80.02	54.75	60.51	38.32	150.17
T5=250 NPS + 100 Urea + 100 KCl	142.86	60.18	57.98	57.07	40.59	183.68
T6=150 NPS + 150 Urea + 100 KCl	166.53	91.54	49.44	84.57	29.69	186.43
T7=200 NPS + 150 Urea + 100 KCl	135.21	86.32	37.82	53.25	27.97	121.44
T8=250 NPS + 150 Urea + 100 KCl	181.1	54.61	46.51	57.04	25.68	204.68
T9=150 NPSB + 100 Urea +100 KCl	152.53	80.50	55.56	75.06	36.43	179.81
T10=200 NPSB + 100 Urea +100 KCl	187.83	82.95	64.75	73.72	34.47	177.49
T11=250 NPSB + 100 Urea +100 KCl	230.47	84.39	64.21	64.92	27.86	142.41
T12=150 NPSB + 150 Urea + 100 KCl	154.13	96.38	53.14	94.44	34.48	194.05
T13=200 NPSB +150 Urea +100 KCl	137.86	84.45	43.52	63.41	31.57	151.84
T14=250 NPSB +150 Urea +100 KCl	126.91	79.74	40.58	51.37	31.96	128.54

AR= Apparent recovery, AE= Agronomic use efficiency, PE= Physiological use efficiency

4.7.2 Agronomic N and P use efficiency of maize

Application of compound NPS and blended NPSB fertilizer along with urea and K fertilizer influenced agronomic fertilizer use efficiencies of maize as compared to the recommended NP fertilizer (Table 8). The highest agronomic fertilizer N use efficiency (64.75 kg ha^{-1}) was obtained from the application of 200 NPSB + 100 urea +100 KCl kg ha^{-1}, while lowest agronomic fertilizer N use efficiency (23.89 kg ha^{-1}) was recorded from recommended NP fertilizer.

Karim and Ramasamy (2000) suggested that higher fertilizer use efficiency which was always associated with low fertilizer rate, cultural practices means promoting integrated nutrient management will help to effect saving in the amount of fertilizer applied to the crops and there to improve fertilizer use efficiency. Agronomic fertilizer use efficiency of any nutrient can be increased by increasing plant uptake and the use of nutrients and by decreasing nutrient losses from the soil plant system. Mengel *et al*. (2006) agronomic fertilizer use efficiency value for a nutrient should not be less than 5 kg ha^{-1}. The results of the studied area were ranged from 23.89 to 64.75 kg ha^{-1} which was the optimum standard of agronomic use efficiency according to Mengel *et al*. (2006). Therefore, the agronomic N fertilizer use efficiency for fertilizer of studied area was above the optimum range. Dobermann (2005) reported that agronomic fertilizer use efficiency should be within the ranges of 10 to 30 kg kg^{-1} and if the value of agronomic N fertilizer use efficiency above 30 kg ha^{-1} in well managed system or at lower levels of N use or low soil N supply.

Application of compound NPS and blended NPSB fertilizer along with urea and K fertilizer influenced agronomic fertilizer P use efficiencies of maize as compared to the recommended NP fertilizer (Table 8). The highest agronomic fertilizer P use efficiency (94.44 kg ha^{-1}) was obtained under the application of 150 NPSB + 150 urea + 100 KCl kg ha^{-1}, while lowest agronomic fertilizer P use efficiency (31.85 kg ha^{-1}) was recorded from recommended NP fertilizer.

4.7.3 Physiological N and P use efficiency of maize

The physiological efficiency of N and P were not influenced by the application compound NPS and blended NPSB fertilizer along with urea and K fertilizer application as compared to the recommended NP fertilizer (Table 8). According to Dobermann (2005), physiological efficiency values should commonly range from 30 to 60 kg kg^{-1}. If the obtained results are above these common values, it could be concluded that the farm was under a well-managed system and the reverse is true, if the results obtained are below the common values. The physiological efficiency of the experimental site most of the treatment was at this range for N and above the range for P physiological efficiency.

4.8 Economic Analysis

Partial budget and Marginal analysis of economic concepts were used to analyze the data. Partial budget is a method of organizing experimental data and information about the costs and benefits of various alternative treatments. Marginal analysis is a method for comparing the costs that vary with the net benefits for selecting the best technology for recommendations from the experiment.

4.8.1 Partial Budget Analysis

Partial budget averaged of the fourteen (14) treatment calculated from income and expenses based on variable cost (Table 9). Net benefit was calculated by subtracting the Total Variable Cost (TVC) from the gross field benefit (GFB) for each treatment. All variable costs were calculated excluding the price of other agronomic practices such as cost of seed, land plowing, sowing, weeding, protection of the farm and harvesting because it was uniform for all treatments. Cost of fertilizer NPS was 15 ETB, NPSB was ETB 15.25 kg^{-1}, TSP was ETB 13.75 kg^{-1}, KCl was ETB 14.50 kg^{-1} and urea was ETB 11 kg^{-1}. The cost of fertilizer transportation was considered as ETB 15 per 100 kg fertilizer and labor cost of fertilizer application ETB 27 per day for 8 hours for 100 kg fertilizer. The Local market selling price of one kilogram maize in Ethiopia birr at the Tepi area was five birr. The variable costs were summed up and subtracted from gross field benefits which were taken as net benefit. The average yield was adjusted downward by 10% and was used to reflect the difference between the experimental field and the expected yield from farmers' fields with farmers' practices from the same treatments (Getachew and Rezene, 2006). Dominance analysis led to the selection of treatments ranked in increasing order of total variable costs (Table 10). For each pair of ranked treatments, the percent marginal rate of return (MRR) was calculated. The MRR (%) between any pair of un-dominated treatments was the return per unit of investment in fertilizer. It was calculated by dividing the change in net benefit to the change in variable costs. Analysis of marginal rate of return (MRR) was carried out for non dominated treatments and the MRRs were compared to a minimum acceptable rate of return (MARR) of 100% to select the optimum treatment (CIMMTY, 1988).

The highest net benefit of 33175.4 ETB ha^{-1} was obtained from the application of 250 NPSB +100 urea + 100 KCl kg ha^{-1} and 31266.45 ETB ha^{-1} followed by 250 NPS + 100 urea + 100 KCl kg ha^{-1} respectively. On the other hand, the lowest net benefit (13360.05 ETB ha^{-1}) was obtained from the application of the control.

Table 9. Partial budget analysis of fertilizer application rate and types on maize

Treatments	GYL kg ha^{-1}	Ad.GYl kg ha^{-1}	GFB	TVC	NB
T1= control	2968.9	2672.01	13360.05	0	13360.05
T2=(92N + P_2O_5)	5166.6	4649.94	23249.7	4409.5	18840.2
T3=150 NPS + 100 Urea + 100 KCl	5682.7	5114.43	25572.15	4947	20625.15
T4=200 NPS + 100 Urea + 100 KCl	7567.9	6811.11	34055.55	5718	28337.55
T5=250 NPS + 100 Urea + 100 KCl	8390.1	7551.09	37755.45	6489	31266.45
T6=150 NPS + 150 Urea + 100 KCl	7789.6	7010.64	35053.2	5518	29535.2
T7=200 NPS + 150 Urea + 100 KCl	7015.6	6314.04	31570.2	6289	25281.2
T8=250 NPS + 150 Urea + 100 KCl	8387.6	7548.84	37744.2	7060	30684.2
T9=150 NPSB + 100 Urea +100 KCl	7033.4	6330.06	31650.3	4984.5	26665.8
T10=200 NPSB + 100 Urea +100 KCl	8291.2	7462.08	37310.4	5768	31542.4
T11=250 NPSB + 100 Urea +100 KCl	8828.2	7945.38	39726.9	6551.5	33175.4
T12=150 NPSB + 150 Urea + 100 KCl	8082.9	7274.61	36373.05	5555.5	30817.55
T13=200 NPSB +150 Urea +100 KCl	7547.1	6792.39	33961.95	6339	27622.95
T14=250 NPSB +150 Urea +100 KCl	7605.3	6844.77	34223.85	7122.5	27101.35

Ad.GYL=Adjusted grain yield down to 10%, GYL=grain yield, GFB=Growth field benefit, TV C=Total cost that varies, NB=Net benefit

4.8.2 Dominance analysis

The highest net benefits from the application of inputs for the production of the crop might not be sufficient for the farmers to accept as good practices. In most cases, farmers prefer the highest profit (with low cost and high income). For this purpose, it is necessary to conduct dominated treatment analysis (CIMMITY, 1988). The MRR% between any pair of un-dominated treatments denotes the return per unit of investment in fertilizer expressed as a percentage. A dominated treatment is any treatment that has net benefits that are less than those of a treatment with lower costs that vary (Stephen and Nicky, 2007).

Table 10. Dominance analysis of fertilizing and marginal analysis

Treatments (fertilizer rate in kg ha^{-1})	TVC	NB	MRR%
T1=control	0	13360.05	-
T2=92N +69 P_2O_5	4409.5	18840.2	124.2805^{UD}
T3=150 NPS + 100 Urea + 100 KCl	4947	20625.15	332.0837^{UD}
T9=150 NPSB + 100 Urea +100 KCl	4984.5	26665.8	16108.4^{UD}
T6=150 NPS + 150 Urea + 100 KCl	5518	29535.2	537.8444^{UD}
T12=150 NPSB + 150 Urea + 100 KCl	5555.5	30817.55	3419.6^{UD}
T4=200 NPS + 100 Urea + 100 KCl	5718	28337.55	1526.15^{D}
T10=200 NPSB + 100 urea +100 KCl	5768	31542.4	6409.7^{UD}
T7=200 NPS+ 150 Urea + 100 KCl	6289	25281.2	1201.77^{D}
T13=200 NPSB +150 Urea +100 KCl	6339	27622.95	4683.5^{D}
T5=250 NPS + 100 Urea + 100 KCl	6489	31266.45	2429^{UD}
T11=250 NPSB + 100 Urea +100 KCl	6551.5	33175.4	3054.32^{UD}
T8=250 NPS + 150 Urea + 100 KCl	7060	30684.2	489.912^{D}
T14=250 NPSB +150 Urea +100 KCl	7122.5	27101.35	5732.56^{D}

UD=Un-dominate, D=dominate, TVC=Total cost that varies, NB=Net benefit, MRR marginal rate of return.

The result indicated that the net benefit was decreased as the total cost that varies increased beyond un-dominated fertilizer treatment application. Therefore, no farmer may choose other dominated treatments in comparison with the un-dominated treatments. This also helps to avoid the dominated treatment in further estimate of marginal rates of return.

4.8.3 Marginal analysis

Economic analysis revealed that the maximum marginal rate of return was recorded with the application of 250 NPSB + 100 urea + 100 KCl kg ha^{-1} with MRR 3054.32 %, followed by 250 NPS + 100 urea + 100 KCl kg ha^{-1} with MRR 2429 % (Table 10). The marginal rates of those treatments were well above the minimum acceptable return (CIMMYT, 1988).

According to CIMMYT (1988) experience and empirical evidence, for the majority of situations indicated that the minimum rates of return acceptable to farmers were between 50 and 100%. In the present study, the treatments that had between 50 and 100% marginal rate of return was recommended for the farmers, with treatments that had the small number of variable cost. Therefore, 250 NPSB + 100 urea + 100 KCl kg ha^{-1} treatment was recommended to the study area. The best recommendation for treatments subjected to marginal rate of return was not necessarily based on the highest marginal rate of return, rather based on the minimum acceptable marginal rate of return and the treatment with the highest net benefit, relatively low variable cost together with an acceptable MRR becomes the recommendation (CIMMYT, 1988).

5. CONCLUSION AND RECOMMENDATION

This study was conducted in Yeki District to determined the optimum rate of new fertilizer type that recommended by EthioSIS.

It is concluded from the results that the new fertilizer type recommended for specific location improved maize yield, nutrient uptake and agronomic use efficiency, but no change on physiological fertilizer use efficiency over the control and recommended NP fertilizer. Application of NPSB at a rate of 250 with 100 urea and 100 KCl kg ha^{-1} had minimum acceptable marginal rate of return, highest net benefit and relatively small total cost of production was recommended for maize production in Yeki District. NPS applied at a rate of 250 kg ha^{-1} with a similar rate of urea and KCl as above can be considered as the second alternative. However, since the experiment was conducted only for one season and one site further validation and demonstration across multiple environments will be necessary to make a conclusive recommendation.

6. REFERENCES

Abebaw T and Hirpa L. 2018. Effects of Fertilizer Rate (Blended) and Sowing Methods on Yield of Bread Wheat (*Triticum aestivum*) and its Economic Profitability in Western Ethiopia. *International Journal of Comprehensive Research in Biological Sciences,* Volume -5: Issue -7; Pages: 1-14ISSN: 2393-8560.

Abebayehu, A., Elias, E., and Diels, J., 2011. Comparative analysis of soil nutrient balance at farm level: a case study in Jimma Zone, Ethiopia. *International Journal of Soil Science,* 6(4): pp.259-266.

Yifru A and Sofiya. 2017. Status of Soil Micronutrients in Ethiopian Soils: A review; *Journal of Environment and Earth Science,* Vol.7, No.4.

Abiye, A., Tekalign, M., Peden, D and Diedhiou, M. 2003. Participatory on farm conservation tillage trial in Ethiopian highland Vertisols: The impact of potassium application on crop yield. *Experimental Agriculture,* **40:**369-379.

Adediran, J. A and Banjoko, V. A. 1995. Response of Maize to Nitrogen, Phosphorus and Potassium fertilizers in the savanna zone of Nigeria. *Commun. Soil Scince. Plant Anal.,* **26:**593-606.

Admassu M., Wassie, H and Worku, W. 2015. Response of Maize (Zea mays L.) to Potassium Fertilizer at Hadero, Southern Ethiopia; 2nd IPI, Ministry of Agriculture and Natural Resources; Hawassa University. Ethiopian ATA Joint Symposium held from 24-26 Novemeber 2015. Hawassa, Ethiopia.

Agarwala, S. C, Sharma, P.N, Chatterjee, C and Sharma, C.P. 1981. Development and enzymatic changes during pollen development in boron deficient maize plants. *Journal of Plant nutrient,* **3:** 329-336.

Ahmad S, Khan AA, Kamran M, Ahmad I and Ali S. 2018. Response of Maize cultivar to Various Nitrogen Levels. *Eur Exp Biol.,* Vol. 8 No. 1:2.

Ali, R. and Raouf, S. S. 2012. Effects of rates and nitrogen application timing on yield, agronomic characteristics and nitrogen use efficiency in corn. *International Journal of Agriculture and Crop Sciences,* **9:** 534-539.

Ali.J, Bakht.J, Shafi.M., Khan, S and Sha,W.A. 2002. Effect of various levels of N and P on yield and yield components of Maize. *Pakistan Journal of Agronomy,* **1(1):** pp.12-14.

Alley, M.M and Vanlauwe, B. 2009. The role of fertilizers in integrated plant nutrient management, First edition, IFA, Paris, France. TSBF-CIAT, Nairobi, p 59.

Amare, T., A. Terefe, Y. G. Selassie, B. Yitaferu, B. Wolfgramm, and H. Hurni. 2013. Soil properties and crop yields along the terraces and toposequence of Anjeni Watershed, Central Highlands of Ethiopia. *Journal of Agricultural Science,* **5 (2):**134–144.

Anonymous. 2000. Fertilizers and their use; FAO, International Industry Association, Rome. pp: 35-38.

Arif, M., Ali,S., Khan, A., Jan, T., Akbar, M. 2006. Influence of farmyard manure application on various wheat cultivars. *Sarhad J. Agric*., **22:** 27-29.

Arif, M., Amin, I., Jan, M.T., Munir, I.Q.B.A.L., Nawab, K.H.A.L.I.D., Khan, N.U. and Marwat, K.B. 2010. Effect of plant population and nitrogen levels and methods of application on-ear characters and yield of maize. *Pak. J. Bot.,* **42(3):** 1959-1967.

Asefa, F, Mohammed, M and Debela, A. 2014. Effects of different rates of NPK and blended fertilizers on nutrient uptake and use efficiency of Teff [*Eragrostis tef* (*Zuccagni*) Trotter] in Dedessa District, Southwestern Ethiopia. *Journal of Biology, Agriculture and Healthcare,* Vol.4, No.25.

Asglil, D., Taye, B and Yesuf, A. 2007. The status of micro-nutrients in Nitisols, Vertisols, Cambisols and Fluvisols in major maize, wheat, teff and citrus growing areas of Ethiopia. In Proceedings of Agricultural Research Fund Research Projects Completion Workshop held on 1-2 February 2007 at EIAR, Addis Ababa, Ethiopia. pp 77-96.

ATA (Agricultural Transformation Agency). 2016. Soil fertility status and fertilizer recommendation atlas for SNNPRS, Ethiopia. Ethiopian Agricultural Transformation Agency (ATA), A.A, Ethiopia.

Attah, L. 2010. Physicochemical characteristics of the rhizosphere soils of some cereal crops in Ambo Woreda, West Shoa, Ethiopia. *Maejo International Journal of Science and Technology,* **4:** 93-100.

Ayalew, A and Habte, M. 2017. Use of balanced nutrients for better production of Teff (Eragrostis tef (zucc.) at Bensa in Southern Ethiopia. *Journal of Resources Development and Management,* Vol.32.

Ayman, H. A. and Samier, K. A. 2015. Maize productivity as affected by plant density and nitrogen fertilizer. *International Journal of Current Microbiology Applied Science*, **4(6):** 870-877.

Bacon, S.C., L.E. Lanyon, and R.M. Schlander, Jr. 1990. Plant nutrient flow in the managed pathways of an intensive dairy farm. *Agronomy Journal,* **82(4):** pp.755-761.

Bationo, A., Mokwunye, U., Vlek, P.L.G., Koala, S., Shapiro, B.I and Yamoah, C. 20 03. Soil fertility management for sustainable land use in the West African Sudano-Sahelian zone, Soil fertility management in Africa: A regional perspective. TSBF-CIAT.

Beede, R.H., Brown, P.H., Kallsen, C., Weinbaum, S.A. 2011. Diagnosing and correcting nutrient deficiencies. Fruit and Nut; Research and Information Center, University of California.

Bekunda, M.A., Bationo, A. and Sali S. 2010. Soil fertility management in Africa: review of selected research trials. *SSSA Journal Special Publication,* **51:** 63-79.

Benti, T., Kebede, M., Legesse, W., Mosisa, W and Leta, T. 1997. Reflections on the achievements of a hybrid maize breeding program in Ethiopia, Maize Productivity Gains through Research and Technology Dissemination: Proceedings of the Fifth Eastern and Southern Africa Regional Maize Conference, Arusha, Tanzania, June 3-7, 1996, CIMMYT, Addis Ababa, Ethiopia.

Brady N.C and R.R. Weil. 2002. The nature and properties of soil, 13th ed. Pearson Education, Asia. 960p.

Brady, N.C. and Weil, R.R. 2007. The Nature and Properties of Soils (13th ed.) Prentice-Hall, New Jersey.

Bremner, J.M. 1965.Total Nitrogen, methods of soil analysis, part 2: chemical and microbiological properties (methods of soilanb), pp.1149-1178.

Bridle, I.A., Bradley, M.S and Reed, A.R. 2004. Non-segregating blended fertilizer development: A new predictive test for optimizing granulometry. Society Proc 547. York, UK: The International Fertilizer Society.

Cakmak, I and Romheld. V. 1997. Boron deficiency-induced impairment of cellular functions in the plant. *Plant Soil,* **193:** 71-83.

Cakmak, I, Torun, B., Erenoglu, B., Ozturk, L., Marschner, H., Kalayci, M., Ekiz, H and Yilaz, A. 1998. Morphological and Physiological Differences in the Response of Cereals to Zn Deficiency. *Euphytica,* **100**: 349-357.

Camacho, C., Rexach, J. J and González, F. A. 2008. Boron in plants, deficiency and toxicity. *J.Integr; Plant Biol.*, **50:** 1247-1255.

Chapman, HD.1965. Cation exchange capacity methods of soil analysis, part 2, chemical and microbiological properties, (methods of soil analysis), pp.891-901.

CIMMYT and IITA. 2010. Maize-Global alliance for improving food security and the livelihoods of the resource-poor in the developing world: Draft proposal submitted by CIMMYT and IITA, to the CGIAR Consortium Board.

CIMMYT. 1998. Economics Program, International Maize and Wheat Improvement Center, from agronomic data to farmer recommendations: an economics training manual (No. 27).

CSA (Central Statistical Agency). 2017. Agricultural Sample Survey 2016/2017 Vol-I. Report on area and production of major crops. Statistical Bulletin 269-278. Addis, Ababa Ethiopia.

CSA (Central Statistics Authority). 2008. Old Agricultural sample survey report on area and production for major crops (Private Peasant Holdings, Meher Season). The FDRE-Statistical Bulletin 132. Addis Ababa, Ethiopia.

Dagne Chimdessa. 2016. Blended fertilizers effects on Maize yield and yield components of Western Oromia, Ethiopia. *Agriculture, Forestry and Fisheries,* **5(5):** pp.151-162.

Dell, B and Huang, L. 1997. Physiological responses of plants to low boron, Plant Soil 193: 103-120.

Demissew, A.K, Tolessa, D., Dange, W., Haji, T., Koste, A and Germa, D. 2002. Recommended Research Results for Improving Crop, Livestock, and Natural Resources Productivity in Western Oromia: Users' Manual. OARI, Bako Agricultural Research Center, Oromia, Ethiopia.

Derbay, N., Casey FX, Kinghton RE, Steel DD. 2004. Midseason nitrogen fertilizer management for corn-based on weather and yield prediction. *Agron J*., **96:** 494-502.

Dobermann, A.R. 2005. Nitrogen Use Efficiency State of the Art: Agronomy and horticulture faculty publications.Paper316.http://digitalcommons.unl.edu/agronomyfacpub/316.

EthioSIS (Ethiopian Soils Information System). 2013. Status of soil resources in Ethiopia and priorities for sustainable management, GSP for eastern and southern Africa Mar 25-27, 2013 Nairobi, Kenya.

EthioSIS (Ethiopia Soil Information System). 2014. Soil fertility status and fertilizer r ecommendation atlas for Tigray regional state, Ethiopia. Addis Ababa, Ethiopia, July 2014.

EthioSIS (Ethiopia Soil Information System). 2015. Ethiopian Agricultural Transform ation Agency. http://www.ata.gov. et/highlighted deliverables/Ethiopian soil informati on system ethiosis.

Fageria, N. K. 2001. Nutrient management for improving upland rice productivity and sustainability. *Commun. Soil Sci. Plant Anal.* 32:2603–2629.

Fageria, N. K., M. P. Barbosa Filho, A. Moreira, and C. M., Guimaraes. 2009. Foliar fertilization of crop plants. *J. Plant Nutr*. **32**:1044–1064.

Fageria, N. K., V. C. Baligar, and C. A. Jones. 2011. Growth and mineral nutrition of field crops, 3rd ed. Boca Raton, FLUSA: CRC Press.

Fageria, N. K., V. C. Baligar., and Y. C. Li. 2008a. The role of nutrient efficient plants in improving crop yields in the twenty-first century. *J. Plant Nutr*,3**1:** 1121–1157a.

Fageria, N.K and Baligar, V. C. 2008b. Ameliorating soil acidity of tropical Oxisols by liming for sustainable crop production. *Advances in Agronomy,* **99**:345–399.

Fageria, N.K., Moraes, M.F., Ferreira, E.P.B and Knupp, A.M. 2012. Bio-fortification of trace elements in food crops for human health. *Communications in soil science and plant analysis,* **43(3):** pp.556-570.

Fageria, N. K., M. P. Barbosa Filho, A. Moreira, and C. M. Guimarães. 2009. Foliar fertilization of crop plants. *J. Plant Nutr,* **32**:1044–1064.

Fageria, N.K., and V. C. Baligar. 2005a. Enhancing nitrogen use efficiency in crop plants. *Adv. Agron.*, **88**:97–185.

FAO (Food and Agriculture Organization of the United Nations). 2015. The State of the World's Land and Water Resources for Food and Agriculture (SOLAW) Managing Systems at Risk: Food and Agriculture Organization of the United Nations: Rome, Italy; Earthscan: London, UK, 2011.

FAO (Food and Agriculture Organization of the United Nations). 1977. Guidelines for soil profile description. 2nd ed; Soil Dev. and Conserv. Serv., Land and Water Dev.FA O, Rome.

FAO UNESCO ISRIC, 1988. Soil Map of World. Revised legend, Reprinted with corr ections; world soil Resources report no.60. FAO, Rome.

Fayera, A., Muktar,M and Adugna , D. 2014. Effects of different rates of NPK and blended fertilizers on nutrient uptake and use efficiency of Teff [*Eragrostis tef* (*Zuccagni*) Trotter] in Dedessa District, Southwestern Ethiopia. *Journal of Biology, Agriculture and Healthcare,* www.iiste.org ISSN 2224 3208 (Paper) ISSN 2225 093X (Online) Vol.4, No.25.

Feller, C. and Beare, M.H. 1997. Physical control of soil organic matter dynamics in the tropics. *Geoderma*, **79(1-4):** pp.69-116.

Fufa, B and Hassan, R.M. 2006. Determinants of fertilizer use on maize in Eastern Ethiopia; A weighted endogenous sampling analysis of the extent and intensity of adoption. *Agrekon*, **45(1):** pp.38-49.

Gebrekorkos, G., YG Egziabher and S, Habtu. 2017. Response of Sorghum (*Sorghum bicolor* L.) Moench) varieties to blended fertilizer on yield, yield component and nutritional content under irrigation in Raya Valley, Northern Ethiopia. *Inter J Agri Biosci*, **6(3):** 153-162.

Geremew Taye, Kindie Tesfaye and Tolessa Debele. 2015 Effects of nitrogen and phosphorus fertilizers on the yield of Maize (*Zea mays* L.) at Nedjo, West Wollega, Ethiopia. *Journal of Natural Sciences Research* www.iiste.org ISSN 2224-3186 (Paper) ISSN 2225-0921; Vol.5, No.13.

Getachew Agegnehu and Berhane Lakew. 2015. Soil Test Phosphorus Calibration for Malting Barley (Hordeum vulgare L.) Production on Nitisols of Ethiopian Highlands. Abstract Paper at Research Gate. https://www.researchgate.net.

Getachew, A and Rezene, F. 2006.Response of faba bean to phosphate fertilizer and weed control on nitisols of Ethiopian highlands. *Italian Journal of Agronomy*, pp.281-290.

Gikonyo E.W. and Smithson P.C. 2003. Effects of farmyard manure, potassium and their combinations on maize yields in the high and medium rainfall areas of Kenya: Managing nutrient cycles to sustain soil fertility in sub-Sahara Africa.

Girma Abera, Endalkachew Wolde Meskel and L. R. Bakken. 2012. Carbon and nitrogen mineralization dynamics in different soils of the tropics amended with legume residues and contrasting soil moisture contents, *Biology and Fertility of Soil*, **48:** 51- 66.

Gomez, K A. and A. A. Gomez. 1984. Statistical procedures for agricultural research. (2nd ed); John Wiley and Sons. New York, USA. 680p.

Habib M. 2009. Effect of foliar application of Zn and Fe on wheat yield and quality. *African Journal of Biotechnology*, Vol. **8 (24**): pp. 6795-6798.

Habtamu A. 2015. Response of Maize (Zea mays l.) to Different levels of Nitrogen and Sulfur Fertilizers in Chilga District, Amhara National Regional State, Ethiopia. *International Journal of Recent Scientific Research,* **6(8):** 5689-5698.

Haileselassie, A., J. A. Priess, E. Veldkamp, D. Teketay, and J. P. Lesschen. 2005. Assessment of soil nutrient depletion and its spatial variability on smallholders' mixed farming systems in Ethiopia using partial versus full nutrient balances. Agriculture, Ecosystems and Environment 108:1–16.

Harris .D, Rashid, A., Miraj.G, Arif, M, Shah, H. 2007. On-farm seed priming with zinc sulfate solution: A cost-effective way to increase the maize yields of resource-poor farmers. *Field Crops Research*, 102 (119–127).

Havlin, J.L., J.D. Beaton, S.L. Tisdale, W.L. Nelson. 1999. Soil Fertility and Fertilizers, 6th edition; Upper Saddle River, N.J: Prentice-Hall, Inc. 499 p.

Hazelton, P. and Murphy, B. 2007. Interpreting soil test results: what do all the numbers mean 2nd (ed). Department of natural resources. CSIRO publishing. Australia. Pp. 77-79.

Heckman. J. R., Sims, J. T., Beegle, D. B. Coale, F. J., Herbert S. J., Bruulsema, T. W. and Bamka, W. J. 2003. Nutrient removal by corn grain harvest. *Agronomy Journal*, Vol. 95.

Hepler , P. K. 2005. Calcium, A central regulator of plant growth and development plant cell, Vol. 17, 2142–2155.

Hofstee, J., and W. Huisman. 1990. Handling and spreading of fertilizers part 1: Physical properties of fertilizer in relation to particle motion. *J. Agri. Eng. Res*., **47(4):** 213-234.

Horneck, D.A., Sullivan, D.M., Owen, J.S and Hart, J.M. 2011. Soil test interpretation guide.

Huber, D. M. and I. A. Thompson. 2007. Nitrogen and plant disease, in mineral nutrition and plant disease, L. E. Datnoff, W. H. Elmer and D. M. Huber, eds., 31–44. St. Paul, MN; the American Phytopathological Society.

Hussain, M.Z., Rehman, N., Khan, MA., Roohullah and Ahmed, SR. 2006. Micronutri ent status of Bannu based soils. *Sarhad J Agric.,* **22:** 283-285.

IFA (International Fertilizer Industry Association). 1992. World fertilizer use manual. Paris. 632 pp.

IFDC (International Fertilizer Development Center). 2012. Ethiopia fertilizer assessment IFDC in support of African Fertilizer and Agribusiness Partnership, Muscle Shoals, AL.

IFPRI (International Food Policy Research Institute). 2005. Poverty and Land Degradation in Ethiopia, How to Reverse the Spiral.

IFPRI (International Food Policy Research Institute). 2010. Maize value chain potential in Ethiopia; Constraints and opportunities for enhancing the system, IFPRI: Washington, DC.

Imran, S., Arif, M., Khan, A., Khan, M.A., Shah, W. and Latif, A. 2015. Effect of nitrogen levels and plant population on yield and yield components of maize. *Advances in crop Science and technology,* ***3*****(2):** 1-7.

Jan, A, Naveed, K., and Jan, T., 2002. Residual effect of groundnut and soil amendments on the Performance of gram under rainfed conditions. *Asian Journal of plant science,***1 (6):** 625-627.

Jarupula S., BS, Dwivedi., AK, Dwivedi and SK, Pandey. 2018. Effect of long term application of nitrogen and sulfur nutrition on nitrogen assimilation in Soybean. *Journal of Pharmacognosy and Phytochemistry,* **7(1):** 2000-2004.

John I. H., E. Mayorga, E. Tsamakis, M. E. McClain, A. Aufdenkampe, P. Quay and J. E. Richey. 2000. Organic matter in Bolivian tributaries of the Amazon River, A comparison to the lower mainstream, Limnol. Oceanogr., 45(7), 1449–1466, American Society of Limnology and Oceanography, Inc., Washington

Jones, C., K. Olson-Rutz and Dinkins C.P. 2011. Nutrient uptake timing by crops, to assist with fertilizing decisions. 2-8.

Kaiser, D.E., A.P. Mallarino and M. Bermudez, 2005. Corn grain yield, early growth and early nutrient uptake as affected by broadcast and in furrow starter fertilization. *Agron. J.,* **97:** 620-626.

Kakade, D. K., Rajput, & Joshi, K. I. 2009. Effect of foliar application of Fe and Zn on growth, flowering and yield of China aster (Callistephus chinensis L. Nees). *The Asian Journal of Horticulture,* **4(1):** 138-140.

Karim, A.A and Ramasamy C. 2000. Expanding frontiers of agriculture: contemporary issues. Kalyani Publishers, Ludhiana, India.

Kebede, M., Gezahegne, B., Benti, T., Mosisa, W., Yigzaw, D., and Assefa, A. 1993. Maize production trends and research in Ethiopia; Proceedings of the First National Maize Workshop of Ethiopia. IAR/CIMMYT, Addis Ababa, Ethiopia.

Lalisa Alemayehu, Hager, H. and M. Sieghard. 2010. Effects of land-use types on soil chemical properties in smallholder farmers of central highland of Ethiopia. *Ekologia (Bratislava,)* **29 (1):** 1– 14.

Lance, G. 1996. Theory of fertilizer blending; in *proceedings No.387*, The Fertilizer Society, Peterborough, UK.

Landon J. R. 1991. Booker Tropical soil manual, a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Longman, Booker. 474p.

Lelago A.B, Mamo, T. A Haile, W.W and Shiferaw, H.D. 2016. Soil micronutrients status assessment, mapping and spatial distribution of Damboya, Kedida Gamela and Kecha Bira Districts, Kambata Tambaro zone, southern Ethiopia. *African Journal of agricultural research,* Vol. **11(44):** pp. 4504-4516.

Lelei, J. J., Onwonga, R. N., Freyer, B. 2009. Organic-based nutrient management strategies: Effect on soil nutrient availability and maize (Zea mays L.) performance in Njoro, Kenya. *African Journal of Agricultural Research,* **4(2):** 092–099.

Malakouti, M.J. 2008. The effect of micronutrients in ensuring efficient use of macronutrients. *Turkish Journal of Agriculture and Forestry,* **32(3):** pp.215-220.

Malakouti, M.J. 2000. Balanced nutrition of wheat an approach towards self-sufficiency and enhancement of national health; A compilation of papers. Ministry of Agriculture, Karaj, Iran. 544 pp.

Mandefro, N., Hussien, M., Gelana, S., Gezahegn, B., Yosef, B., S. Hailemichaiel, and Aderajew, H. 2002. Maize improvement for drought-stressed areas of Ethiopia; Proceedings of the Second National Maize Workshop of Ethiopia. EARO/CIMMYT, Addis Ababa, Ethiopia. Pp. 15–30.

Marschner, H. 2011. Mineral nutrition of higher plants; 13th edn. Jamestown Road, London NW1 7BY, UK.

Mehlich, A. 1984. Mehlich 3 soil test extractant, a modification of Mehlich 2 extractant. Commun. *Soil Sci. Plant Anal.,* **15**: 1409-1416.

Mengel, K., Hutsch, B. and Kane, Y. 2006. Nitrogen fertilizer application rates on cereal crops according to available mineral and organic soil nitrogen. *European Journal of Agronomy*, **24(4):** pp.343-348.

Mesfin,. A. 1998. Nature and management of Ethiopian soils, Alemaya University of Agriculture, Ethiopia. 272p.

Miserque, O., E. Pirard, Y. Schenkel, O. Mostade and B. Huyghebaert. 2008. Spreading segregation of blended fertilizers, Influence of the particle properties. *Applied Eng. in Agric*. **24(2):** 137-144.

MoA (Minister of Agriculture). 2016. Agriculture and natural resources Sector Growth and Transformation Plan II (2015-2020).

MoA (Minister of Agriculture). 2014. Ethiopia first-ever fertilizer blending plant inaugurated report.

Mohsin, A.U., Ahmad, J., Ahmad, A.U.H., Ikram, R.M. and Mubeen, K. 2012. Effect of nitrogen application through different combinations of urea and farmyard manure on the performance of spring maize. *J. Anim. Plant Sci.*, **22(1):** 195-198.

Moraditochaee, M., Motamed, M.K., Azarpour, E., Danesh, R.K and Bozorgi, H.R. 2012. Effects of nitrogen fertilizer and plant density management in corn farming. *ARPN Journal of Agricultural and Biological Science*, **7(2):** pp.133-137.

Morgan, M.F. 1941. Chemical diagnosis by the universal soil testing system; conn. agr. exp. sta. (New Haven) bull. 450.

Muhammad, A., Mohammad, T. J., Naqib, U.K., Habib, A., Shad, A.K., Khan, M.J., Ahmad K., IqbaL, M., Muhammad, S., and Aqib, I. 2010. Impact of plant populations and nitrogen levels on maize. *Pakistan Journal of Biotechnology*, **42(6):**3907-3913.

Muhammad.F.J, Waqas.L, Haseeb.A, Muhammad.D.A and Wazir.R. 2018. Phenology, growth, yield and yield components of *maize (Zea mays L*) hybrids to different levels of mineral potassium under semiarid climate. *International Journal of Environmental Sciences and Natural Resources Research Article,* Volume 9 Issue 5.

Mulugeta, H and Abay, A. 2017. Blended fertilizers as sources of balanced nutrients for growth and yield of Wheat at Hulla District in Southern Ethiopia. *Journal of Natural Sciences Research,* www.iiste.org ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online) Vol.7, No.9.

Murphy, H. F. 1968. A report on fertility status and other data on some soils of Ethiopia, experimental station bulletin No. 44. Haile silassie College of Agriculture, *Oklahoma State University,* 551P; of Agriculture Faisalabad.

National Meteorological Services Agency. 2008. Unpublished rainfall and temperature data of Yeki district and Keffa zone from 1980-2005.

Nigussie, H., Poesen, J., Paridaens, K., Nyssen, J., Deckers, S., Mitiku, H. and Govers, G. 2007. Nutrient export and associated costs from micro-dam catchments in Tigray, pp.27-28.

Omotayo, O.E and Chukwuka K.S. 2009. Soil fertility technique in Sub Saharan Africa using organic resources. *African journal of agricultural research* **4(3):** *144-150.*

Onasanya, R.O., Aiyelari, O.P., Onasanya, A., Oikeh, S., Nwilene, F.E. and Oyelakin, O.O. 2009. Growth and yield response of maize to different rates of nitrogen and phosphorus fertilizers in southern Nigeria. *World J. of Agr. Sciences,* **5(4):** 400-407.

Osakabe Y, Osakabe K, Shinozaki K, Tran LS, 2014. Response of plants to water stress. *Front Plant Sci., 5:86.*

Ozanne, P.G. 1980. Phosphate nutrition of plants a general treatise. Phosphate nutrition of plants-a general treatise., pp.559-589.

Pessarakli, M. 2002. Handbook of Plant and Crop Physiology. Eastern Hemisphere Distribution, Marcel Dekker Inc., New York, Basel, 940.

Quinones, M.A., Borlaug, N.E. and Dowswell, C.R. 1997. A fertilizer-based green revolution for Africa; replenishing soil fertility in Africa, (replenishingsoi), pp.81-95.

Rajeshwari, R.S., Hebsur, N.S., Pradeep, H.M. and Bharamagoudar, T.D. 2010. Effect of integrated nutrient management on growth and yield of maize. *Karnataka Journal of Agricultural Science,* **20(2):** 399-400.

Rashid, A. and Akhtar, M. E. 2006. Soil fertility research and nutrient management in Pakistan, in proceedings of symposium on balanced fertilizer use: impact on crop production, 90-113, October 30-31, National Fertilizer Development Centre (NFDC), Islamabad, Pakistan.

Rashid, A., Muhammad, S. and Rafique, E. 2005. Rice and wheat genotypic variation in boron use efficiency. *Soil Environ.,* Vol. 24, pp. 98-102.

Rashid, A., Rafique, E. and Bughio, N. 1997. Micronutrient deficiencies in rainfed calcareous soils of Pakistan. III. Boron nutrition of sorghum. *Communications in soil science and plant analysis*, 28(6-8): pp.441-454.

Rehm, G.W. and Lamb, J.A. 2004. Impact of balanced potassium on crop yield and soil potassium in ridge-till planting. *Soil Science Society of America Journal*, **68(2):** pp.629-636.

Rehman, S.U., M. Ahma Alias Haji A. Bukhsh and M.Ishaque. 2008. Comparative performance and profitability of two corn hybrids with organic and inorganic fertilizers. *Pakistan Journal of Agricultural science.,* **45:** 8-12.

Russel, M. P., E. J. Deibert, R. D. Stevanovic and R. O. Olson, 1988. Effects of water and nitrogen management on yield and 15N-depleted fertilizer use efficiency of irrigated corn, *Soil Sci. Soc. Am. J. 45: 553-558.*

Saddiq, A. M., L. Singh, Mustapha, S. and Voncir, N. 2013. Effects of phosphatic fertilizer on growth and yield of three upland rice varieties in soils of savanna zone of Nigeria. *Journal of League of Researchers in Nigeria,* **14(1):**42-56.

Sanchez, P.A. 2002. Soil fertility and hunger in Africa. *Soil Science,* **295(5562)**: pp.2019-2020.

Sanchez, P.A., Denning, G.L and Nziguheba, G. 2009. The African green revolution moves forward. *Food Security*, **1(1)**: pp.37-44.

Sanchez, P.A., Denning, G.L., and Nziguheba G., 2009. The African Green Revolution moves forward. Food Security 1:37-44.

Sanchez, P.A. 1976. Properties and Management of Soils in the tropics. *Soil science*, **124(3**): p.187.

Sasakawa-Global 2000. 1995. Agricultural project in Ethiopia, Sasakawa-Global 2000, Addis Ababa.

Seilsepour, M., Rashidi, M. 2011. Effect of different application rates of nitrogen on yield and quality of cotton (Gossypium hirsutum); *Am. Euras. Journal of Agriculture. Environmental. Science,* **10(3):** 366-370.

Selamyihun, K., Mamo, T and Stroosnijder, L. 2005. Biomass production of Eucalyptus boundary plantations and their effect on crop productivity on Ethiopian highland Vertisols. *Agroforestry Systems*, **63(3):** pp.281-290.

Shanti, K.V.P., M.R. Rao, M.S. Reddy and R.S. Sarma, 1997. Response of maize *(Zea mays)* hybrid and composite to different levels of nitrogen. *Indian Jounal of Agriculture. Science.*, **67:** 424-425.

Sharma, S.K., Jain, N.K. and Upadhyay, B. 2012. Effect of balanced fertilization on productivity and soil fertility status of maize. *Research on Crops,* **13 (1):** 95-99.

Shiferaw, B., Mulugeta, H., Atinafu, A and Abay, A. 2018. Macro and Micronutrients for optimizing maize production at Hawassa Zuria District, Southern Ethiopia. *Journal of Biology, Agriculture and Healthcare,* ISSN 2224-3208 (Paper) ISSN 2225-093X (Online) Vol.8.

Siam, H. S., Abd El Kader, M. G and El Alia, H. I. 2008. Yield and yield components of maize as affected by different sources and application rates of nitrogen fertilizer. *Research Journal of Agriculture and Biological Sciences,* **4(5):** 399-412.

Simons AM. 2014. Food and agriculture in Ethiopia: progress and policy challenges. Agriculture and Human Values 31(2):329–330.

Sims, J.T., Simard, R.R. and Joern, B.C. 1998. Phosphorus loss in agricultural drainage, historical perspective and current research. *Journal of environmental quality*, **27(2):** pp.277-293.

Singh, M. Kumar, V and Singh, N. 1981. Sulfur and zinc interaction concerning yield, uptake and utilization of sulfur in soybean. *Plant and Soil*, 59:3-8.

Singh, M.V. 2008. Micronutrient deficiencies in crops and soils in India. In micronutrient deficiencies in global crop production (pp. 93-125), Springer, Netherland.

Smith, D. B., Willcutt, M. H, and Y. Diallo. 2005. Uniformity of size and content of granular fertilizers. *Applied Eng. In Agric*., **21(4):** 559-562.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures of statistics. McGraw Hill Book Co. Inc. New York.

Stocking, M.A. 2003. Tropical soils and food security: the next 50 years. Soil *Science*, **302 (5649)**: pp.1356-1359.

Taddese G. 2001. Land degradation, a challenge to Ethiopia; Environmental managementVol. 27, No. 6, pp. 815– 824.

Taye, B., Hassan Y., Setsu, S., Gorfu, A., Hassana, M.,. Tanner, D. G. Tesemma, T and Gebre, T. 2000. Optimizing fertilizer use in Ethiopia correlation of soil analysis with fertilizer response in Hetosa Woreda, Arsi Zone. Addis Ababa, Sasakawa-Global (2000): 54p.

Tekalign M., Richter, C and B. Heiligtag. 2002. Phosphorus availability studies on ten Ethiopian Vertisols. *Journal of Agriculture and Rural Development in the Tropics and Subtropics,* **103 (2):**177–183.

Tekalign, T. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis working document. *International Livestock Research Center for Africa (ILCA)* No 13, Addis Ababas.

Tekalign, M and Haque. I. 1991. Phosphorus status of some Ethiopian soils:III, Evaluation of soil test methods for available phosphorus. *Tropical Agriculture (Trinidad)*, **68**: pp.51-56.

Teklu, B, Amnat, S., Yongyuth, O and Ed Sarobol. 2005. Status of B, Cu, Fe, Mo and Zn of Soils of Ethiopia for maize production: Greenhouse assessment. *Kasetsart Journal*, p.357.

Tilahun, A. 2003. Restoring soil fertility in the highlands of East Africa through participatory research. AHI brief/African Highlands Initiative, strategies for systems intensification; November 2003, no. A1.

Tilahune, A., Endrias, G and Takele, B. 2007. Reversing the degradation of arable land in Ethiopian highlands. Managing Africa's soil. No. 23, IIED-London.

Tolessa, D, Gemechu, G and Melakeselam, L. 1994. Response of maize to split application of nitrogen fertilizer at Bako. In 6 Annual Conference of the Crop Science Society of Ethiopia. Addis Abeba (Ethiopia). 3-4 May 1994.

Tolessa, D., Tesfa, B., Wakene, N., Tenaw, W., Minale, L., Tewoddros M., Burtukan, M and Waga, M. 2002. A review of fertilizer management research on maize in Ethiopia; Enhancing the contribution of maize to food security in Ethiopia, proceeding of the National maize workshop Ethiopia 12-16 November 2001, Addis Aababa, Ethiopia Ethiopian Agricultural Research Organization (EARO) and the International Maize and Wheat Improvement Center (CIMMYT); 46-54p.

Van Beek, C.L., Elias, E., Yihenew, G.S., Heesmans, H., Tsegaye, A., Feyisa, H., Tolla, M. Melmuye, M., Gebremeskel, Y and Mengist, S. 2016. Soil nutrient balances under diverse agro ecological settings in Ethiopia. Nutrient Cycling in Agro-ecosystems, **106(3**), pp.257-274.

Van Reeuwijk L.P. 1992. Procedures for Soil Analyses.3rd ed. Int. Soil Reference and Information Centre Wageningen (ISRIC), The Netherlands.

Vanlauwe, B., Descheemaeker, K., Giller, K.E., Huising, J., Merckx, R., Nziguheba, G., Wendt, J. and Zingore, S. 2015. Integrated soil fertility management in sub-Saharan Africa. unravelling local adaptation. *Soil science*, **1(1)**: pp.491-508.

Wakene, N., Tolera, A., Minale, L., Tolessa, D., Tenaw, W., Assefa, M. and Zirihun, A. 2011. Soil fertility management technologies for sustainable maize production in Ethiopia. In meeting the challenges of global climate change and food security through innovative maize research: pp. 123-127

Waldren, R.P. and Flowerday, A.D. 1979. Growth stages and distribution of dry matter, N, P, and K in Winter Wheat. *Agronomy Journal*, **71(3):** pp.391-397.

Walkley, A. and Black, I.A. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science*, **37(1):** pp.29-38.

Wassie, H and Shiferaw, B. 2011. Response of Irish Potato (Solanum tuberosum) to the application of Potassium at acidic soils of Chencha, Southern Ethiopia. *International Journal of Agricultural Biology, **13**: 595–598.*

Withers, P., Chalmers, A., Hodgson, I., Kane, R., Mcgrath, S. Zhao, F. Sinclair, A. Evans, E. and Bilsborrow, P. 1997. Diagnosis and prediction of sulfur deficiency in winter wheat and barley, Project report No. 142. London: Home-Grown Cereals Authority. 48pp.

Woubshet, D., Selamyihun, K., Tolera, A and Cherukuri.V. 2017. Effects of lime, blended fertilizer (NPSB) and compost on yield and yield attributes of Barley (*Hordium vulgare* L.) on acid soils of Wolmera District, West Showa, Ethiopia. *Ethiopia journal of applied science,* Technol. Vol.**8 (2):** 84-100.

Yihenew, G. 2015. The effect of N fertilizer rates on agronomic parameters, yield components and yields of maize grown on Alfisols of North-western Ethiopia. *Envi. Syst Research,* **4(1):** 1-7.

Yihenew, G.S. 2016. Response and Economic Feasibility of Maize (Zea mays L.) to P Fertilization in Acidic Alfisols of Northwestern Ethiopia. *Environ Syst Res,* **5(3):** pp1-6.

Zingore, S. 2011. Maize productivity and response to fertilizer use as affected by soil fertility variability, manure application, and cropping system, *Better crops*, **95(1):** pp.4-6.

7. APPENDICES

Appendix Table 1. The annual rainfall and temperature of experimental District during 2018

	Rainfall (mm)	Temperature °C	
Month		Maximum	Minimum
January	14.9	32.58	13.47
February	57.9	32.68	15.51
March	146.1	31.66	15.53
April	74.0	29.32	17.01
May	189.3	29.38	17.36
June	158.9	27.92	16.62
July	193.9	27.48	16.63
August	209.3	28.02	16.29
September	136.6	29.36	15.75
October	128.6	30.16	15.77
November	56.2	30.88	14.9
December	30.6	31.56	14.86

Appendix Table 2. Effects of balanced fertilizer on, plant height, Ear height and Ear length of maize number of leaves per plant

Source	Df	Mean Square						
		PH (cm)	EH (cm)	El (cm)	CL (cm)	NEP	NRPC	NGR
Treatments	13	152.89*	77.99*	13.03*	4.59**	0.004ns	1.08*	16.10*
Replications	3	157.79	155.30	11.12	1.70	0.0095	0.87	11.42
Error	39	188.74	102.06	5.33	1.10	0.005	1.07	14.12
CV		5.31	7.38	6.66	6.24	6.811	7.44	9.58

*CV=coefficient variation, Df=degree freedom, *=highly significant at P value of 1%, **=significant at P-value of 5%, ns=none significant PH =plant height, El=Ear length, CL=Cob Length, NEP=Number of Ear per plant, NRP=number of grain rows per cob, NGC=number of grains per row, cm =centimeter*

Appendix Table 3. ANOVA table showing mean square values of yield and yield parameter of maize as influenced by fertilizer type at Tepi

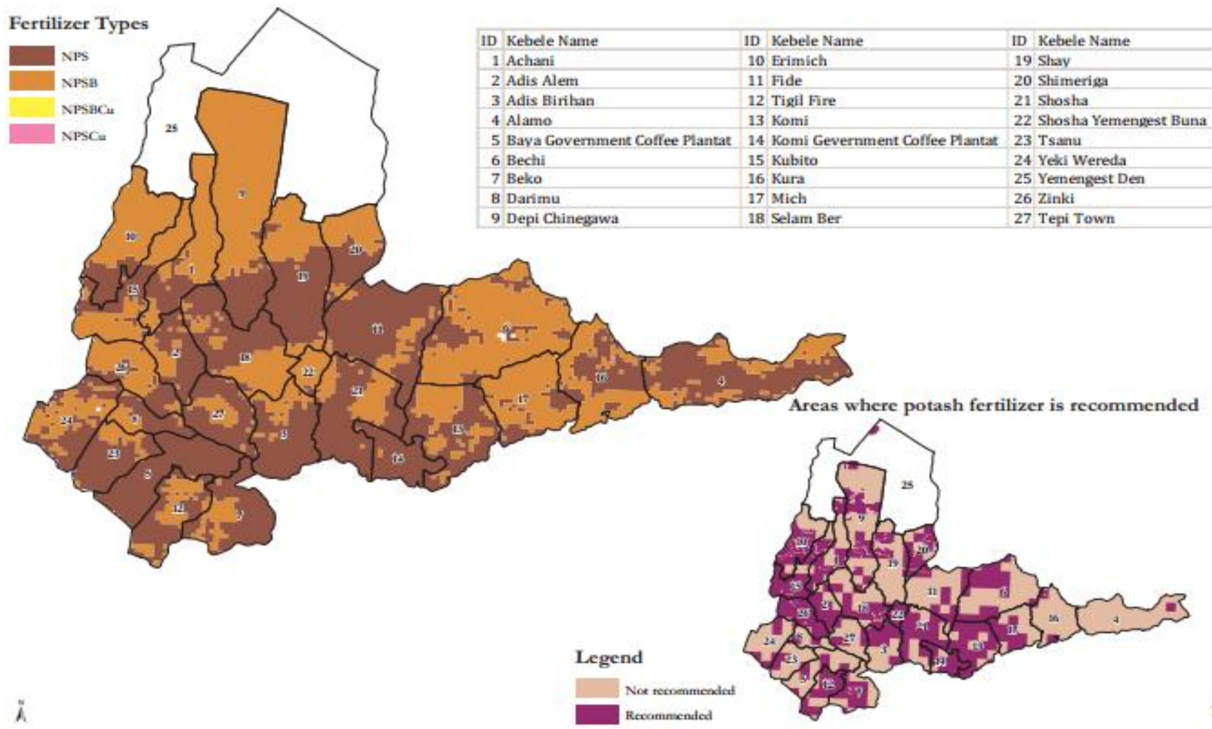
Source	Df	Mean Square						
		TW	SW	Cw	GYL	BY	HI	shell
Treatments	13	3185.90**	8765175.10**	51168.74**	10031755.20**	39236428.00**	15.74**	48.20**
Replications	3	277.58	139834.90	40770.37	6840.50	268664.20	3.20	3.67
Error	39	900.40	143226.40	8460.40	253699.10	614451.30	2.53	4.03
CV		7.83	4.99	8.08	7.03	4.93	3.55	2.40

*CV=coefficient variation, Df=degree freedom, *=highly significant at P value of 1%, **=significant at P-value of 5%, TW= thousand grain weight (g ha^{-1}), SW=straw weight (kg ha^{-1}), CW=cob weight kg ha^{-1}, GYL=grain yield (kg ha^{-1}), BY=Biological yield (kg ha^{-1}), HI=harvest index (%), shell=shelling percentage (%).*

Appendix Table 4. Pearson Correlation Coefficients among different growth, yield and yield component parameters of maize

Parameter	PH	EH	EL	CL	NEP	TW	NRC	NGC	SW	CW	GYL	BM	HI	shell
PH	1	0.78^{**}	0.42^{**}	0.40^{**}	-0.10^{ns}	0.21^{ns}	0.15^{ns}	0.35^{**}	0.26^{*}	0.10^{ns}	0.34^{**}	0.30^{*}	0.45^{**}	0.40^{**}
EH		1	0.26^{*}	0.39^{**}	-0.12^{ns}	0.14^{ns}	0.25^{ns}	0.25^{*}	0.13^{ns}	0.17^{ns}	0.16^{ns}	0.15^{ns}	0.25^{ns}	0.21^{ns}
EL			1	0.50^{**}	0.14^{ns}	0.39^{**}	-0.07^{ns}	0.23^{ns}	0.45^{**}	0.19^{ns}	0.51^{**}	0.48^{**}	0.55^{**}	0.48^{**}
CL				1	0.07^{ns}	0.39^{**}	-0.16^{ns}	0.40^{**}	0.40^{**}	0.38^{**}	0.57^{**}	0.59^{**}	0.42^{**}	0.52^{**}
NEP					1	0.06^{ns}	-0.06^{ns}	-0.29^{ns}	-0.05^{ns}	-0.06^{ns}	-0.02^{ns}	-0.04^{ns}	0.09^{ns}	0.08^{ns}
TW						1	-0.11^{ns}	0.15^{ns}	0.55^{**}	0.52^{**}	0.61^{**}	0.40^{**}	0.57^{**}	0.51^{**}
NRC							1	0.08^{ns}	-0.13^{ns}	-0.26^{*}	-0.10^{ns}	-0.12^{ns}	0.01^{ns}	0.03^{ns}
NGC								1	-0.22^{ns}	0.06^{ns}	0.27^{*}	0.29^{*}	0.19^{*}	0.29^{*}
SW									1	0.50^{**}	0.97^{**}	0.99^{**}	0.66^{**}	0.82^{**}
CW										1	0.45^{**}	0.51^{**}	0.16^{ns}	0.11^{ns}
GYL											1	0.99^{**}	0.81^{**}	0.89^{**}
BM												1	0.74^{**}	0.85^{*}
HI													1	0.89^{**}
shell														1

* = highly Significant at P-value 1%, ** = Significant at P-value 5%, ^{ns}=non-significant, PH=plant height in cm, EH=Ear height in cm, Ear Length in cm, CL=cob length in cm, NEP= Number of ear per plant, TW=thousand seed weight in gram, NGC=number of grain per row, SW= straw weight in kgha-1, CW=cob weight in kg ha-1, GYL=grain yield in kg ha-1, BM= biological yields in kg ha-1, HI=harvest index in %,and shell = shelling percentage in %.



Source: - EthioSIS, 2016

Appendix Figure 1. Recommended fertilizer type for Yeki District