Soil Characterization and Response of Maize (*Zea mays* L.) to Application of Blended Fertilizer Types and Rates in Asossa District, Western Ethiopia

M.Sc. Thesis

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Soil Characterization and Response of Maize (*Zea mays* L.) to Application of Blended Fertilizer Types and Rates in Asossa District, Western Ethiopia

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Hawassa, Ethiopia

May, 2018
STATEMENT OF THE AUTHOR

First of all, I declare that this thesis is a result of my genuine work and all sources of materials used for writing it have been duly acknowledged. I have submitted this thesis to Hawasa University in partial fulfillment of the Degree of Master of Science in Soil Science. The thesis is deposited at the library of the University to be made available to borrowers under the rules and regulations of the library. I solemnly declare that I have not submitted this thesis to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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School: Plant and Horticulture Sciences
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<tr>
<td>AfSIS</td>
<td>Africa Soil Information Service</td>
</tr>
<tr>
<td>AE</td>
<td>Agronomic Efficiency</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>ATA</td>
<td>Agricultural Transformation Agency</td>
</tr>
<tr>
<td>DAP</td>
<td>Diammonium Phosphate</td>
</tr>
<tr>
<td>EhioSIS</td>
<td>Ethiopian Soil Information System</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
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<tr>
<td>FC</td>
<td>Field Capacity</td>
</tr>
<tr>
<td>HSD</td>
<td>Hundred Seed Weight</td>
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<tr>
<td>IAA</td>
<td>Indole acetic acid</td>
</tr>
<tr>
<td>ITTA</td>
<td>International Institute of Tropical Agriculture</td>
</tr>
<tr>
<td>Kg</td>
<td>Kilogram</td>
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<tr>
<td>LSD</td>
<td>Least significant difference</td>
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<td>MoA</td>
<td>Ministry of Agriculture</td>
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<tr>
<td>MRR</td>
<td>Marginal rate of return</td>
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<tr>
<td>PBS%</td>
<td>Percent of base saturation</td>
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<tr>
<td>RNA</td>
<td>Ribose nucleic acid</td>
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<tr>
<td>RNP</td>
<td>Recommended Nitrogen and Phosphorus</td>
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<td>SSA</td>
<td>Sub-Saharan Africa</td>
</tr>
<tr>
<td>TC</td>
<td>Total Cost</td>
</tr>
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<td>WRB</td>
<td>World Reference Base</td>
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Soil Characterization and Response of Maize (*Zea mays* L.) to Application of Blended Fertilizer Types and Rates in Asossa District, Western Ethiopia

Bakala Anbessa (Bsc.), Girma Abera (PhD) and Sofiya Kassa (PhD)

**ABSTRACT**

The scientific information available with regards to the response of maize (*Zea mays* L.) to different blended fertilizer rates for its optimum production in Nitisols of Asossa area is very limited. Therefore, a field experiment was conducted on Nitisols of Asossa Agricultural Research Centre during 2016/17 cropping season to investigate the response of growth, yield and nutrient use efficiency of maize (*Zea mays* L.) to different blended fertilizer rates and types. The treatments consists of: control, three rates of N and P combined (92/46, 115/57 and 138/69 N/P2O5 kg ha⁻¹ and two formula of blended fertilizers with different rates, formula 2 consists of 100 kg NPSB + 73.9 N, 150 kg NPSB + 110.8 N and 200 kg NPSB + 147.8 N kg ha⁻¹ and formula 4 consists of 100 kg NPSZnB + 75.1 N, 150 kg NPSZnB + 112.6 N kg ha⁻¹ and 200 kg NPSZnB + 150.2 N kg ha⁻¹. The treatments were laid out as a Randomized Complete Block Design with three replications. To characterize the experimental area soil, two pedons were opened from cultivated and uncultivated adjacent plots. The experimental soil was strongly acid to moderately acidic in pH, very low organic carbon, medium to very low in total nitrogen, below the critical level of available P (Olsen extractable), high CEC, medium to low percentage base saturation and low to medium in basic cation. The soils represented by both pedon were classified as Humic-dystric Nitisols. Application of blended fertilizers (NPSB, NPSZnB) hastened days to tasseling silking and maturity by 10, 7 and 15 days, respectively as compared to combined N and P rates. Application of blended fertilizer increases significantly (*p* < 0.01) the plant height, cob weight, ear length, 100 kernels weight, number of kernels per row and ear height as compared to combined N and P and the control. The analysis of variance revealed that fertilizer types and rates significantly (*p* < 0.01) affected on biomass yield, grain yield, straw yield and harvest index. However there was no significant difference between the two blended fertilizer types. Maximum grain yield (7056.2 kg ha⁻¹ ) was recorded with 200 Kg NPSZnB + 150.2 N kg ha⁻¹ application, while minimum grain yield 2996.0 kg ha⁻¹ was recorded from control treatment. Blended fertilizers had improved nutrient concentration, uptake, agronomic efficiency, physiological efficiency and apparent recovery of maize as compared to the combined N and P rates applied. The application of 150 kg NPSB + 110.8 N kg ha⁻¹ had highest Marginal rate of return (MRR%) and net benefit. Therefore, we recommended the treatment (150 Kg NPSB + 110.8N kg ha⁻¹) since it produced high marginal rate of return, high net benefit and relatively small total cost of production, for maize production in Asossa area. Furthermore, based on yield, net benefit and relatively low total cost of production the farmer of Asossa area also can use 150 kg NPSZnB + 112.6 N in case of absence of NPSB in market. However, since the experiment was conducted only for one season and one site, repeating the trial at different sites as well as in the same trial site would be important in order to draw sound recommendation.

**Key words;** Blended, pedons, yield, uptake, efficiency, recovery, net benefit
1. INTRODUCTION

Soil is the most important resource required for Agricultural production (Khanif, 2010). Soils have many variables, which have multiple types of characteristics. The variables influence not only the pedogenesis and development, but also the uses and productivity of soils. Therefore, in order to understand the similarities, dissimilarities and relationships among different soil types, it is important to study the physico-chemical properties of soils under land use. The existence of various types of soils in different parts of Ethiopia is related to the variability of soil forming factors in type, degree and intensity. Soil types and characteristics show great variations across the various regions of Ethiopia.

Agricultural land productivity is related to these various soil characteristics (Mesfin, 1998). Natural conditions, such as geology, climate, topography, biotic and land use/land cover changes are largely responsible in creating regional and local differences in soil types and characteristics. However, although knowledge on soil physical and chemical characteristics plays a vital role in enabling production and productivity of the agricultural sector on sustainable basis and to undertake research in the Asossa Wereda, there is no much information about the soils of the research farm of the studied area as well as the Asossa Wereda as a whole.

Among cereals, maize (Zea mays L.) is an important crop which ranks third after wheat and rice in the world (Rasheed et al., 2004). It is one of the important cereal crops used in the human diet in large parts of the world, and besides serving as important feed component for livestock. In terms of total world production, maize out ranked paddy rice (Oryza sativa) and wheat (Triticum aestivum) (Rasheed et al., 2004). Maize was originated in Mexico (Dowswell et al., 1996)) and
introduced to Ethiopia in the late 16th and early 17th century by the portuguese (Orkaido, 2004). Maize is one of the most important cereals cultivated in Ethiopia as primary stable food (Abera et al., 2013).

The results of the year 2015/16, Meher season post harvest crop production survey indicated that total land areas of about 12,486,271 hectares were covered by grain crops. Out of the total grain crop areas, 79.88% (9,974,316 hectares) was under cereals. Of this maize covered 16.91% (about 2,111,518 hectares) and gave 71,508,354 quintals of grain yields (CSA, 2015/16). Maize is one of the important cereals cultivated in Ethiopia. Despite the large area under maize, the national average yield of maize is about 3.387 t ha⁻¹ (CSA, 2015). This is by far below the world’s average yield which is about 5.21t ha⁻¹ (FAO, 2011).

Low soil fertility is one of the bottlenecks to sustain agricultural production and productivity in Ethiopia. Thus, maize is one of the heaviest feeder of nutrients to produce high and quality yields among cereals. This is because of the fact that it produces higher grain and straw yields than other cereals. Application of balanced fertilizers is the basis to produce more crop output from existing land under cultivation and nutrient needs of crops is according to their physiological requirements and expected yields (Ryan, 2008). Most research works focus on N and P requirements of crops, limited information is available on various sources of nutrients such as K, S, Zn and B and other micronutrients. Different fertilizers produced in factory by blending different nutrients is used to nourishing two or more nutrient to the plants at once time. Crop producers used to supply different nutrients for the crop, save resources and economy of the farmers.
Fertilizer application by most farmers is mainly done to maize in many places, particularly in Asossa district, is based on blanket recommendation i.e. application of 46 kg ha\(^{-1}\) N and 46 kg ha\(^{-1}\) P\(_2\)O\(_5\) ha\(^{-1}\) in the form of Urea and DAP, which are commonly applied at once (during planting time). Continuous cultivation of most of Ethiopian soils with application of only N and P containing fertilizers may cause reduction of the quantity of other nutrients from the soils such as potassium (K) and sulphur (S) ATA, (2016). In addition these nutrients might be lost via fixation of potassium and leaching of sulphur in different types of soils (Murashkina et al., 2006). Therefore, application of other sources of nutrients beyond Urea and Diammonium Phosphate (DAP), especially those containing K, S, Zn and other micro-nutrients could increase crop productivity (CSA, 2011). This can be achieved by application of blended fertilizers, the mechanical mixture of two or more granular fertilizer materials containing N, P, K and other essential plant nutrients such as S, Zn, and B, recently known to Ethiopia.

In order to speed up agricultural growth, the government of Ethiopia has established Agricultural Transformation Agency (ATA) by federal regulation to handle initiatives of helping to achieve its goal of boosting agricultural productivity under the Agricultural Growth Plan (MoFED, 2010). The ATA, in partnership with the MoA and other federal and regional stakeholders, launched Ethiopian Soil Information System (EthioSIS) in 2011 with the major purpose of mapping the soil fertility status of the country's agricultural land targeted at woreda (administrative district) level. Moreover, in collaboration with the Africa Soil Information Service (AfSIS) and the Ministry of Agriculture, the agency is currently developing the Ethiopian Soil Information System (EthioSIS) and database that will provide high-resolution soil maps for effective land use decision-making (AfSIS, 2013). Based on this information the initial mapping work conducted on 162 woredas showed that, in addition to nitrogen and phosphorus,
sulfur, potassium, boron and zinc nutrients are deficient in many areas. This data indicated that one compound fertilizer (NPS) and three blended fertilizers (NPSB, NPSZnB, and NPSZn) plus or minus potash fertilizer are needed to address the key nutrient deficiencies in the tested soils in Ethiopia (ATA, 2014).

Application of fertilizers in relation to initial soil fertility status and crop requirement leads to economic and judicious use of fertilizers. Experiments conducted by different researchers to decide rate of fertilizer under different research stations and their surrounding on-farm resulted in different rates of recommendations in terms of both N and P (Kelsa et al., 1992). Nutrient mining due to sub optimal fertilizer use in one hand and unbalanced fertilizer uses on other have favored the emergence of multi nutrient deficiency in Ethiopian. Different research reports indicate that nutrients like K, S, Ca, Mg and all micro-nutrients except Fe are becoming depleted and deficiency symptoms are being observed on major crops in different areas of the country (Wassie et al., 2009). Recently acquired soil inventory data from EthioSIS (Ethiopian Soil Information System) also revealed that in addition to N and P, nutrients such as S, B, Zn are widespread in Ethiopian soils. EthioSIS (Ethiopian Soil Information System) indicated that, the soils of Asossa area also deficient in, sulphur, boron and zinc in addition to phosphorous and nitrogen, which all potentially hold back crop productivity despite continued use of N and P fertilizer as per the blanket recommendation. According to Bekabil et al. (2011), the lack of appropriate fertilizer blends and lack of micronutrients in fertilizer blends are the national problem which is major constraints to crop productivity. It is imperative to increase the productivity along with desirable attributes through production management practices and application of other sources of nutrients beyond the blanket recommendation of Urea and DAP, especially those that contain potassium, sulphur and other micro-nutrients (CSA, 2011).
Therefore, the present study was designed to assess the effects of different types and rates of nutrient on maize production in Asossa.

**General Objectives:**

- Soil Characterization and Response of Maize (*Zea mays* L.) to Application of Blended Fertilizer Types and rates in Asossa District, Western Ethiopia

**Specific Objectives:**

- To characterize and classify the soil of the study area.
- To assess the role of blended and conventional fertilizer effects on growth, yield, nutrient uptake and nutrient use efficiency of maize at Asossa district
- To determine economically optimum nutrient types and rates for maize crop production in Assosa district
2. LITERATURE REVIEW

2.1. Characteristics and Classification of Major Soils of Ethiopia

Ethiopia is a country of great geographical diversity with mountains, highlands, extensive plateaus, valleys, deep gorges and lowlands. In response to variation in climate, topography, parent materials, vegetation and land use, different kinds of soils are formed in Ethiopia (Mitiku, 1987). In support of this, Mishra et al. (2004) described that Ethiopia is a land of soil museum where different soil orders except Gelisol of the USDA Soil Taxonomy occur in varying frequencies depending upon existing physiographic and agroecologic positions. There are about 17 dominant soil types in the region, of which Phaeozems cover 19.8%, Luvisols 15.10%, Cambisols 14.3%, Leptosols 14.3%, Nitisols 13.7% and Vertisols 10.8% of the total land area of the region (Biru, 2003). According to the same author, the major soils Leptosols, Nitisols, Cambisols and Vertisols cover 16%, 12%, 11.5% and 10%, respectively of the total area. The types and distribution of the soils are strongly influenced by the physiographic and geology of the region. Color is one of the most important morphological properties of soil, which can be highly influenced by land use differences. The moist soil color of both the cultivated and grazing lands of the lower elevation zones of Mount Chilalo were very dark gray (10YR 3/1) in the surface whereas the subsoil horizons were characterized by variable soil color which varied from black to dark gray (10YR 4/1) for the grazing land and from very dark gray (10YR 2/1) to very dark grayish brown (10YR 3/2) for the cultivated land (Ahmed, 2002).

The term structure relates to the arrangement of primary soil particles in to aggregates or peds. The formation and maintenance of a high degree of aggregation are among the most difficult tasks of soil management, and yet they are among the most important properties, since they are a
potent means of influencing ecosystem function (Brady and Weil, 2002). Texture is an important soil physical characteristic because it in part, determines water intake rate (infiltration), water storage in the soil, the ease of tilling the soil, the amount of aeration (vital to root growth), and also influence soil fertility (Gupta, 2000).

The depth of profile, organic matter content, pH, percent base saturation and type of clay mineral are affected by the type of climate in a given area (Mitiku, 1987). Vegetation affects the amount and type of organic matter added to a soil (Parker, 2000) and this tends to significantly affect soil structure, colour, pH, CEC, infiltration and water holding capacity of soils (Ahmed, 2002). The physical properties of soil such as soil colour, texture, structure, density, porosity and water content are the dominant factors affecting the use of a soil (Sharma, 2002). They have crucial role in describing several productivity level of a given area (Ahmed, 2002). Most of them change with landuse-system and its management such as cultivation and its intensity, the instruments used, and the nature of the land under cultivation as well as management of crop residues and application of manure.

The phosphorus content in soil solution is low as compared to other nutrients such as nitrogen, potassium, calcium and magnesium (Tisdale et al., 1993). Many soils fix large quantity of phosphorus by converting readily soluble phosphorus to forms less available to plants in the above combinations (Miller et al., 1995). The concentration of organic matter usually decreases with depth with the exception of Podozols and Palaeosol (Wild et al., 1988). Organic carbon influences structural stability, water holding capacity, nutrient bioavailability, buffering capacity and biodiversity of soil (Tisdale et al., 1993).
2.2. The Importance of Maize

Maize is an important cereal in many developed and developing countries of the world and it is widely used for animal feed and industrial raw material in the developed countries where as the developing countries use it in general for feed (reviewed in Farnham et al. 2003). Because of its worldwide distribution and relatively lower price maize has wider range of uses. It is used directly for human consumption, in industrially processing foods, as Live-stock feed and in industrially non food products such as starches and alcohols. Recently, there has been interest in using maize for production of ethanol a substitute for petroleum based fuels.

Maize is one of the oldest cultivated grains and one of the most productive crop species with a global average yield of more than 4 ton per hectare (reviewed in Farnham et al., 2003). It can be directly consumed as food at various developmental stages from baby corn to mature grain. More maize is produced annually more than any other grain (ITTA, 2009). The abundant production of maize could be linked to its uses for food, feed and industry. Maize has become the world’s high animal feed ingredient than any other grain. It is high in energy, low in fibre and easily digested by most livestock species (Du Plessis, 2003). A high proportion of maize produced is used as stock feed, eg 40% in tropical areas and up to 85% in developed countries (reviewed in Farnham et al., 2003).

In developing countries, it serves as staple diet for some 200 million people especially in Latin America and Africa (ITTA, 2009). The grains are rich in vitamins A, C and E (ITTA, 2009). It also contains proteins such as lysine and tryptophan (Onimisi et al., 2009), minerals and fat (Buah et al., 2009). Maize is the major source of starch world-wide, and is used as a food
ingredient, either in its native form or chemically modified (White, 1994). The oil and protein are often of commercial value as by-product of starch production and are used in food manufacturing (McCutcheon, 2007). The production, processing and sales of maize both locally and export as a commodity were major means of occupation and income generation for thousands of people worldwide (Bourdillon et al., 2003; USDA, 2009).

2.3. Soil fertility Status in Sub-Saharan Africa

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.

From a chemical standpoint, Sab-Sahara Africa soils are typically low in available nitrogen (N), and commonly deficient in phosphorus, sulphur (S), magnesium (Mg) and zinc (Zn) (Vanlauwe and Giller, 2006). In addition, they are heavily leached, have a high acidity (pH< 5.5) and have low amounts of soil organic matter (SOM) and low cation exchange capacity (CEC). On the
sandy loam and clay loam soils derived from granite which are common in Africa (Katherine et al., 2015), in addition to chronic deficiencies in macro-nutrients, micro-nutrients such as Zn and B are reported to be limiting at many sites under continuous cultivation (Chianu et al., 2012).

From a physical standpoint, low levels of SOM combined with poor land cover have resulted in poor soil structure, limited rooting depth, susceptibility to accelerated erosion and water logging problems on Vertisols that covers 43 million ha in tropical Africa soils and requires special management (Zingore et al., 2007). 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 not restored by new inputs. Intensively cultivated highlands in East Africa lose an estimated 36 kg N ha⁻¹ yr⁻¹, 5 kg P ha⁻¹ yr⁻¹, and 25 kg K ha⁻¹ yr⁻¹ (Bekunda et al., 2010).

2.4. Soil Fertility Status in Ethiopia

Soil is the most important resource required for Agricultural production (Khanif, 2010). The fertility status of Ethiopian soils has also declined and continued to decline posing a challenge to crop production. 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). According to Mesfin (1998) another challenges of soil fertility decline in Ethiopia are related to cultural practices like traditional cultivation, removal of vegetative cover (such as straw or stubble) or burning plant residues as practiced under the traditional system of crop production or the annual burning of vegetation on grazing lands. These are the major contributors to the loss of nutrients.
Land degradation and nutrient depletion are further aggravated by overgrazing, deforestation, population pressure and the poor land use planning. The nutrient mining of Ethiopian soils might be caused by the losses of soil organic matter, macronutrient, and micronutrient depletion; topsoil erosion; acidity; salinity; and deterioration of other soil physical properties. Due to their low OM 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 denitrification 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 (Tekalgn 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 very low level of P due to depletion and/or P fixation (Lalisa et al., 2010).

Zinabu and Wassie (2015) studied P-sorption capacity of cultivated soils in the southern Ethiopia and found that soils of Chencha, Hagere Selam, Bullie and Halaba were high P-fixing soils whereas soils of Hawassa, Damote Gale and Wonago were low P-fixing soils respectively. The research conclusion of Murphy (1968) which stated that, Ethiopian soils are rich in K and there was no need for K application is not valid, nowadays since many crop responses to K have been reported from recent studies (Asgelil et al., 2007; Haile et al., 2009; Ayalew et al., 2010; Wassie and Shiferaw 2011). Wassie and Shiferaw (2011) also reported that application of potassium has significantly and positively increased the tuber yield of potato at Chencha suggesting low level
of soil K and there is a need for application of K fertilizer. There is very little information available in Ethiopia about micronutrient levels in soils. However, Tuma et al. (2014) and Itanna (2005) reported considerable variation in micronutrient contents of soils and crops in Ethiopia. Also, Preliminary findings of the EthioSIS soil fertility mapping project (EthioSIS, 2014; 2015) reported the deficiency of N, P, K, S, B Zn and Cu in many soils collected from more than 600 woredas.

2.5. Nutrients Requirements of Maize

2.5.1. Nitrogen requirements of maize

If water and temperature conditions are ideal productivity of maize is mainly limited by availability of nitrogen (Lafitte, 2000a). Nitrogen is a component of a number of compounds (eg proteins, nucleic acids, chlorophylls) and has an important role in many plant physiological processes (Uribelarrea et al., 2009). Maize begins to rapidly take up nitrogen (and other nutrients) during the middle vegetative growth period with the maximum rate of nitrogen uptake occurring near silk (Hughes, 2006c). Nitrogen deficiency is indicated by leaf yellowing (first in the lowest leaves) that starts at the tip and then extends along the mid-rib, stunted plants, delayed flowering and short, poorly filled ears (Hughes, 2006c).

Maize can utilise nitrogen in both the ammonium and nitrate forms but, because of the ready conversion of ammonium to nitrate by soil microbes, most nitrogen is taken up as nitrate (Farnham et al., 2003). Nitrogen is the most important and limited nutrient in maize production. Several studies have reported positive effects of N fertilization on corn plant biomass, photosynthesis and grain yield (Uribelarrea et al., 2009). Nitrogen availability has been shown to play an important role in maize plant growth and elongation (Rui et al., 2009). Increasing N
application increased N content and chlorophyll content in maize (Rambo et al., 2010). Increasing N fertilization increased maize grain yield. It was consistent with other studies (Gagnon and Ziadi, 2010). A significant increase in grain yields with rates up to 224 kg N ha\textsuperscript{-1} under irrigated conditions was reported (Halvorson et al., 2006). But Ma et al. (2005) observed that corn grain yields increased significantly with rates up to 120 kg N ha\textsuperscript{-1}.

2.5.2. Phosphorous requirements of maize

Two of the most essential functions of phosphorus in plants are energy storage and energy transfer. Plants absorb P as orthophosphates, as H\textsubscript{2}PO\textsubscript{4}\textsuperscript{-} which is absorbed greatest at low soil pH values (below pH 7.2), or HPO\textsubscript{4}\textsuperscript{2-} which is absorbed greatest at high pH values (above pH 7.2). Plants may then also absorb certain soluble organic phosphates such as nucleic acids and phytin, both which is produced by the degradation of organic matter in the soil (Brady & Weil, 2008). Adenosine di- and triphosphates (ADP and ATP) are formed and regenerated in the presence of sufficient P. Furthermore, P also aid in structural integrity of nucleic acids, phosphoproteins, phospholipids and sugar phosphates (Marschner, 1995).

Adequate supply of P in the early life of a plant is essential for crop development and reproduction. A large quantity of P is found in the seed and fruit, and is considered essential for seed development FAO (2000). A good supply of P is associated with increased root growth. It is also associated with early maturity of crops, especially grain crops (Epstein and Bloom, 2005). This is due to the fact that sufficient supply of P reduces the time required for grain ripening, improved straw strength of cereals, reduced cold damage and the improvement of root-rot disease tolerance (Haberle et al., 2008). Phosphorus is a component of the complex nucleic acid
structure of plants, which regulates protein synthesis. Phosphorus is, therefore, important in cell division and development of new tissue. Phosphorus is also associated with complex energy transformations in the plant. Adding phosphorus to soil low in available phosphorus promotes root growth and winter hardiness, stimulates tillering, and often hastens maturity.

It is crucial for cell differentiation and for the development of the tissues, which form the growing points of the plant FAO (2000), found that, there was increase in grain protein of about two percent higher in P fertilized grain as compared to control treatment. It is needed in large quantities, and is often taken up very early in the plant's life, and later moved internally to rapidly growing parts of the plant, meaning it is often concentrated in younger tissues, flowers and seeds (Epstein and Bloom, 2005).

Phosphorus deficiency reduces the leaf area index (LAI) of maize, thus reducing the amount of photosynthetically active radiation absorbed by the canopy and leading ultimately to lower biomass accumulation (Pellerin et al., 2000). The negative effect of phosphorus deficiency on LAI also adversely affects adventitious root emergence and therefore may further exacerbate phosphorus uptake (Pellerin et al., 2000). Symptoms of phosphorus deficiency are slow growth, late maturity, a reddening of leaves, poorly developed root systems and small ear size (Lafitte 2000a; Hughes 2006c).

2.5.3 Potassium requirement of maize

Consumption of potassium increased absorption consequent from osmosis potential and expand cell pressure and length, on the other hand, consumption of potassium with increasing dry matter production and leaf area extension the large rate produced and improve water in plant tissue at
intension water stress condition (Aziz et al., 1999). Potassium deficit decreased ATP and plant transfer system is disturbance and result phosphorus assimilation assembling and decreased photosynthesis rate which led to unusual resources organization development (Aziz et al., 1999).

Important roles of potassium in material transfer, leaf made assimilates transfer to productive organs and causes better seed filling and weight (Marschner, 1995). Potassium increased cell division, grains number per row, row numbers per cob, 1000 grains weight and grains yield (Nesmith and Ritchie, 1992). Potassium regulate stomata closure and prevent water wasting and regulating osmosis, increase efficiency and improved growth condition in corn (Wiebold and Scharf, 2006). It plays a critical role in lowering cellular osmotic water potentials, thereby reducing the loss of water from leaf stomata and increasing the ability of root cells to take up water from the soil (Havlin et al., 1999) and maintain a high tissue water content even under drought conditions (Marschner, 2002).

The minimum (4,687 kg ha⁻¹) and maximum (4,905 kg ha⁻¹) maize yield at Dangla in 2009 cropping season from control and 100 kg K₂O ha⁻¹, respectively (Tadele et al., 2010). The same author found, that the minimum (2,951 kg ha⁻¹) and maximum (3,929 kg ha⁻¹) yield of maize in the 2008 cropping season from the control and application of 100 kg K₂O ha⁻¹, respectively at Mota.

2.5.4. Sulfur requirement of maize

Sulfur deeply concerned in amino acids, bio-synthesis and plays a key role in the defense of plants against nutrients stress, attacks of pests and increases the synthesis of chlorophyll and vitamins in the cell (Kacar and Katkat, 2007). Nitrogen application in higher rates increases the
intensity of sulfur deficiency (Rafiq et al., 2016). Without nitrogen fertilizer application, plants show no visible sulfur stress, whereas nitrogen fertilizer application to plants especially at higher levels without applying sulfur shows severe physiological disorders (Kopriva and Rennenberg, 2004). By applying sulfur in the forms of ammonium sulfate makes maize an ideal crop for all soils especially calcareous and alkaline soils (Ghosh et al., 2000). Complete yield potential of a crop cannot be obtained where soil is suffering with sulfur deficiency, even irrespective of all the other nutrients application and under excellent management practices (Rahman et al., 2011). Most often S deficiencies are observed in low OM soils and coarse-textured soils where S can be easily leached out (Rafiq et al., 2016).

In general, good growth and productivity of crops require availability of necessary nutrient elements in balanced proportions (FAO and IFA, 2000). If the concentration of a given element in the crop root zone is low, a deficiency of that element occurs and crop growth is restricted. S plays an essential role in the growth and development of plant, in agricultural crops S deficiency is exceptional in wheat, (Withers et al., 1995). Sulfur additionally enhances efficiency of use of supplementary nutrients of plants, chiefly N and P (Rafiq et al., 2016). One of the major nutrients essential for plant growth, root nodules formation of legumes and plant protection mechanism is sulfur. Sulfur application up to 60 kg ha\(^{-1}\) can make nitrogen and phosphorus efficient (Sarfaraz et al., 2014).

5.5.5. Zinc fertilizer requirement of maize

Maize grown on alkaline soils such as the vertosols can show severe zinc deficiency symptoms (Birch et al., 2003). These symptoms include light streaking of leaves in the leaf margins (leaf edges, midrib and tip remain green), and stunted growth of the crop (Hughes 2006). To achieve
higher yield, Zn is limiting among all the micronutrients in cereal crops because of its low availability at pH above 7.0 (Alloway, 2008). The yield is reduced extensively without showing any deficiency symptoms due the shortage of minor nutrients (Alloway, 2004).

Plant physiologist reported that deficiency of Zn affects various plant metabolic processes such as nitrogen uptake, photosynthetic activity, nitrogen metabolism chlorophyll synthesis and protein quality (Cakmak, 2008). Several studies on Zn showed that their deficiency caused reduction in yield and level may differ from plant to plant and region to region (Kalayci et al., 1999). Sandy and eroded soils and soils with high pH are more likely to be zinc deficient. Plant health benefits zinc is important for maximizing leaf and vascular growth, increasing plant root growth and promoting a massive root system crop (Hughes 2006). These fortified roots help increase nutrient uptake and water-use efficiency for larger overall plant growth (Hughes 2006).

2.5.6. Boron requirement of maize

Boron (B) is an essential micronutrient needed for normal plant growth and development. It is involved in many plant processes such as sugar transport, cell wall synthesis, petal and leaf bud formation, cell wall structure integrity, sugar and hydrocarbon metabolism and their transport, ribose nucleic acid (RNA) metabolism, respiration, nitrogen fixation, pollen germination, pollen tube formation and seed formation (Ahmad et al., 2014). Globally, B deficiency has been recognized as the second most important micronutrient constraint in crops after zinc (Zn) (Ahmad et al., 2014). Maize has a low requirement for B, but can be very sensitive to excess B. The interaction of B with other nutrients (N, P, K, Ca, Mg, Al, and Zn) can be synergistic or antagonistic which can influence B availability to plants (Gupta, 1993).
Boron is absorbed by plants as boric acid, which is easily leached in soils. Boron is relatively immobile in plant and its availability is essential at all growth stages, particularly during fruit and seed development. Boron has also helped to reduce disease severity in some crops because of its effect that B has on plant metabolism, cell membranes and cell wall structure (Dordas, 2009). Boron reduced the infection of pathogens by improving cell wall and membrane strength with cross-linked polymers and by strengthening the plant’s vascular bundles (Liew et al., 2013).

2.6. Review on Importance of Blended Fertilizers in Ethiopia

Blended fertilizer is defined as the mechanical mixture of two or more granular fertilizer materials containing N, P, K and other essential plant nutrients in defined proportions (James, 1997). The ingredients of a blended fertilizer can be straight materials, such as urea or potassium chloride; they can be granulated compound fertilizer materials mixed together; or they can be a combination of the two (Oldham, 2000). Application of blended fertilizer with Cu and Zn significantly increased leaf area of maize as compared to blended fertilizer, recommended NP + Cu + Zn, recommended NP and control (Dagne, 2016).

Lemlem et al. (2015) reported that the main effect of blended fertilizer, DAP and urea fertilization significantly increased the N, P, K, Zn, Mg and S concentration of tef grains in both Regosols and Vertisols. An experiment conducted at Laelay Maychew, Central Tigray, to evaluate agronomic and economic effects of blended fertilizers under row planting method on Vertisols and Nitosols with improved tef variety “Kuncho” (DZCR-387), showed that the application of blended fertilizers under the row planting method resulted a significant difference
to all yield and yield components. The treatment which received blended fertilizers under row planting responded more significantly to plant height, panicle length, seed weight/panicle by 260, 133 and 65% respectively, than the check on both Vertisols and Nitosols (Brhan, 2012). Compared to the recommended NP fertilizers, mean grain yield of maize was increased by 7.7% with the application of blended fertilizer at Kejo and the same trend was observed at Ongobo (Dagne, 2016). The increase in grain yield is could be attributed to beneficial influence of yield contributing characters and positive interaction of nutrients in the blended fertilizer. Blended fertilizer allows small batches of high analysis soil and crop specific fertilizers to be mixed and transported in an economical manner contributing additional profit for farmers and improving the environment because it provides balanced fertilization (James, 1997).
3. MATERIALS AND METHODS

3.1. Description of the Study Sites

The experiment was conducted in Benishangul Gumuz Regional State, at Asossa Agricultural Research Center (AARC) research farm in 2016/17 main cropping season under rain fed field condition. Benishangul Gumuz Regional State is geographically located at 9°30' to 11°39’ N latitude and 34° 20' to 36° 30'E longitude covering a total land area of 50,000 square kilometer. The study site is located at 10° 02' 05” N latitude and 34° 34’ 09” E longitudes. The study area is situated east of Asossa town and west of Addis Ababa about 4 km and 660 km distance, respectively. Asossa has unimodal rainfall pattern, which starts at the end of April and extends to mid-November, with maximum rainfall received in June, to October. The total annual average rainfall of Asossa is 1275 mm. The minimum and maximum temperatures are 16.75°C and 27.92°C, respectively. The dominant soil type of Asossa area is Nitosols with the soil pH ranges from 5.0 to 6.0.

Figure 1. Map of the study area
3.2. Experimental Materials

A high yielding maize hybrid BH546, which is adapted to the agro-ecology of the area, was used for the study. BH546 is one of the most successful hybrid varieties released in 2013 by National Maize Research program based at Bako Agricultural Research Centre, Oromia Regional State, Ethiopia. It has a wider adaptability and grows well at altitudes ranging from 1000 to 2000 meters above sea level with annual precipitation of 1000 to 1200 mm (Table 1).
Table 1 .Description of the maize varieties used for the studied

<table>
<thead>
<tr>
<th>Variety name</th>
<th>Variety type</th>
<th>Year of released</th>
<th>Altitude (m.a.s.l)</th>
<th>DM</th>
<th>Rain (mm)</th>
<th>Potential Yield Qt/ha</th>
<th>Seed</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH546</td>
<td>Hybrid</td>
<td>2013</td>
<td>1000-2000</td>
<td>145</td>
<td>1000-55-70</td>
<td>85-95</td>
<td>Bako NM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Farmers Research</td>
</tr>
</tbody>
</table>

Source: Backo Notational Maize Research Coordinating Center leflate prepared for 50th year Celebration of Ethiopian Institute of Agricultural Research and Assosa Agricultural Research Center Variety Evaluation Result.

Recommended blended fertilizer type for Assosa specific area was obtained from EthioSIS map which were released by ATA. Nitrogen had to be adjusted for the blend fertilizer from Urea source. Based on the soil information data of EthioSIS for each limiting nutrients identified compared among each other and against the blanket recommended N and P from TSP and Urea fertilizers. Blended fertilizers and TSP were applied at planting and Urea was top dressed in twice. The fertilizer materials to be used are, recommended NP, NPSB and NPSZnB based on the soil information data of EthioSIS of the area and the rate of each are given in detail in the Table 2 below.

3.3. Treatments and Experimental Design

The treatments were laid out in randomized complete block design with three replications. Hybrid maize variety (BH546) was used as test crop. The Ten treatments which includes: control, three rates of nitrogen and phosphorus (92N & 46 P$_2$O$_5$, 115N & 57.5 P$_2$O$_5$, 138 N & 69 P$_2$O$_5$ kg ha$^{-1}$) and two different formula of blended fertilizers with rates, formula 2 consists of 100 kg NPSB+ 73.9N $^1$, 150 kg NPSB +110.8N and 200 kg NPSB + 147.8 N kg ha$^{-1}$ and formula
4 consists of 100 kg NPSZnB + 75.1 N, 150 kg NPSZnB + 112.6 N \(^1\) and 200 kg NPSZnB +150.2 N kg ha\(^{-1}\) based Map recommended fertilizers were used as treatments. Blended fertilizers and TSP were basal applied at planting and Urea was top dressed twice (at knee height and tasseling). The plot size of 4.5 m x 5.1 m (22.95 m\(^2\)) was used. The crop was planted in rows with recommended spacing (75 x 30 cm) the space between row and plant respectively. The other crop management practices were applied uniformly for all plots as per the recommendation for the crop.

The treatments include:

1. Control (no any amendment)
2. 100% RNP (Recommended Nitrogen and Phosphorus Fertilizer)
3. 125% RNP (Recommended Nitrogen and Phosphorus Fertilizer)
4. 150% RNP (Recommended Nitrogen and Phosphorus Fertilizer)
5. 100 kg NPSB +73.9 N kg
6. 150 kg NPSB + 110.8N kg
7. 200 kg NPSB +147.8 N kg
8. 100 kg NPSZnB +75.1 N kg
9. 150 kg NPSZnB +112.6 N kg
10. 200 kg NPSZnB +150.2 N kg
Table 2. Fertilizer rates based on recommended N and P, and blended fertilizer types and rates applied.

<table>
<thead>
<tr>
<th>Trt. No</th>
<th>Rate (kg/ha)</th>
<th>Compound fertilizers’ mineral contents (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Control (no fertilizer)</td>
<td>0</td>
</tr>
<tr>
<td>T2</td>
<td>200 kg Urea &amp; 100 kg TSP</td>
<td>92N &amp; 46 P₂O₅</td>
</tr>
<tr>
<td>T3</td>
<td>250 kg Urea &amp; 125 kg TSP</td>
<td>115N &amp; 57.5 P₂O₅</td>
</tr>
<tr>
<td>T4</td>
<td>300 kg Urea &amp; 150 kg TSP</td>
<td>138N &amp; 69 P₂O₅</td>
</tr>
<tr>
<td>T5</td>
<td>100 kg NPSB + 73.9 N</td>
<td>18.1 N - 36.1 P₂O₅ - 0.0 K₂O + 6.7 S + 0.0 Zn + 0.71 B</td>
</tr>
<tr>
<td>T6</td>
<td>150 kg NPSB + 110.8 N</td>
<td>27.15 N – 54.15 P₂O₅ – 0.0 k₂O + 10.05 S + 0 Zn + 1.07B</td>
</tr>
<tr>
<td>T7</td>
<td>200 kg NPSB + 147.8 N</td>
<td>36.2 N – 72.2 P₂O₅ – 0.0 k₂O + 13.4 S + Zn + 1.42B</td>
</tr>
<tr>
<td>T8</td>
<td>100 kg NPSZnB + 75.1 N</td>
<td>16.9 N – 33.8 P₂O₅ – 0.0 k₂O + 7.3 S + 2.23 Zn + 0.67B</td>
</tr>
<tr>
<td>T9</td>
<td>150 kg NPSZnB + 112.6 N</td>
<td>25.35 N – 50.7 P₂O₅ – 0.0 k₂O + 10.95 S + 3.35 Zn + 1.01B</td>
</tr>
<tr>
<td>T10</td>
<td>200 kg NPSZnB + 150.2 N</td>
<td>33.8 N – 67.6 P₂O₅ – 0.0 k₂O + 14.6 S + 4.46 Zn + 1.34B</td>
</tr>
</tbody>
</table>

3.4. Data Collection and Measurement

3.4.1. Phenological and growth parameters

Plant height (cm):- It was measured as the height from the soil surface to the base of the tassel of five randomly taken plants from the net plot area at physiological maturity.

Days to physiological maturity (DPM):- It was recorded as the number of days after sowing to the formation of a black layer at the point of attachment of the kernel with the cob.

3.4.2. Yield and yield components

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.

Number of kernels per ear: - It was computed as the average number of kernels of five randomly taken ears from the central net plot areas.

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

Grain yield (kg ha\(^{-1}\)): - Grain yield per plot was measured using electronic balance and then adjusted to 12.5% moisture and convert to hectare basis.

Biological Yield (kg ha\(^{-1}\)): - Plants from the net plot area was harvested at physiological maturity and weighed after sun drying.

Harvest index: - It calculated as the ratio of grain yield to total aboveground biomass yield

### 3.5. Soil Characterization and Sampling.

A 2m x 2m area, and 2m depth for uncultivated pedon 1 and 2m x 2m, and 1.2 m depth for cultivated pedon 2, soil pit was excavated at representative spot in the research station from cultivated and uncultivated land. The soil pedon was described in situ following guidelines for soil description (FAO, 1990). Lastly soil samples were collected from every identified horizon of the pedon.

### 3.6. Soil Sampling and Analysis

The soil samples collected from each horizon of the soil pedon were air dried and ground to pass through 2 mm sieve for all the soil parameters to be studied except for total nitrogen and organic carbon which were passed through 0.5 mm sieve to remove the coarser materials. Finally, the
soil pedon samples were analyzed for selected agriculturally relevant soil physicochemical properties at the Regional Soil Laboratory in Benshal-gul Gumuz following the standard analytical procedures.

Two soil pedons were opened (uncultivated and cultivated land) from representative landform to characterize and classify the soil of study area. Field observation, pedon opening, horizon designations, pedon description and sampling of freshly opened soil pedons were carried out using the procedures of FAO (1990) guidelines. The Munsell soil color chart (Munsell Color Company, 1975) was used to identify soil colors both in moist and dry conditions. Unfortunately, uncultivated pedon 1 was opened on site covered with annual grass and the second pedon was opened on ploughed site recently. Soil morphological characteristics such as soil color, structure, and soil consistence were described in the field during soil sample collections. The soil samples collected from the soil profile on genetic horizon basis were air dried and ground to pass through a 2 mm size sieve in preparation for the analysis of all soil properties. Finally, the soil profile samples were analyzed for physicochemical properties at the Benshal-gul Gumuz Soil Laboratory using standard analytical procedures.

The undisturbed core samples were used from all horizon for the determination of dry bulk densities and soil moisture contents. The soil physical properties analysed in the laboratory, included soil moisture content, soil texture, bulk density and particle density. The moisture contents at field capacity (FC) and permanent wilting point (PWP) were measured at -1/3 and -15 bars soil water potential, respectively, using the pressure plate apparatus (Klute, 1965). Available water holding capacity (AWHC) was then obtained by subtracting PWP from FC. Determination of particle size distribution was carried out by the Bouyoucos hydrometer method.
as described by Okalebo et al. (2002). Hydrogen peroxide (H$_2$O$_2$) was used to destroy the organic matter and sodium hexa-metaphosphate (NaPO$_3$) was used as dispersing agent. Once the sand, silt, and clay separates were calculated in percent, the soil was assigned to a textural class based on the soil textural triangle (Rowell, 1994).

Particle density (Pd) was estimated by the pycnometer method as described by Blake (1965). Total porosity was estimated from the bulk density (Bd) and particle density (Pd) as:

$$\text{Total porosity (\%)} = \left[1 - \frac{\text{Bd}}{\text{Pd}}\right] \times 100$$

The chemical properties studied included pH, CEC, exchangeable acidity, exchangeable bases (Ca, Mg, Na, K), organic carbon, total nitrogen, and available P) were analyzed for all horizon of both pedon.

Soil pH was determined using a pH meter with combined glass electrode in water (H$_2$O) at 1:2.5 soil: water ratio as described by Carter (1993). Organic carbon, was determined by oxidizing carbon with potassium dichromate in sulfuric acid solution following the Walkley and Black method (1934). Finally, the organic matter content of the soil was calculated by multiplying the organic carbon percentage by 1.724. The total nitrogen contents in soils were determined using the Kjeldahl procedure by oxidizing the organic matter with sulfuric acid and converting the nitrogen into NH$_4^+$ as ammonium sulfate (Sahlemedhin and Taye, 2000). Exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrated with sodium hydroxide as described by Mclean (1965). Available phosphorus was determined in Olsen methods. In the Olsen procedure, the soil samples were shaken with 0.5M sodium
bicarbonate at nearly constant pH of 8.5 in 1:20 of soil to solution ratio for half an hour and the extract was obtained by filtering the suspension as indicated by Olsen et al. (1954).

Exchangeable bases (Ca, Mg, K and Na) in the soil were estimated by the ammonium acetate (1M NH₄OAc at pH 7) extraction method. In this procedure, the soil samples were extracted with excess of NH₄OAc solution, and Ca and Mg in the extracts were determined by atomic absorption spectrophotometer, while flame photometer was used to determine the contents of exchangeable K and Na as described by Rowell (1994). Soil cation exchange capacity (CEC) was measured after leaching the ammonium acetate extracted (ammonium ion standard) soil samples with 10% sodium chloride solution. The cation exchange capacity of the clay fraction was estimated by dividing the CEC of the soil by the percentage of the clay and then multiplied by hundred and expressed as cmol(+) kg⁻¹ clay. Finally, the percent base saturation (PBS) was computed as the ratio of the sum of the exchangeable bases to the CEC of the soil as:

\[
\text{PBS (\%)} = \left(\frac{\text{Sum of exchangeable bases (Ca, Mg, K, and Na)}}{\text{CEC of soil}}\right) \times 100
\]

\[
\text{CEC clay} = \left(\frac{\{\text{CEC soil} - (\%\text{OM} \times 2)\}}{\%\text{clay}}\right) \times 100.
\]

3.7. Plant Tissue Sampling and Analysis

When the crop completed its physiological maturity, the representative grain and straw samples were taken from each plot per treatment. The samples were oven dried and ground for laboratory analysis of total N, P, S and K. The measurement of N was carried out according to the Kjeldahl procedure by transforming organic N into ammonium N by digesting with H₂SO₄ and a catalyst (Chapman, 1965).
After calcination, K was measured using dry ashing, Black, C.A (flame Photometer) as described by Chapman (1965). P was determined by spectrophotometer of the dry ashing maize samples. Total S was analyzed using Calorimeter. The grain and straw concentrations of N, P, S and K were used to estimate the N, P, S and K uptake which was calculated by multiplying grain and straw yields on hectare basis with the respective N, P, S and K percentage.

Apparent fertilizer N and P recovery were calculated following the formula as \([(Un - Uo) / n] \times 100\); where Un stands for nutrient uptake at ‘n’ rate of fertilizer nutrient and Uo stands for nutrient uptake at control (no fertilizer nutrient). Agronomic and physiological N and P use efficiencies were calculated by using procedures described by Craswell and Godwin (1984) as: \((Gn - Go) / n\) for agronomic efficiency and \((Gn - Go) / (Un - Uo)\) for physiological efficiency; where Gn and Go stand for grain yield of fertilized at ‘n’ rates of fertilizer and grain yield unfertilized, respectively, and Un and Uo stand for nutrient uptake at ‘n’ rate of fertilizer and uptake at control (no fertilizer nutrient), respectively.

3.8. Statistical Data Analysis

Analyses of variances for the data were recorded and conducted using the SAS GLM procedure (SAS 1998). Least significant difference (LSD) test at 5% probability used for mean separation when the analyses of variance indicate the presence of significant differences.

3.9. Economic Analysis

Mean grain yield of the selected treatment was used in partial budget analysis (CIMMYT, 1988). Economic analysis was performed to investigate the economic feasibility of the treatments
(fertilizer rates). A partial budget, dominance and marginal analysis were used. The average open market price (Birr kg\(^{-1}\)) for maize and the official prices of blended, Urea and TSP fertilizers were used for economic analysis. The dominance analysis procedure as detailed in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The selected and discarded treatments using this technique are referred to as undominated and Dominated’ treatments, respectively. The undominated treatments were ranked from the lowest (the farmers’ practice) to the highest cost treatment. For each pair of ranked treatments, a % marginal rate of return (MRR) was calculated. The % MRR between any pair of undominated treatments denotes the return per unit of investment in fertiliser expressed as a percentage.
4. RESULTS AND DISCUSSION

4.1. Morphological Properties of Soil Pedons

The results of pedon description and laboratory analysis of soil physical and chemical properties are presented and discussed in the following subsections. Four horizons (A, AB, Bt1 and Bt2) for pedon 1 (uncultivated) and three horizons (Ah, BA and Bt) for pedon 2 (cultivated) were identified. The morphological properties of the soil are given in Table 3. Soil color of the surface horizon of uncultivated was 2.5YR 2.5/1 when moist and 2.5YR 3/3 when dry (Table 3). The dry colors of the surface horizons contained the same hues Munsell notations but increased by one to two units of value and chroma from the moist colour. The increment of dry value and chroma over moist colour might be due to the reflection of light under dry soil and moist soil adsorbed the light. In uncultivated pedon1 the colour rages from redish black (2.5YR 2.5/1) to very dusk red (2.5 YR 2.5/2) to dusky red (10 R 3/4) and finally to dark redish brown (2.5 YR 3/4) from top to down within depth under moist condition.

The same as under dry condition in uncultivated pedon1 the colour ranges from dark redish brown (2.5YR 3/3) to dusky red (10 R 3/3) to Dark red (2.5 YR 3/6) and finally to red (2.5 YR 4/6) from top to down with depth. The redder (2.5 YR 4/6, dry) in subsoil horizons indicate the well drainage conditions of the pedon (hence described as well drained class soils) as well as relatively low contents of organic matter of subsoil horizons, as verified in the analyzed organic matter levels (Table 5.). In cultivated pedon 2 the colour ranges from Dark redish brown (5 YR 2.5/1) to dusky red (10 R 3/3) and finally to dark redish brown (2.5 YR 2.5/3) under moist condition. On the other hand under dry condition in cultivated profile 2 the colour ranges from dark redish brown (2.5 YR 2.5/2) to dark redish grey (2.5 YR 3/1) and finally to dark red (10 R...
The top soils dark colour of this pedon could reflect the higher amount of organic matter of the surface soil than subsurface soil. This result is similar with Tadele and Alemu, (2016), who reported that relatively dark brown surface soil colour could be attributed to a relatively high content of organic matter of the surface soils. As a result, reddening of colour with depth in uncultivated pedon1 could be associated with a direct decline in contents of organic matter.

The existing slight variability in structure characteristics could be related to horizons in the pedon and contents of organic matter. The topsoil (A horizon) of uncultivated pedon1 had strongly very coarse granular structure that changed to a weakly very coarse prismatic within depth under primarily structure. On the other hand in cultivated pedon 2, the Ap horizon had moderately very coarse granular structure and that changed to Weakly very coarse prismatic structure in the lower horizon (Bt horizon) in primarily structure. The same as in both pedons the top soil (A & Ap horizon) had strongly coarse granular that changed to a moderately fine angular blocky with in depth under lower horizon (Bt1, Bt2 and Bt horizon) in secondarily structure. The angular blocky structure of sub surface horizon is slightly in line with (De Wispelaere et al., 2015) those characterized the nitic horizon of nitosols south western Ethiopia as well-developed blocky soil structure. The development of blocky structure types could be related to the low level of organic matter, reduction in abundance of plant roots and higher clay percentage of subsoil horizons (Tadele and Alemu, 2016).

With depth of the both pedons soft, very firm, very sticky and very plastic consistence characteristics were common in the lower underlying horizons. This result is might be the change in consistence characteristics from surface to subsurface soil horizons reflects the high contents of clay and low contents of organic matter of subsoil horizons. Some variability in consistence
characteristics was observed among the studied pedon and horizons within a pedon. In the pedon 1 the dry soil consistence characteristics of the surface horizons varied from very hard (surface horizon) to soft (sub surface horizon). On the other hand with very firm (surface horizon) to very friable (sub surface horizon) moist and Sticky and plastic (surface horizon) to Very sticky and very plastic (subsurface horizon) in wet consistency. The surface horizon of cultivated pedon 2 had a slightly hard (surface horizon) to soft (sub surface horizon) and very firm (surface horizon) to very friable (subsurface horizon) moist and Sticky and plastic (surface horizon) to Very sticky and very plastic (subsurface horizon) in wet consistency. this change in consistence might be from its overlying horizon may be attributed to a change in particle size classes as there was a slight increase in clay content and a slight decrease in sand size particles.

In all of the horizons the boundary topography was described to be smooth but changing from a diffuse to gradual distinctness with depth of the pedon (Appendix Table 3). The gradual and diffuse boundaries in the lower horizons reflect lack of presence of distinct morphological differences between the subsequent subsoil horizons of Nitisols. The same as in all of the horizons the root size and abundance was described as many medium to very few fine roots with in horizon depth. In all of the horizons of both pedon was described to be well drained of the water. This result is similar with (Bekele and Getahun, 2016b) those reported the nitisols of Asossa soil are well drained, porous with clay-to-clay loam texture and low organic matter content.
Table 3. Soil morphological characteristics of the pedons in the study area.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth(cm)</th>
<th>Soil color</th>
<th>Structure (one)</th>
<th>Consistence</th>
<th>Structure (Two)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedon 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0-20</td>
<td>Moist 2.5YR 2.5/1 Moist (Redish black)</td>
<td>Strongly very coarse, granular</td>
<td>Dry 2.5YR 3/3 Moist (Dark redish brown)</td>
<td>Very hard Moist</td>
</tr>
<tr>
<td>AB</td>
<td>20-35</td>
<td>Moist 2.5 YR 2.5/2 Moist (Very dusk red)</td>
<td>Moderately coarse granular</td>
<td>Dry 10 R 3/3 Moist (Dusky red)</td>
<td>Very friable</td>
</tr>
<tr>
<td>Bt₁</td>
<td>35-100</td>
<td>Moist 10 R 3/4 Moist (Dusky red)</td>
<td>Weakly very coarse prismatic</td>
<td>Dry 2.5 YR 3/6 Moist (Dark red)</td>
<td>Very friable</td>
</tr>
<tr>
<td>Depth</td>
<td>Pedon</td>
<td>Color Chart 1</td>
<td>Color Chart 2</td>
<td>Texture</td>
<td>Consistency</td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
<td>---------------</td>
<td>---------------</td>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>100-200</td>
<td>Bt&lt;sub&gt;2&lt;/sub&gt;</td>
<td>2.5 YR 3/4 (Dark redish brown)</td>
<td>2.5 YR 4/6 (Red)</td>
<td>Weakly very coarse prismatic</td>
<td>Soft</td>
</tr>
<tr>
<td>0-20</td>
<td>Ap</td>
<td>5 YR 2.5/1 (Dark redish brown)</td>
<td>2.5 YR 2.5/2 (Dark redish brown)</td>
<td>Moderately very coarse granular</td>
<td>Slightl y hard</td>
</tr>
<tr>
<td>20-45</td>
<td>BA</td>
<td>10 R 3/3 (Dusky red)</td>
<td>2.5 YR 3/1 (Dark redish grey)</td>
<td>Moderately very coarse granular</td>
<td>Soft</td>
</tr>
<tr>
<td>45-120</td>
<td>Bt</td>
<td>2.5 YR 2.5/3 (Dark redish brown)</td>
<td>10 R 3/6 (Dark red)</td>
<td>Weakly very coarse prismatic</td>
<td>Soft</td>
</tr>
</tbody>
</table>
4.2. Soil Physical Properties of Pedons.

4.2.1. Soil texture

The textural class of the studied soil varied from loam in surface soil to clay in sub soil of uncultivated pedon 1. On the other hand, the textural class of the cultivated pedon 2 was clay through surface to subsurface soil (Table 4). This revealed that the sand and silt content of the soil was decreased and the clay content became increased with in the soil depth of both soil pedons (Table 4). The percent of clay on the surface was 43% for uncultivated and 47% for cultivated pedon respectively. Clay contents of the surface horizon were high in cultivated pedon 2 as compared to uncultivated pedon. This is might be the result of long time cultivation that possibly facilitate clay formation (Wakene and Heluf, 2003). The silty content of both pedon was high at the soil surface and revealed a regular decreased with the soil depth of the pedon. This decrease may reflect the weathering process of silt to clay size particles in the subsoil horizons.

Clay content increases during the weathering processes. Therefore, the silt/clay ratio is often used to distinguish young and old parent materials. Silt/clay ratio of less than 0.15 is characteristics of young materials (Boule et al., 1997). Thought the horizons the soil have silt/clay ratio above 0.15. The horizon depths have influence on soil silt/clay ratio, and the surface horizons have higher silt/clay ratio as compared to subsurface horizons. The decrease in silt/clay ratio with depth is an indication that with depth shows clay migration from the upper to the lower horizon. Lower silt/clay ratio in the lower horizons also indicates better water retention capacity than the overlaying horizon.
4.2.2. Bulk density, particle density and porosity

The bulk densities of the studied soils showed great variability with respect to contents of organic matter and position of horizons in a pedon (Table 4). In both of pedons the lower values were recorded under the surface horizon than the underlying horizon. The surface horizon bulk density value ranges from 1.04 g cm$^{-3}$ to 1.10 g cm$^{-3}$, the lowest value was recorded under uncultivated pedon 1 that had higher organic matter than the other subsurface and surface horizon as was confirmed from soil characterized (Table 5). Hence, the systematic increasing pattern in bulk densities with depth of pedon could be related to a decrease in contents of organic matter and a presence of blocky types of soil structure characteristics. Consequently in sub surface horizons the bulk density varied with 1.14 g cm$^{-3}$ to 1.35 g cm$^{-3}$. Uncultivated pedon had the highest bulk density 1.35 g cm$^{-3}$ in sub surface horizon (100 - 200 cm ) depth and followed by 1.31 g cm$^{-3}$ in 45-120 cm depth of cultivated pedon.

The fact that the bulk density is lower at the surface than the under-lying horizons observed in both pedon of studied area were in agreement with the established fact that bulk density is lowest at the surface due to relatively high organic matter content of the surface soil. According to Miller and Donahue (1997), for good plant growth, bulk densities should be below 1.4 g cm$^{-3}$ and 1.6 g cm$^{-3}$ for clay and sand soils, respectively. So the bulk density values observed in these soils were within the normal range for mineral soils. The highest particle density 2.6 g cm$^{-3}$ was recorded at sub surface horizon and lowest particle density 2.4 g cm$^{-3}$ was obtained at surface horizon of both pedon. So the particle density values observed at the studied area were smaller than the standard average mineral soil particle density (2.65 g cm$^{-3}$).
The total porosity of soil depends on the bulk density of the soil. As the bulk density of the soil was increased the total porosity of the soil become decreased. Regarding to the total porosity, the highest total porosity (56.6%) was obtained in uncultivated pedon 1 than cultivated pedon 2 (52%) in the study site (Table 4). The higher values of total porosity corresponded to the higher amount of organic matter contents and lower bulk density values.

Table 4. Particle size distribution, soil moisture holding capacity, particle density, bulk density and total porosity of soil/or pedon.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Particle size distribution</th>
<th>TC</th>
<th>BD</th>
<th>PD</th>
<th>TP%</th>
<th>SWHC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>g/cm³</td>
<td>g/cm³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedon 1</td>
<td></td>
<td>Sa Si C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>% % %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0-20</td>
<td>29 28 43 L</td>
<td>1.04</td>
<td>2.4</td>
<td>56.6</td>
<td>30.5</td>
<td>20</td>
</tr>
<tr>
<td>AB</td>
<td>20-35</td>
<td>16 31 53 C</td>
<td>1.14</td>
<td>2.5</td>
<td>54.4</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Bt₁</td>
<td>35-100</td>
<td>8 17 75 C</td>
<td>1.30</td>
<td>2.6</td>
<td>50.0</td>
<td>28</td>
<td>21</td>
</tr>
<tr>
<td>Bt₂</td>
<td>100-200</td>
<td>8 15 77 C</td>
<td>1.35</td>
<td>2.6</td>
<td>48.07</td>
<td>35</td>
<td>24.5</td>
</tr>
<tr>
<td>Pedon 2</td>
<td>Ap</td>
<td>0-20 28 25 47 C</td>
<td>1.10</td>
<td>2.5</td>
<td>52.0</td>
<td>27.4</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>BA</td>
<td>20-45 18 21 61 C</td>
<td>1.25</td>
<td>2.5</td>
<td>50.0</td>
<td>26</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Bt</td>
<td>45-120 16 17 67 C</td>
<td>1.31</td>
<td>2.6</td>
<td>49.6</td>
<td>35</td>
<td>26.5</td>
</tr>
</tbody>
</table>

Where Sa = sandy, Si = silt, L= loam, C = clay, TC = textural class, BD = bulk density, PD = particle density, TP = total porosity, SWHC = soil water holding capacity, FC = field capacity, PWP = permanent wilting point, = AW = available water.
The smallest number of total porosity of soil (48.07%) recorded in the sub surface horizon of pedon 1 and followed by (49.6%) sub surface horizon of pedon 2. According to Brady and Weil (2002), ideal total porosity values, which are acceptable for crop production, are around 50%. Hence, the soil of Humic-dystric Nitisols of Asossa area has an acceptable range of total porosity values for crop production. Wakene (2001) reported that the low total porosity was the reflection of the low organic matter content and the high bulk density that was imposed by the use of heavy farm machinery for tillage activity and intense grazing of the fallow land of Bako area. As general trend, soil porosity decreased with depth in both pedons.

4.2.3. Soil water content

In most of the cases, there was no clear pattern of variation in field capacity (FC) at the studied soils of the area. Soil field capacity (FC), ranged from 27.4% to 30% at surface (Table 4), the higher field capacity being recorded for the horizon containing relatively high content of clay. On the other hand, the lowest field capacity was not recorded for horizons having low contents of clay, revealing an absence of any clear pattern of association with this soil attribute. These variations in moisture contents of the soil at FC might be due to variation in soil organic matter as soil organic matter makes the soil to retain water by increasing its surface area.

In sub soil horizon field capacity varied from 25% to 35%, the lowest in pedon 1 from 20-35cm soil depth. The increase in clay content as well as a decline in organic matter levels with depth of both pedons had great change on the field capacity of the study area. In surface soil horizon the field capacity of the soil high due to high organic matter content of soil surface. This could reflect the presence of relatively high content of soil organic matter that could result in increasing the water holding capacity of the soil in surface horizon. In sub surface horizon it become increased because of the increases the percentage of clay content in
both pedons. Because of its clay texture, the water content at FC, PWP and AWC of the both pedons showed an increasing trend with increasing depth in sub surface horizon.

There were narrow differences between field capacity and permanent wilting point among the studied pedon and identified horizons of the soils. It varied from 5.4 % (pedon 2) to 10.5% (pedon 1) for the surface horizon. In sub soil horizons it ranged between 5% to 11.5% , the same as it showing a relatively narrow difference in field capacity and permanent wilting point for underlying horizon. The highest levels of moisture at FC and PWP corresponded with the highest clay contents in the sub surface horizon of both pedon (Table 4). Abayneh (2001) has also reported that although the degree of correlation was weak, available water capacity (AWC) showed positive correlation with organic matter and clay contents, but negative correlation with bulk density and silt content and this implies the improvement of soil structure and organic matter content could increase AWC.

The highest (35%) field capacity values were observed in the subsoil horizon (100 - 200 cm) and (45 - 120 cm) for pedon 1 and 2 respectively. The lowest (25%) field capacity values were observed in the subsoil horizon (20-35 cm) of pedon 1. This could reflect the presence of relatively high content of clay mineral that could result in increasing the water holding capacity of the soil in subsurface horizon and the increment of clay content with in depth. Similarly, the highest (26.5%) and the lowest (20%) of soil water contents at permanent wilting point were recorded in subsurface and surface horizon respectively. With respect to the surface soil, the highest available water (11.5%) followed by (10.5 %) was recorded under sub surface (100 - 200 cm) and surface horizon (0 - 20cm) respectively of pedon 1.

The morphological and physical characteristics soil of the studied area indicated that the well drained condition, clay loam to clay texture, relatively low soil bulk density, strongly coarse
granular to moderately finer angular blocky values favorable soil condition for agricultural purpose. Consequently these properties bring proper aeration, free drainage, and increasing infiltration of water and reduce surface run off or soil erosion. Furthermore, very friable consistence, absence of hard pan fragments implies that the soils are good for agriculture, as easy to root penetration and cultivate.

4.3. Soil Chemical Properties of Pedons

4.3.1. Soil reaction, exchangeable acidity and exchangeable Al$^{+3}$

The pH value of the studied soils showed an irregular increase with depth of the soil horizon of both pedon (Table 5). It normally decreased regularly in the upper three horizons, and then after showed an increasing pattern in pedon 1, and decreased in the upper two horizons, and then after showed an increasing pattern in pedon 2. At the surface soil horizon the soil reaction (pH) varied from 5.6 to 5.7 in cultivated pedon 1 and uncultivated pedon 2 respectively. The higher soil pH in surface horizon might be related with the high cation exchangeable capacity, relatively low exchangeable acidity and low exchangeable Al$^{+3}$ surface horizon than the sub surface soil of the studied area.

EthioSIS (2014), classified pH values into five classes, strongly acidic < 5.5, moderately acidic 5.6 - 6.5, neutral 6.6 - 7.3, moderately alkaline 7.3 - 8.4 and strongly alkaline > 8.4. The soils in the study area had 5.2 (strongly acid) to 5.7 (moderately acidic) in the subsurface and surface horizons respectively (Table 5). The most favorable pH for availability of most plant nutrients correspond roughly with the optimum range of 6 to 7 (Brook, 1983). The range of soil reaction in experimental site may limit crop production by influencing the availability of important plant nutrients. According to Landon (1991), Soil pH value below 5.5 could be an indication of presence of appreciable amount of exchangeable acidity and exchangeable Al$^{+3}$, and removal of exchangeable cations, such as calcium and magnesium.
These levels of soil pH could further indicate that phosphorus availability would be lowered through the binding effects of Al and Fe. The same as the exchangeable acidity and exchangeable Al\(^{+3}\) value of the studied area showed an irregular increase with depth of the soil horizon in uncultivated pedon 1, on the other hand showed a regular increase with depth of the soil horizon in cultivated pedon 2 (Table 5). The surface horizon of pedon 2 had lower exchangeable acidity and Al content than subsurface soil might be attributed to organic matter addition from straw and fertilizer supply that increased yield and the high cation exchangeable capacity of surface soil. On the other hand uncultivated pedon 1 had low exchangeable acidity and Al content thought all horizon soil, might be attributed to organic matter addition from the decomposition grass straw, litter fall and relatively higher CEC than the cultivated one. Exchangeable acidity consists of any aluminum or iron, as well as any exchangeable H that may be present in the exchange sites (Bohn et al., 2001). Exchangeable Al normally occurs in significant amounts only at soil pH values less than about 5.5.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>pH</th>
<th>Exch. acidity</th>
<th>Exch. Al(^{+3})</th>
<th>OC%</th>
<th>OM%</th>
<th>TN%</th>
<th>C/N</th>
<th>Available P mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedon 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0-20</td>
<td>5.7</td>
<td>0.16</td>
<td>0.24</td>
<td>3.3</td>
<td>0.28</td>
<td>11.78</td>
<td>3.22</td>
<td></td>
</tr>
<tr>
<td>AB</td>
<td>20-35</td>
<td>5.6</td>
<td>0.56</td>
<td>0.48</td>
<td>2.7</td>
<td>4.65</td>
<td>0.23</td>
<td>11.73</td>
<td>3.22</td>
</tr>
<tr>
<td>Bt(_1)</td>
<td>35-100</td>
<td>5.4</td>
<td>0.48</td>
<td>0.24</td>
<td>1.1</td>
<td>1.89</td>
<td>0.06</td>
<td>13.00</td>
<td>3.18</td>
</tr>
<tr>
<td>Bt(_2)</td>
<td>100-200</td>
<td>5.6</td>
<td>0.56</td>
<td>0.56</td>
<td>0.58</td>
<td>1.0</td>
<td>0.05</td>
<td>11.60</td>
<td>3.08</td>
</tr>
<tr>
<td>Pedon 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-20</td>
<td>5.6</td>
<td>0.72</td>
<td>0.48</td>
<td>3.0</td>
<td>5.17</td>
<td>0.26</td>
<td>11.53</td>
<td>3.94</td>
</tr>
<tr>
<td>BA</td>
<td>20-45</td>
<td>5.2</td>
<td>1.2</td>
<td>2.8</td>
<td>1.9</td>
<td>1.9</td>
<td>0.16</td>
<td>11.87</td>
<td>3.26</td>
</tr>
<tr>
<td>Bt</td>
<td>45-120</td>
<td>5.3</td>
<td>4.0</td>
<td>3.92</td>
<td>1.1</td>
<td>1.9</td>
<td>0.09</td>
<td>12.22</td>
<td>3.11</td>
</tr>
</tbody>
</table>

Where pH = soil reaction with water (1:2.5), Exch. = exchangeable, OC = organic carbon, OM = organic matter, TN = total nitrogen, C/N carbon to nitrogen ratio, P = phosphorous.
4.3.2. Organic carbon, total nitrogen and available phosphorous

The limited available data indicated that the soil organic carbon revealed slight variation between uncultivated pedon 1 and cultivated pedon 2 and it decreasing with the depth of soil. This result is similar with (Bahilu et al., 2014) those found the organic carbon of soil had significantly affected by land use and slope at Delta Sub-wateeshed of South Western Ethiopia. The organic carbon of studied area varied from 3.0% to 3.3% for cultivated pedon 2 and uncultivated pedon 1 respectively. The high organic carbon content of surface soil could be related with organic matter content due to litter fall, crop residue etc. of the soil surface.

Total nitrogen contents of the soils also showed the same trend as soil organic carbon. Studies made in Ethiopia (Mohammed et al., 2005) show that levels of soil organic carbon are related to land use history, and are generally expected to be low in cultivated soils as compared to the same fallow land. Considering the surface soil layers, the highest organic carbon (3.3%) and total nitrogen (0.28%) were recorded under uncultivated pedon 1 similarly the lowest organic carbon (0.58%) and total nitrogen (0.05%) were recorded under the same pedon of subsurface horizon (Table 5).

The amounts of organic carbon content recorded can be categorized as low (2-4%), at surface, and very low (< 2%) in sub surface horizons of both pedons (Landon, 1991). Similarly the rating of total N of > 1% as very high, 0.5 to 1% high, 0.2 to 0.5% medium, 0.1 to 0.2% low and < 0.1% as very low N status as indicated by Landon (1991). Therefore, the experimental soils qualify for medium in total N at the surface horizon to the first layer of sub surface horizon of both pedons. On the other hand sub surface horizon categorized to < 0.1% as very low total nitrogen. The very low organic carbon and medium to very low total nitrogen content in the study area indicate low fertility status of the soil. This result is similar with (Bekele et al., 2016c), those report very low OC and very low to medium N content of
Asossa area of Benshal-gul gumuz indicated low fertility status of the soil could be due to continuous cultivation and lack of incorporation of organic materials.

Carbon to nitrogen (C/N) ratio is an index of nutrient mineralization and immobilization whereby low C/N ratio indicates higher rate of mineralization and higher C/N ratio indicates greater rate of immobilization. In this study there is no much difference C/N ratio due to land use system or between cultivated and uncultivated land. The carbon-to- nitrogen ratio showed an irregular variation with depth of uncultivated pedon 1, on the other hand it systematically increased with depth in cultivated of pedon 2. The high carbon-nitrogen ratio (13.00) was observed for the subsurface horizon of pedon 1 of (35-100 cm) depth. According to Yihenew (2002), optimum range of the C:N ratio is about 10:1 to 12:1 that provides nitrogen in excess of microbial needs. Therefore, the C:N result obtained in both pedons showed optimum range for active microbial activities of humification and mineralization of organic residues except Bt1 horizon of uncultivated pedon 1.

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 characteristics, soil fertility status, plant nutrition and biological activity in the soil (Brady and Weil, 2002). The highest value of soil organic matter was recorded at the surface soil layers and it decreased with increase in soil depth. The highest value of organic matter (5.7%) was recorded under uncultivated surface soil of pedon 1 and followed by 5.2% in surface horizon of cultivated pedon 2 (Table 5). The amount of organic matter content showed a sharp decline with depth of all studied profiles, suggesting the relatively more addition of decomposable organic materials in the surface horizons. Yihenew (2002) reported that most cultivated land soils of Ethiopia are poor in their organic matter content due to low amount of organic materials applied to the soil and complete removal of the biomass from the field.
According to Landon (1991), available (Olsen extractable) soil P level of less than 5 mg kg\(^{-1}\) is rated as low, 5-15 mg kg\(^{-1}\) as medium and greater than 15 mg kg\(^{-1}\) is rated as high. Thus, the available (Olsen extractable) P throughout the studied soils (Table 1) was below the critical level. In surface horizon it varied from 3.22 mg kg\(^{-1}\) to 3.94 mg kg\(^{-1}\) in uncultivated profile 1 and cultivated pedon 2 respectively, similarly it were varied from 3.08 mg kg\(^{-1}\) to 3.11 mg kg\(^{-1}\) in uncultivated pedon 1 and cultivated pedon 2 respectively, in subsurface horizon.

Available P showed almost constant distribution with depth of the studied soil pedons. The low P content of the soils could be related to P fixation by Al and Fe. Consequently, low available P of the soils could form one of the major soil fertility limiting factors in the study area as well as in the other similar environments of Asossa district. Most location of Asossa Wereda of Benshagul-gumuz Region had very low (bray II extractable) available phosphorous (Getahun et al., 2016a). Also studies in Ethiopia indicate that Ethiopian agricultural soils particularly Nitisols and other acidic soils due to their inherently low P content and high P fixation capacity, have low available phosphorous contents (Yihenew, 2002).

4.3.3. Cation exchange capacity and percent base saturation

The CEC of the surface horizon was 38.0 cmol (+) kg\(^{-1}\) and 35.7 cmol (+) kg\(^{-1}\) pedon 1 and pedon 2 respectively, showing an increase by 7.07% at the surface, which may be due to relatively high organic matter in the uncultivated pedon 1 of surface horizons. According to Landon (1991), CEC of the soils greater than 40 cmol (+) kg\(^{-1}\) are rated as very high and 25-40 cmol (+) kg\(^{-1}\) as high and CEC of soil from 15-25, 5-15 and < 5 cmol (+) kg\(^{-1}\) of soil are classified as medium, low, and very low, respectively. According to Landon (1991), rating the CEC soil of studied area ranges from 25.8 cmol (+) kg\(^{-1}\) depth to 34.5 cmol (+) kg\(^{-1}\) that
high, implying good for agricultural purpose. 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. CEC values generally showed declining trends with depth of both pedons.

In sub soil horizon CEC were varied from 25.8 cmol (+) kg\(^{-1}\) (100 - 200 cm) depth to 34.5 cmol (+) kg\(^{-1}\) (20-35 cm) of uncultivated pedon 1. The increase in clay contents with depth of the profiles were not parallel with increase in CEC, this indicated that the clay content of soil did not influence the CEC of soil in studied area. This result is opposed with (Donahue et al., 1990) who reported as the cation exchange capacity has a relationship with texture. The cation exchange capacity of a soil could then relate with the organic matter content of a soil (Brady and Weil, 2002). The CEC/clay values were also found to be higher for the surface horizons than the subsoil horizons of the studied pedon and it had proportionality with the CEC, but not parallel with increasing of the clay. The decline in total CEC and CEC/clay with depth of pedon reflect the role of organic matter in influencing the CEC of a soil.

The percent of base saturated of the studied area varied from 22.5% to 24.2%, which showed medium percent base saturation of the surface horizon (Table 5). Landon (1991) reported that base saturation is an indication of soil fertility. Soils with percentage base saturation of <20%, 20-60% and>60% are considered as low, medium, and high in fertility quality (Landon, 1991). Thus, the Nitisols of the present study area exhibited medium to low percentage base saturation levels (Table 6) which implies basic cations were lost from the soil through the processes of leaching due to the high rainfall. Thus, as mentioned above low potential levels of basic cations could be the other major constraints of these soils. In subsoil
horizon the percent of base saturation varied from 14.1% to 19.2%, low percent base saturation, which showed us to describe these soils as infertile (FAO-WRB, 1998).

Table 6. Exchangeable cation, CEC and percent base saturation

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Exchangeable cation (cmol(+) kg⁻¹soil)</th>
<th>CEC (cmol(+)) kg⁻¹</th>
<th>CEC clay (cmol(+)) kg⁻¹</th>
<th>PBS%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ca/Mg</td>
<td>K/Mg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedon1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0-20</td>
<td>6 2 0.1 0.4 3 0.05 38.0 61.8 22.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AB</td>
<td>20-35</td>
<td>4 2 0.1 0.5 2 0.05 34.5 47.5 19.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bt1</td>
<td>35-100</td>
<td>3 1 0.1 0.3 3 0.1 29.9 34.8 14.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bt2</td>
<td>100-200</td>
<td>2 2 0.1 0.6 1 0.05 25.8 30.9 17.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedon 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-20</td>
<td>5 3 0.1 0.5 1.7 0.03 35.7 53.9 24.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BA</td>
<td>20-45</td>
<td>2 2 0.1 0.4 1 0.05 31.5 40.8 14.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bt</td>
<td>45-120</td>
<td>2 2 0.1 0.3 1 0.05 27.6 35.5 15.9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Where, Ca = calcium; Mg = magnesium; K= potassium; Na = sodium; CEC = cation exchangeable capacity; PBS = percent of base saturation.

Exchangeable Ca was found to predominate the exchange complex of the soil colloidal particles in both of the soil of the studied area (Table 6). Landon (1991) categorized Ca as <2.0 Cmol (+) kg⁻¹ soil very low, 2.0 to 5.0 Cmol (+) kg⁻¹ low, 5.1 to 10.0 Cmol (+) kg⁻¹ medium, 10.1-20.0 high and >20.0 Cmol (+) kg⁻¹ as very high. Based on this categorization, the status of Ca in tested soils is ranges from low to medium in sub surface and surface horizon respectively. The highest exchangeable Ca (6 cmol(+)) kg⁻¹) soil was recorded under surface horizon of uncultivated pedon 1, while it decreased with the depth of the both pedons.

The analytical result of Ca and Mg indicated that surface horizon has higher amount of these
cations than sub-surface horizons. According to Mesfin (1998), most Nitisols profiles show Ca and Mg higher in the surface horizon than in the horizon below, this can be attributed to recycling through leaf fall and decay.

The concentrations of the monovalent basic cations (exchangeable K and Na) were far lower than the concentrations of the diivalent basic cation (exchangeable Ca and Mg) in both soil pedons and soil horizons within apedon. However, exchangeable Na was relatively higher than K in all soil horizone. Exchangeable K in studied soils had 0.1 Cmol (+) kg⁻¹ through all horizons as given in Table 6. This was very low according to Landon, (1991) rating. He categorized the exchangeable K in soils as <0.2 very low, 0.2 to 0.4 Cmol (+) kg⁻¹ low, 0.41-1.2 medium, 1.21-2.00 high and >2.00 Cmol (+) kg⁻¹ as very high. The soils in the study area had, very low K, indicating that these soils have no adequate levels of K for crop production. The result disagrees with the common idea that Ethiopian soils are reach in K. But it agrees with Belay (1996) and Wakene (2001) who reported K deficiency in Eutric Vertisols of Melbe (Tigray) and Dystric Nitisols of Bako area, respectively. In both of land forms, the analytical values of cations are in the order: Ca > Mg > Na > K. Yihenew (2002) reported a similar order (Ca > Mg > Na > K) for Alfisols.

The potassium to magnesium ratio of the studied soil was less than 0.7. In contrast to this result, Fanuel (2015) and Hillette (2015) reported K to Mg ratio lower than 0.7 and probability of Mg induced K deficiency in soil of southern and central highland of Ethiopia, respectively. On the other hand the Ca/Mg ratio observed in the soils studied ranged between 1 to 3 and crop not likely to Mg fertilizer application. It is stated that Mg deficiency can occur in soils with high ratio of exchangeable Ca/Mg exceeding 10 (Tisdale et al., 1995). This confirmed that the Ca not induced Mg deficiency in the soil of studied area. The recommended Ca/Mg ratios are < 5/1 for field crops, < 3/1 for vegetables and sugar beets and
< 2/1 for fruit and greenhouse crops (Havlin et al., 1999). In the study area, K : Mg ratio was less than 1:1 in all of soil samples collected. This confirmed that Mg induced K deficiency existed in the study areas. This can be corrected by K application to bring the K to Mg ratio closer to 1:1.

4.4. Classification of Soil at Experimental Site

Major diagnostic criteria in recognizing a nitic subsurface horizon of both pedons are, diffuse to gradual/and diffuse to smooth boundary, moderate coarse granular to moderately fine angular blocky, no gleyic or stagnic properties, clay loam or finer texture and silt/clay ratio less than 0.4 with subsoil, low value and chroma with 2.5 YR hues but sometimes 5 YR and 10 YR hues in some horizon is observed under moist and dry consistence and the CEC (in 1M NH4OAc at pH 7) corrected for organic matter is less than 36 Cmolc kg⁻¹.

On the basis of pedon description (Table 3, Appendix Table 1 and 2) and the results of analysis of soil samples collected from each horizon (Tables 4, 5 and 6) the soil of experimental site were characterized. The subsurface horizons of both pedon had maximum accumulation of clay which was 9% more than the surface horizon. The percentage base saturation of the pedon decreasing with depth highest (24.2%) at the surface horizon while the lowest (14.1%) at the subsurface horizon.

Accordingly, both pedon had low base saturation status (less than 50 percent) in all of its parts between 20 cm and 100 cm from the soil surface and qualified for dystric concept at the subunit level. It also had a humic soil property which is having organic carbon content of greater than 1 percent as weighted average over a depth of 100 cm from the soil surface and recognized meeting a humic qualifier at third unit level of classification. Therefore, soils represented by both pedons were classified as Humic-dystric Nitisols (FAO –WRB, 1998).
4.5. Effects of Blended Fertilizer Types and Rates on Crop Phenology and Growth Parameters of Maize

4.5.1. Days to 50% silking, tasseling and maturity

Days to 50% silking, tasseling and maturity were highly significantly (P≤ 0.01) affected by application of fertilizer types and rates (Table 7 and Appendix table 4). Early silking, tasseling and maturity were recorded from plots which received blended fertilizers followed by recommended N and P. On the other hand the longest days to 50% silking, tasseling and maturity were recorded from the control (without fertilizer applied). This result is in agreement with the finding of Dagne (2016), who indicated early tasseling, silking and maturity days were recorded with the application of blended fertilizer and the longest days to 50% tasseling, silking and maturity were recorded for control (without fertilizers).

This result indicated that the fertilizer blend in different proportion of N,P,S Zn and B might have encouraged early establishment, rapid growth and development of crop thus shorten the day to tasseling silking and heading. whereas plot that were received recommended N and P of nutrient supply took longer time to establish and grow than the blend (balanced one), but took short time than the control (without fertilizer). In conformity with the results obtained from this study plant growth retarded if any of nutrient element is less than its threshold value in the soil or if not adequately balanced with other nutrient elements (Landon, 1991). This indicates that the balanced fertilizers enhanced the vegetative growth of maize. Similarly, Siddiqui et al., (2009) reported that incorporation of Zn with macro nutrients (NPK) fertilizer increased the nutrient uptake of N, P and B which in turn facilitated grain filling process and shortened the maturity period in sunflower.
Table 7. Mean of days to 50% silking, tasseling and maturity of maize as influenced by blended fertilizer types and rates at Asossa district.

<table>
<thead>
<tr>
<th>Treatments (Nutrients ha⁻¹)</th>
<th>Days to 50%</th>
<th>Days to 50%</th>
<th>Days to 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>tasseling</td>
<td>silking</td>
<td>maturity</td>
</tr>
<tr>
<td>Control</td>
<td>78.66a</td>
<td>88.66a</td>
<td>146.66a</td>
</tr>
<tr>
<td>100 Kg TSP and 200 Kg Urea</td>
<td>72.00b</td>
<td>82.00b</td>
<td>140.00b</td>
</tr>
<tr>
<td>125 Kg TSP and 250 Kg Urea</td>
<td>72.00b</td>
<td>82.00b</td>
<td>140.00b</td>
</tr>
<tr>
<td>150 Kg TSP and 300 Kg Urea</td>
<td>72.00b</td>
<td>82.00b</td>
<td>140.00b</td>
</tr>
<tr>
<td>100 Kg NPSB + 73.9 N</td>
<td>62.00c</td>
<td>72.00c</td>
<td>125.00c</td>
</tr>
<tr>
<td>150 Kg NPSB + 110.8 N</td>
<td>62.00c</td>
<td>72.00c</td>
<td>125.00c</td>
</tr>
<tr>
<td>200 Kg  NPSB + 147.8 N</td>
<td>62.00c</td>
<td>72.00c</td>
<td>125.00c</td>
</tr>
<tr>
<td>100 Kg NPSZnB + 75.1 N</td>
<td>62.00c</td>
<td>72.00c</td>
<td>125.00c</td>
</tr>
<tr>
<td>150 Kg NPSZnB + 112.6 N</td>
<td>62.00c</td>
<td>72.00c</td>
<td>125.00c</td>
</tr>
<tr>
<td>200 Kg NPSZnB + 150.2 N</td>
<td>62.00c</td>
<td>72.00c</td>
<td>125.00c</td>
</tr>
<tr>
<td>LSD(0.01)</td>
<td>3.13**</td>
<td>3.13**</td>
<td>3.13**</td>
</tr>
<tr>
<td>CV</td>
<td>1.39</td>
<td>2.38</td>
<td>2.74</td>
</tr>
</tbody>
</table>

Mean value of followed the same letter(s) are non-significant difference at 1%; probability level: CV = coefficient variation.

Application of blended fertilizers hastened the days to 50% silking, tasseling and maturity possibly because the maize plants were able to take up sufficient nutrients from the blended and also because uptake of one nutrient (N) may have enhanced the uptake of other nutrients such as P and K which might speed up growth and development of the crop plant. Sufficient application of nitrogen result in rapid growth and hastened time of silking, tasseling and maturity, while too little or no nitrogen resulted in slow growth and stunted silking, tasseling
and maturity (Cock. and Ellis. 1992). Application of blended fertilizers hastened days to tasseling, silking, and maturity by 10, 7, and 15 days, respectively as compared to recommended nitrogen and phosphorous. This could be attributed to the positive interaction of S, B, and Zn in the blended fertilizers, which agreed with the finding of (Fageria., et al. 2002) who reported positive relations between B, K, and N fertilizers for improving crop yields and maturity.

4.5.2. Plant height and ear height of maize in Asossa area

Blended fertilizer types and rates had highly significantly (P < 0.01) influenced on plant height and ear height (Table 8). Application of treatments had increased the plant height and ear height as compared to recommended N and P and the control. Similarly the recommended N and P fertilizers increased the plant height and ear height over the control. This result is agreement with Dagne (2016), who found the application of blended fertilizer significantly increased plant height as compared to the recommended N and P fertilizers and the control. This plant height increment might be the cell elongation and vegetative growth that attributed to different nutrient (N, P, S, B, and Zn) contents in blended fertilizers.

The highest plant height (245.67 cm) and ear height (113.67 cm) were recorded under the applications of 200 kg of F4 (T10), while the least plant height (186.13 cm) and ear height (72.33 cm) were recorded from plot that received the control plants. In conformity with the results obtained from this study, Plant growth and development may be retarded significantly if any of nutrient elements is less than its threshold value in the soil or not adequately balanced with other nutrient elements (Landon, 1991). Thus, the results indicated that blended fertilizers application has enhanced the maize vegetative growth.
Table 8. Mean of ear height and plant height of maize as influenced by blended fertilizer rates and types at Asossa district.

<table>
<thead>
<tr>
<th>Treatments (nutrients ha⁻¹)</th>
<th>Ear height (cm)</th>
<th>Plant height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>72.33c</td>
<td>186.13e</td>
</tr>
<tr>
<td>100 Kg TSP and 200 Kg Urea</td>
<td>80.33c</td>
<td>201.50bcde</td>
</tr>
<tr>
<td>125 Kg TSP and 250 Kg Urea</td>
<td>80.17c</td>
<td>188.00de</td>
</tr>
<tr>
<td>150 Kg TSP and 300 Kg Urea</td>
<td>76.33c</td>
<td>199.83cde</td>
</tr>
<tr>
<td>100 Kg NPSB Kg +73.9 N</td>
<td>100.67ab</td>
<td>235.17a</td>
</tr>
<tr>
<td>150 Kg NPSB Kg + 110.8N</td>
<td>101.83ab</td>
<td>232.67ab</td>
</tr>
<tr>
<td>200 Kg NPSB Kg + 147.8 N</td>
<td>99.00ab</td>
<td>238.33a</td>
</tr>
<tr>
<td>100 Kg NPSZnB + 75.1 N</td>
<td>87.00bc</td>
<td>221.67abc</td>
</tr>
<tr>
<td>150 Kg NPSZnB + 112.6 N</td>
<td>88.33bc</td>
<td>219.00abcd</td>
</tr>
<tr>
<td>200 Kg NPSZnB + 150.2 N</td>
<td>113.67a</td>
<td>245.67a</td>
</tr>
<tr>
<td>LSD(0.01)</td>
<td>16.869**</td>
<td>32.667**</td>
</tr>
<tr>
<td>CV</td>
<td>10.93</td>
<td>8.78</td>
</tr>
</tbody>
</table>

Mean value of followed the same letter(s) are non-significant difference at LSD 1%; LSD (0.01) least significant probability level: CV = coefficient variation

The lower ear heights obtained at the recommended N and P treatments might be due to retarded growth due to imbalance nutrient availability. The ear height of plot grown at the highest rate of blended fertilizers supply exceeded by 57.13% of the ear height of plant grown in the control plot. The result obtained showed an increase in ear height of maize is generally due to different nutrient content in blended fertilizers containing macronutrient (N, P and S) and micro nutrient (Zn and B). The highest ear height observed T10 could be due to the combined effect of nutrients like N, P, S, Zn and B in blended fertilizer which might have enhanced growth and development of crop compared to the recommended N and P, and
control plants. However these result of blended formula types (NPSZnB) had non-significant from (NPSB) which contain different nutrient like, N, P, S and B. The analyzed data indicated that the addition of Zn to F2 (N, P, S and B) had no significant effect on the ear height and plant height of maize.

4.6. Effect of Blended Fertilizer Types and Rates on Yield Components of Maize

4.6.1. Cob weight and number of cob per plants

The analysis of variance of treatment on cob weight revealed highly significant ($P < 0.01$) difference among fertilizer rates and types (Table 9). The highest mean value (9695.0 kg) of cob weight was obtained under the application of 200 kg NPSZnB + 150.2 N of blended fertilizer (T10). However this treatments is statistically the same with plot that received 150 kg NPSZnB + 112.6 N (T9), 200 kg NPSB kg + 147.8 N (T7), and 150 kg NPSB kg + 110.8N (T6). Application of blended fertilizer increases the cob weight by 128.2% over the control plot while non-significant difference was observed between the blended fertilizer formulas. However the blended fertilizer rates had significant ($P < 0.01$) influence on cob weight (Table 9).

When compared to the recommended N and P, the mean value of cob weight increased by 102.2% for application of blended fertilizer (200 kg NPSZnB + 150.2 N). The application of treatments had non-significant ($P > 0.05$) difference on number cob per plants (Table 9). The result indicated that blending of fertilizers with different macro and micro nutrients did not bring significant effect on number of cob per plants. This result disagree with the finding of Dagne (2016), who stated that the application of blended fertilizer had significant difference on number of cob per plants over the recommended N and P and the control.
Table 9. Cob diameter, cob weight and number of cob per plants of maize as influenced by blended fertilizer types and rates at Asossa districts.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Cob weight</th>
<th>kg/ha</th>
<th>Number of cob per plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>4248.4e</td>
<td></td>
<td>1.10</td>
</tr>
<tr>
<td>100 Kg TSP &amp; 200 Kg Urea</td>
<td>4793.0de</td>
<td></td>
<td>1.17</td>
</tr>
<tr>
<td>125 Kg TSP &amp; 250 Kg Urea</td>
<td>5010.9de</td>
<td></td>
<td>1.13</td>
</tr>
<tr>
<td>150 Kg TSP &amp; 300 Kg Urea</td>
<td>5555.6d</td>
<td></td>
<td>1.13</td>
</tr>
<tr>
<td>100 Kg NPSB Kg +73.9 N</td>
<td>8061.0bc</td>
<td></td>
<td>1.17</td>
</tr>
<tr>
<td>150 Kg NPSB Kg + 110.8 N</td>
<td>9477.1a</td>
<td></td>
<td>1.20</td>
</tr>
<tr>
<td>200 Kg NPSB Kg + 147.8 N</td>
<td>9150.3a</td>
<td></td>
<td>1.13</td>
</tr>
<tr>
<td>100 Kg NPSZnB + 75.1 N</td>
<td>7559.9c</td>
<td></td>
<td>1.13</td>
</tr>
<tr>
<td>150 Kg NPSZnB + 112.6 N</td>
<td>9041.4ab</td>
<td></td>
<td>1.17</td>
</tr>
<tr>
<td>200 Kg NPSZnB + 150.2 N</td>
<td>9695.0a</td>
<td></td>
<td>1.13</td>
</tr>
<tr>
<td>LSD(0.05)</td>
<td>1036.6**</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>CV</td>
<td>8.32</td>
<td></td>
<td>5.54</td>
</tr>
</tbody>
</table>

Mean value of followed the same letter(s) are non-significant difference at LSD 5%; LSD(0.05) least significant probability level: CV = coefficient variation

4.6.2. Ear length, hundred kernels weight, number of kernels per row and number of kernel row per cob

The mean value and analysis of variance of treatment on ear length, 100 kernels weight, number of kernels per row revealed highly significant difference \( P \leq 0.01 \) among blended fertilizer types and rates (Table 10 and Appendix Table3). However the application of fertilizer treatments had non-significant \( P > 0.05 \) effects on number of kernel row per cob (Table 10). Blended fertilizer rates and types had highly significant \( P \leq 0.01 \) effects on ear length of maize (Table 10). However, there were no significant differences between the two
formula types. Blended fertilizer which contains B improved cob weight. This results agree with the finding of Mozafar (1989), who reported that application of B fertilizer to maize production encourage good cob development.

The largest ear length (16.10cm) was obtained under the application of 200 kg NPSZnB + 150.2 N (T10), while the shortest ear length of maize (11.57cm) was recorded under the control. The two types of blended fertilizer formulas (NPSZnB and NPSB) gave similar response to these parameters. The application of blended fertilizer had highly significant (p < 0.01) influence on 100 kernels weight (Table10), however there were no significant differences between the two blended fertilizer formula. The maximum number of 100 kernels weight (48.85 g) was obtained under T9, while it was at par with T5, T6, T7 and T10. On the other hand, minimum number of 100 kernels weight (40.96 g) was recorded under the control.

Comparing the 100 kernels weight showed that 150 kg NPSZnB + 112.6 N kg ha\(^{-1}\) application resulted in 20.05% and 15.15% more 100 kernels weight as compared to the control treatment and recommended N and P respectively (Table10). The mean analysis of variance of treatment on number of kernels per row revealed highly significant (P<0.01) difference among fertilizer rates and types. However there were no significant differences between the two blended fertilizer formulas (Table 10). Both blended fertilizer types (NPSZnB and NPSZnB) gave more response to number of kernels per row than recommended N and P, and the control. The maximum number of kernels per row (37.10) was obtained under application of (T10), while minimum number of kernels per row (24.23) was recorded under the control plants.
Table 10. Ear length, hundred kernels weight, number of kernels per row and number of kernel row per cob of maize as influenced by blended fertilizer types and rates.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Ear length(cm)</th>
<th>100 kernels weight(g)</th>
<th>Number of kernels per row</th>
<th>Number of kernel row per cob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>11.57e</td>
<td>40.69d</td>
<td>24.23d</td>
<td>14.567</td>
</tr>
<tr>
<td>100 Kg TSP&amp;200 Kg Urea</td>
<td>14.13abcd</td>
<td>42.42cd</td>
<td>30.700bc</td>
<td>14.567</td>
</tr>
<tr>
<td>125 Kg TSP &amp; 250 Kg Urea</td>
<td>13.067cde</td>
<td>40.83d</td>
<td>30.50bc</td>
<td>14.467</td>
</tr>
<tr>
<td>150 Kg TSP &amp; 300 Kg Urea</td>
<td>12.100de</td>
<td>42.92cd</td>
<td>29.100cd</td>
<td>14.933</td>
</tr>
<tr>
<td>100 Kg NPSB Kg +73.9 N</td>
<td>14.47abc</td>
<td>46.60abc</td>
<td>34.63ab</td>
<td>15.067</td>
</tr>
<tr>
<td>150 Kg NPSB Kg + 110.8N</td>
<td>15.53ab</td>
<td>46.61abc</td>
<td>35.67ab</td>
<td>15.167</td>
</tr>
<tr>
<td>200 Kg NPSB Kg + 147.8 N</td>
<td>14.20abc</td>
<td>46.59abc</td>
<td>32.70abc</td>
<td>14.900</td>
</tr>
<tr>
<td>100 Kg NPSZnB + 75.1 N</td>
<td>13.933bcd</td>
<td>43.32bcd</td>
<td>31.43bc</td>
<td>15.433</td>
</tr>
<tr>
<td>150 Kg NPSZnB + 112.6 N</td>
<td>13.36cde</td>
<td>48.850a</td>
<td>33.17abc</td>
<td>15.067</td>
</tr>
<tr>
<td>200 Kg NPSZnB + 150.2 N</td>
<td>16.10a</td>
<td>47.303 ab</td>
<td>37.10a</td>
<td>15.100</td>
</tr>
<tr>
<td>LSD(0.05)</td>
<td>2.04**</td>
<td>4.26**</td>
<td>5.42**</td>
<td>-</td>
</tr>
<tr>
<td>CV</td>
<td>8.61</td>
<td>5.66</td>
<td>9.90</td>
<td>2.95</td>
</tr>
</tbody>
</table>

Mean value of followed the same letter(s) are non-significant difference at LSD 5%; LSD(0.05) least significant probability level: CV = coefficient variation

The analyzed data of number of kernel row per cob indicated that non-significant difference was observed among fertilizer rates tasted. Application of blended fertilizer T10 increases the number of kernels per row by 53.11% over the control plot. As compared to the recommended N and P, the mean value of number of kernels per row increased by 20.84% for T10. The highest ear length, 100 kernels weight and number of kernels per row observed under blended fertilizer could be due to the combined effect of nutrients like N, P, S, Zn and
B in blended fertilizer which might have enhanced growth and development of crop as compared to the recommended N and P and control or without fertilizer. Data regarding to the number of kernel row per cob for various treatments are indicated in (Appendix table 5). The mean value and analysis of variance of treatment on number of kernels per row revealed non-significant (P ≥ 0.05) difference among fertilizer rates and types. The maximum number of kernel row per cob (15.43) was obtained under application T8 (100 kg NPSZnB + 75.1 N), while this treatment was at par with all other treatments.

4.7. Influence of Blended Fertilizer Types and Rates on Grain Yield, Straw Yield, Biological Yield and Harvest Index of Maize.

4.7.1. Grain yield

The analysis of variance of among blended fertilizer rates, types and recommended N and P on grain yield revealed highly significant (P < 0.01) difference, however there was no significant differences between the two blended fertilizer types (Appendix table 6). The two types of blended fertilizer had significantly improved grain yield. The grain yield increment from plot that treated with blended fertilizer might be the contribution of balance nutrient (macro and micro nutrient) present in blended fertilizer as compared to recommended N and P, and control. The low yield of maize under application of recommended N and P might be due to the absence of macronutrient like K and S and other micronutrients (Zn, B). Similar trend was observed with (Boorboori et al., 2012).

Comparing the grain yield, T10 resulted in 135.5% and 111.1% increased as compared to T1 and T2 respectively. Similar trend was observed by Singh et al. (2009) in wheat crop who claimed that 100% NP plus single spray of micronutrients gave best results in comparison to other treatments. Grain yield increment with the blended fertilizer which contained S, B and Zn indicated that the need to supplement the element for maize production. Similarly finding
was concluded that, use of micro nutrients especially boron and zinc had positive effect on yield and yield components of cereals (Majid et al., 2012). The increase in grain yield could be attributed to beneficial influence of yield contributing characters and positive interaction of nutrients in the blended fertilizer Dagne (2016). The strong relationships were found between grain yield and ear length, grain yield and 100 kernels weight, and number of kernels per row and between grain yields. Therefore those three yield attributes are the most important components directly related to grain yield in maize.

Table 11. biomass yield, grain yield, straw yield and harvest index of maize as influenced by blended fertilizer types and rates at Asossa district.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Grain yield (kg)</th>
<th>Straw yield (kg)</th>
<th>Biological yield (kg)</th>
<th>Harvest index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2996.0e</td>
<td>4400.9e</td>
<td>7397e</td>
<td>0.41bcd</td>
</tr>
<tr>
<td>100 Kg TSP&amp;200 Kg Urea</td>
<td>3342.5de</td>
<td>5119.8de</td>
<td>8462de</td>
<td>0.40cd</td>
</tr>
<tr>
<td>125 Kg TSP &amp; 250 Kg Urea</td>
<td>3569.3de</td>
<td>5337.7de</td>
<td>8907d</td>
<td>0.40cd</td>
</tr>
<tr>
<td>150 Kg TSP &amp; 300 Kg Urea</td>
<td>3958.9d</td>
<td>5882.4cd</td>
<td>9841d</td>
<td>0.40cd</td>
</tr>
<tr>
<td>100 Kg NPSB Kg +73.9 N</td>
<td>5789.8bc</td>
<td>6971.7ab</td>
<td>12761bc</td>
<td>0.46ab</td>
</tr>
<tr>
<td>150 Kg NPSB Kg +110.8N</td>
<td>6863.4a</td>
<td>7886.7a</td>
<td>14750a</td>
<td>0.47a</td>
</tr>
<tr>
<td>200 Kg NPSB Kg +147.8 N</td>
<td>6563.8a</td>
<td>6971.7ab</td>
<td>13536ab</td>
<td>0.48a</td>
</tr>
<tr>
<td>100 Kg NPSZnB + 75.1 N</td>
<td>5473.3c</td>
<td>6644.9bc</td>
<td>12118c</td>
<td>0.45abc</td>
</tr>
<tr>
<td>150 Kg NPSZnB + 112.6 N</td>
<td>6538.7ab</td>
<td>7124.2ab</td>
<td>13663ab</td>
<td>0.48a</td>
</tr>
<tr>
<td>200 Kg NPSZnB + 150.2 N</td>
<td>7056.2a</td>
<td>7559.9ab</td>
<td>14616a</td>
<td>0.49a</td>
</tr>
<tr>
<td>LSD(0.05)</td>
<td>758.71**</td>
<td>1065.4**</td>
<td>1396.3**</td>
<td>0.05**</td>
</tr>
<tr>
<td>CV</td>
<td>8.48</td>
<td>9.72</td>
<td>7.01</td>
<td>6.95</td>
</tr>
</tbody>
</table>

Mean value of followed the same letter(s) are non-significant difference at LSD 5%; LSD(0.05) least significant probability level: CV = coefficient variation
As the rate of N and P increases the grain yield was also increased. Therefore grain yield obtained from recommended N and P was slightly superior to the control. The low yield in unfertilized plots might have been due to reduced leaf area development resulting in lesser radiation interception and, consequently, low efficiency in the conversion of solar radiation (Sallah et al., 1998). The yield advantage of blended fertilizer over recommended N and P might be due to the presence of macronutrient S and micronutrient like Zn, B. If levels of these nutrients are too low, this can lead to poor plant growth; reduced uptake, inhibited cell division, respiration, nitrogen mobilization and inefficient water use by plants.

4.7.2. Straw yield

The mean value and analysis of variance of treatment on Straw yield revealed highly significant (P≤0.01) difference among fertilizer types and rates. However there were no significant differences between the two blended fertilizer types (Appendix table 4). Nitrogen increases shoot dry matter, which is positively associated with grain yield in cereals and legumes (Fageria, 2007). The maximum maize straw was recorded with T6 (7886.7 kg ha⁻¹), while minimum value (4400.9 kg ha⁻¹) was recorded with control treatment. Comparing the straw yield showed that T6 resulted in 79.21% more biomass yield as compared to the control treatment (Table11). Compared to the recommended N and P, the mean value of straw yield was increased by 54.04% when T6 was applied. Nitrogen application increases stover yield and this might be due to that N increases leaves per plant, leaf area and stem diameter (Kaur et al., 2012).

4.7.3. Biological yield

The analysis of variance of among blended fertilizer types and rates of biological yield revealed highly significant (P≤0.01) difference. The two types of blended fertilizer had significantly improved biological yield over recommended N and P. These results were in
conformity with findings of Sharma et al. (2011) those stated that application of micronutrients combinations with macronutrients gave highest biological yield as grain yield was also influenced which might be attributed to the additional availability of nutrients.

The maximum amount of biological yield (14750 kg ha\textsuperscript{-1}) was obtained under application of 150 kg NPSB Kg + 110.8N (T6). However, it was non-significantly different from other treatments T7, T9 and T10. This is might be due to the basal application of nitrogen fertilizer in addition to the blended fertilizers. In agreement with the results of this study, Abera (2013 unpublished) reported significantly higher biological yield at higher N rates. The minimum amount of biological yield (7397 kg ha\textsuperscript{-1}) was obtained from control plot, while this treatment is statistically parity with the recommended N and P. Comparing the biological yield showed that T6 resulted in 99.4% more biological yield compare to the control plants (Table 11) On the other hand compared to the recommended N and P, the mean value of biological yield increased by 74.3% for application of blended fertilizer via nitrogen (150 Kg NPSB kg + 110.8N).

The biological yield increment might be due to micronutrients attributed to enhanced photosynthesis, early growth and nitrogen fixation as Zn and other vital nutrients was present in multi-nutrients solution (Azhar et al., 2011). As the rate of N and P increases the biological yield was also non significantly increased. This increment in biological with the blended fertilizer showed that both macro and micro plant nutrients are deficient in the study area. Therefore biological yield increment of maize with the application of blended fertilizer over the control and recommended N and P might be due to the balanced nutrient (macro and micro nutrient) present in the blended fertilizer.
4.7.4. Harvest Index

The physiological ability of maize to convert total dry matter in to grain yield is determined by its harvest index (HI). The analysis of variance revealed that fertilizer rates and types had highly significant \( P \leq 0.01 \) influence on harvest index. However there were no significant differences between the two blended fertilizer types (Appendix table 6). Both blended fertilizer types (NPSZnB and NPSZnB) gave more response to harvest index than recommended N and P and the control. Nevertheless, non-significant difference between recommended N and P and control was observed with regard to harvest index. The maximum harvest index (0.49) was obtained at application of 200 kg NPSZnB + 150.2 N kg ha\(^{-1}\) (T10) and minimum harvest index (0.40) was recorded under the recommended N and P.

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 economic part. Comparing the harvest index showed that 200 kg NPSZnB + 150.2 N kg ha\(^{-1}\) application resulted in 19.51\% more harvest index as compared to the control treatment (Table 11). Compare to the recommended N and P, the mean value of harvest index increased by 22.50\% for application of blended fertilizer (200 kg NPSZnB + 150.2 N kg ha\(^{-1}\)). The higher harvest index expressed was for the reason of the physiological potential for converting dry matter into grain yield.

4.8. Influence of Blended Fertilizer Types and Rates on Nutrient Concentration Uptake and Nutrient Use Efficiency of Maize

4.8.1. Nitrogen concentration and uptake in straw and grain of maize

The application of blended fertilizer and recommended N and P had influenced the grain and straw N uptake. The maximum N uptake by grain (56.10 kg ha\(^{-1}\)) was obtained at application
200 kg NPSZnB + 150.2 N kg ha\(^{-1}\), and this value exceeds by 250.4% the value obtained at the control treatment. Similarly application of 200 kg NPSZnB + 150.2 N kg ha\(^{-1}\) improved grain N uptake by 151.7% over recommended N and P. This fertilizer also improved total biomass uptake at the recomended N and P, and control treatments by 145.62% and 238.19% respectively. The maximum N concentration of grain and straw was 0.80 and 0.08%, respectively with T10 and T8, where as the least was for control plots (Table.12). The grain N concentration increased from the minimum of 0.54% obtained with control to a maximum of 0.8% recorded for the 200 kg NPSZnB + kg ha\(^{-1}\) + 150 N kg ha\(^{-1}\). Compared to recommended N and P, blended fertilizer had improved grain and straw N concentration by 19.4% and 100% respectively. This increment in N uptake and concentration over recommended N and P could be due to improved efficiency of N attributed to macro and micro nutrient present in blended fertilizer applied.

The grain and straw nutrient concentration of nitrogen was very low than recorded with several others studies (Dagne, 2016, Brady & Wiel, 2002 and Iżewska & Wołoszyk, 2015) in number, might be the small rate of sulfur that present in blended fertilizer limit the efficiency of added and indigenous soil N. This is in line with Fazili et al. (2008) who reported that low rate of S limits the efficiency of added N, therefore, S addition becomes necessary to achieve maximum efficiency of applied nitrogenous fertilizer and those found that uptake of N was considerably reduced under S deficiency in \textit{E. sataiva}. Omission of S in fertilizer schedule (100%NPK-S) declined the nutrients uptake over balanced NPK with sulphur (Jarupula et al., 2018). A number of studies indicated synergistic effect of combined application of S and N on the uptake of these nutrients by maize, rapeseed (Fazli et al., 2008). N, P and S uptake by maize plant were influenced significantly with application of S and N fertilizer, furthermore highest N uptake was recorded with application of S (Rahman et al., 2011).
Unfortunately the studied area is prone to high rain fall and the leaching of N on the other hand can limit the nitrogen availability to the plant, consequently it limit the N concentration in plant tissue. The same as N uptake is influenced by soil chemical properties of the experimental site which had medium to very low total N, low organic matter and strongly acidic to moderately acidic as was also confirmed by soil characterisation of the studied area (Table 5). This result is in line with (Sheleme et al., 2016), who reported nutrient uptake is influenced by several factors including nutrient availability, soil water availability, soil organic matter, soil chemical and physical properties, type of previous crop, plant population and the genotype.

Table 12. Grain and straw nitrogen concentration and uptake of maize at Asossa district

<table>
<thead>
<tr>
<th>Treatments</th>
<th>N concentration (%)</th>
<th>N uptake (Kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Grain 0.54 Straw 0.04</td>
<td>Grain 16.01 Straw 1.74 Total 17.75</td>
</tr>
<tr>
<td>100 Kg TSP and 200 Kg Urea</td>
<td>Grain 0.67 Straw 0.04</td>
<td>Grain 22.29 Straw 2.15 Total 24.44</td>
</tr>
<tr>
<td>125 Kg TSP and 250 Kg Urea</td>
<td>Grain 0.69 Straw 0.05</td>
<td>Grain 24.50 Straw 2.48 Total 26.99</td>
</tr>
<tr>
<td>150 Kg TSP and 300 Kg Urea</td>
<td>Grain 0.70 Straw 0.06</td>
<td>Grain 27.57 Straw 3.47 Total 31.04</td>
</tr>
<tr>
<td>100 Kg NPSB Kg +73.9 N</td>
<td>Grain 0.70 Straw 0.05</td>
<td>Grain 40.38 Straw 3.17 Total 43.56</td>
</tr>
<tr>
<td>150 Kg NPSB Kg + 110.8 N</td>
<td>Grain 0.70 Straw 0.04</td>
<td>Grain 48.18 Straw 3.43 Total 51.61</td>
</tr>
<tr>
<td>200 Kg NPSB Kg + 147.8 N</td>
<td>Grain 0.69 Straw 0.06</td>
<td>Grain 45.13 Straw 3.94 Total 49.07</td>
</tr>
<tr>
<td>100 Kg NPSZnB + 75.1 N</td>
<td>Grain 0.65 Straw 0.08</td>
<td>Grain 35.80 Straw 5.35 Total 41.14</td>
</tr>
<tr>
<td>150 Kg NPSZnB + 112.6 N</td>
<td>Grain 0.678 Straw 0.07</td>
<td>Grain 44.30 Straw 4.70 Total 49.00</td>
</tr>
<tr>
<td>200 Kg NPSZnB + 150.2 N</td>
<td>Grain 0.80 Straw 0.05</td>
<td>Grain 56.10 Straw 3.93 Total 60.03</td>
</tr>
</tbody>
</table>
4.8.2. Phosphorus Concentration and uptake in straw and grain of maize

The highest removal of P (11.15 kg ha\(^{-1}\)), in grain was obtained with T10- (200 kg NPSZnB + 150.2 kg N ha\(^{-1}\)). The nutrient uptake increased through application of blended macronutrients and micronutrients in appropriate form of fertilizer to nutrient deficient soil. The mean values of P uptake of grain, straw and total biomass of maize supplied with blended fertilizer were higher than that of the recommended N and P and control plants.

As of all blended fertilizer rates, application of 200 kg NPSZnB + 150.2 N ha\(^{-1}\) (11.15 kg ha\(^{-1}\)) and 100 kg NPSZnB + 75.1 N ha\(^{-1}\) (2.33 kg ha\(^{-1}\)) increase the grain and straw P uptake of maize respectively. Application of blended fertilizer improved grain P uptake by 178.1% as compared to recommended N and P fertilizer. Similarly the application of blended fertilizer improved grain P uptake by 197.3% as compared to control plants. This increment might be synergic effect of Zn present in blended fertilizer improved uptake of phosphorus and potassium over recommended N and P. Similarly the positively strong and highly significant association of P uptake with K grain uptake, N grain uptake, P recovery and S grain uptake was observed, consequently improve the grain P uptake over recommended N and P.

Increased blended fertilizer rates also increased the grain content of P (Table 13). This result is line with (Dagne, 2016), who reported blended fertilizer with Cu and Zn the highest grain uptake and contents of P were observed. Application of blended fertilizer improved grain and straw P contents by 33.3% as compared to the control plants. Similarly application of blended fertilizer also improved grain and straw P contents by 33.3% over the plot receiving recommended N and P fertilizer. This indicated that there were no difference between recommended N and P and control plants on grain and straw P contents. The highest P content of grain (0.16%) and straw (0.04) were observed at blended fertilizer rate of 200 kg
NPSZnB + 150.2 N kg ha\(^{-1}\) and 100 kg NPSZnB + 75.1 N kg ha\(^{-1}\) respectively. Generally the highest removal of P was observed more toward the grain as compared to the straw. These result is in line with the funding of (Waldren and Flower day, 1979), who reported that the quantity of P in grain at harvest ranged from 78% to 90% of the total P content.

Table 13. Grain and straw phosphorous plant tissue nutrient content and uptake of maize at Asossa district.

<table>
<thead>
<tr>
<th>Treatments (Nutrients ha(^{-1}))</th>
<th>P Concentration ( % )</th>
<th>P uptake ( Kg ha(^{-1}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grain</td>
<td>Straw</td>
</tr>
<tr>
<td>Control</td>
<td>0.12</td>
<td>0.03</td>
</tr>
<tr>
<td>100 Kg TSP and 200 Kg Urea</td>
<td>0.12</td>
<td>0.03</td>
</tr>
<tr>
<td>125 Kg TSP and 250 Kg Urea</td>
<td>0.14</td>
<td>0.02</td>
</tr>
<tr>
<td>150 Kg TSP and 300 Kg Urea</td>
<td>0.15</td>
<td>0.03</td>
</tr>
<tr>
<td>100 Kg NPSB Kg +73.9 N</td>
<td>0.12</td>
<td>0.02</td>
</tr>
<tr>
<td>150 Kg NPSB Kg + 110.8 N</td>
<td>0.13</td>
<td>0.02</td>
</tr>
<tr>
<td>200 Kg NPSB Kg + 147.8 N</td>
<td>0.14</td>
<td>0.02</td>
</tr>
<tr>
<td>100 Kg NPSZnB + 75.1 N</td>
<td>0.14</td>
<td>0.04</td>
</tr>
<tr>
<td>150 Kg NPSZnB + 112.6 N</td>
<td>0.14</td>
<td>0.03</td>
</tr>
<tr>
<td>200 Kg NPSZnB + 150.2 N</td>
<td>0.16</td>
<td>0.03</td>
</tr>
</tbody>
</table>

The low P uptake and concentrations in plant materials might be therefore be attributed to low soil fertility, low available P, strongly acidity to moderately acidity, and Al toxicity, and P deficiencies of the in the experimental soil; as was also confirmed by soil characterised of the studied area (Table 5). The nutrient uptake increased through application of lime and compost with blended macronutrients and micronutrients in appropriate form of fertilizer to nutrient deficient soil (Woubshet \textit{et al.}, 2017). On the other hand the divalent basic cation (Ca, Mg) of the experimental
site were ranges from very low to medium and replaced by $\text{Al}^{3+}$ and $\text{H}^+$ consequently limit the availability of P by fixation.

4.8.3. Potassium Concentration and uptake, in straw and grain of maize

Unlike nitrogen and phosphorous, K content and uptake in straw were higher as compared to the grain removal (Table 14). The highest K uptake in grain, straw and total biomass (12.28, 71.03 and 83.30 kg ha$^{-1}$ were obtained under application of 200 kg NPSZnB + 150.2 N ha$^{-1}$ respectively (Table 14). These increments might be the optimum supply of nitrogen via blended fertilizer ensures optimum uptake of potassium as well as phosphorus. similarly optimal levels of zinc present in blended fertilizer improve uptake of potassium. Generally blended fertilizer (T10) had improved K uptake in grain, straw and total biomass of maize plants by 298.7%, 82.3% and 98.1% as compared to recommended N and P fertilizer respectively. Similarly blended fertilizer (T10) had increased K uptake in grain, straw and total biomass maize plant by 490.4%, 350% and 366.4% as compared to control plants.

On other hand, a treatment that accumulates the maximum of total biomass K nutrients gave the highest yield. The highest contents (0.939 cmoil(+) kg$^{-1}$ and 1.114 cmoil(+) kg$^{-1}$) of K in straw and total biomass respectively, were recorded for 200 kg NPSZnB N + 150.2 kg N ha$^{-1}$, whereas the least value (0.359 and 0.428 cmoil (+) kg$^{-1}$) were recorded for control plants respectively (Table 14). On the other hand the highest content (0.198 cmoil (+) kg$^{-1}$) of K in maize grain was recorded for 150 kg TSP & 300 kg Urea, where as the least value (0.049 cmoil(+)) was recorded for 150 kg NPSB kg + 110.8N treatment. This indicated that the blended fertilizer had relatively less contribution on K content of grain maize for this experiment.
Table 14. Grain and straw potassium plant tissue nutrient content and uptake of maize at Asossa district.

<table>
<thead>
<tr>
<th>Treatments (Nutrients ha⁻¹)</th>
<th>K Concentration Cmoil(+) kg⁻¹</th>
<th>K uptake ( Kg ha⁻¹ )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Grain 0.069</td>
<td>Straw 0.359</td>
</tr>
<tr>
<td></td>
<td>2.08</td>
<td>15.78</td>
</tr>
<tr>
<td></td>
<td>17.86</td>
<td></td>
</tr>
<tr>
<td>100 Kg TSP &amp; 200 Kg Urea</td>
<td>Grain 0.092</td>
<td>Straw 0.761</td>
</tr>
<tr>
<td></td>
<td>3.08</td>
<td>38.96</td>
</tr>
<tr>
<td></td>
<td>42.04</td>
<td></td>
</tr>
<tr>
<td>125 Kg TSP &amp; 250 Kg Urea</td>
<td>Grain 0.122</td>
<td>Straw 0.528</td>
</tr>
<tr>
<td></td>
<td>4.34</td>
<td>28.18</td>
</tr>
<tr>
<td></td>
<td>32.52</td>
<td></td>
</tr>
<tr>
<td>150 Kg TSP &amp; 300 Kg Urea</td>
<td>Grain 0.198</td>
<td>Straw 0.5465</td>
</tr>
<tr>
<td></td>
<td>7.82</td>
<td>32.15</td>
</tr>
<tr>
<td></td>
<td>39.97</td>
<td></td>
</tr>
<tr>
<td>100 Kg NPSB Kg + 73.9 N</td>
<td>Grain 0.068</td>
<td>Straw 0.558</td>
</tr>
<tr>
<td></td>
<td>3.94</td>
<td>38.90</td>
</tr>
<tr>
<td></td>
<td>42.84</td>
<td></td>
</tr>
<tr>
<td>150 Kg NPSB Kg + 110.8N</td>
<td>Grain 0.049</td>
<td>Straw 0.560</td>
</tr>
<tr>
<td></td>
<td>3.40</td>
<td>44.17</td>
</tr>
<tr>
<td></td>
<td>47.56</td>
<td></td>
</tr>
<tr>
<td>200 Kg NPSB Kg + 147.8 N</td>
<td>Grain 0.094</td>
<td>Straw 0.609</td>
</tr>
<tr>
<td></td>
<td>6.14</td>
<td>42.49</td>
</tr>
<tr>
<td></td>
<td>48.63</td>
<td></td>
</tr>
<tr>
<td>100 Kg NPSZnB + 75.1 N</td>
<td>Grain 0.185</td>
<td>Straw 0.582</td>
</tr>
<tr>
<td></td>
<td>10.10</td>
<td>38.67</td>
</tr>
<tr>
<td></td>
<td>48.77</td>
<td></td>
</tr>
<tr>
<td>150 Kg NPSZnB + 112.6 N</td>
<td>Grain 0.147</td>
<td>Straw 0.534</td>
</tr>
<tr>
<td></td>
<td>9.61</td>
<td>38.01</td>
</tr>
<tr>
<td></td>
<td>47.62</td>
<td></td>
</tr>
<tr>
<td>200 Kg NPSZnB + 150.2 N</td>
<td>Grain 0.174</td>
<td>Straw 0.939</td>
</tr>
<tr>
<td></td>
<td>12.28</td>
<td>71.03</td>
</tr>
<tr>
<td></td>
<td>83.30</td>
<td></td>
</tr>
</tbody>
</table>

Blended fertilizer had improved K content in straw and total biomass of maize plants by 23.4 and 30.6% respectively as compared to recommended N and P fertilizers. The same as blended fertilizer application (200 kg NPSZnB + 150.2 N ) had increased K content in straw and total biomass by 161.5% and 160.1% respectively as compared to the control plants. This result is line with (Malkouti, 2008), who reported fertilizer use efficiency for different crops increased by the application of suitable micronutrients.

According to (van Duivenbooden, 1996) the grain and strover potassium concentration ranges from 0.2 - 0.53 and 0.57 - 1.61 for maize respectively. However the grain potassium concentration is blow the range. On the other hand potassium removal is more by straw than
grain, and the potassium concentration of stover is within the range for maize crops. The nutrient contents of the plant tissues reflect the availability of the respective elements from the soil (Mengel and Kirkby, 1987), and hence the amendments of soil with different fertilizer types and rates might be having improved the indigenous K availability.

4.8.4. Sulfur Concentration and uptake in straw and grain of maize

Data regarding to sulfur uptake and content were listed in Table 15. It is clear from table that Sulfur uptake was affected by different levels of blended fertilizer and recommended N and P application. Maximum grain, straw and total biomass uptake (2.82, 4.54 and 7.36 kg ha\(^{-1}\)) of sulfur was noted in T10 respectively, where blended fertilizer were applied and minimum removal of sulfur from grain, straw and total biomass (1.20, 2.64 and 3.84 kg ha\(^{-1}\)) were recorded in control plot respectively. On the other hand maximum concentration of sulfur (0.05%) was recorded treatment where 100 kg TSP and 200 kg Urea applied. The less responsive concentration of sulfur in grain and straw to blended fertilizer might be due to blow recommended rate of sulfur in blended fertilize for cereal crops. Sulfur uptake of grain and straw increased with levels of blended fertilizer and their maximum uptakes were obtained at T10, hence grain and straw uptake increased by 135% and 71.9% over control, respectively. Similarly T10 increased grain and straw uptake by 68.6% and 47.8% over recommended N and P, respectively. N application increased the grain S concentration at high but not at low S and increased grain N concentration in all S treatments (Jarupula et al., 2018). The S nutrient content and uptake were the contribution of macro and micro nutrients present in blended fertilizer. This result is line with the founding of Jones et al. (2011) stated matching appropriate essential macronutrients and micronutrients with crop nutrient uptake could optimize nutrient use efficiency and crop yield.
Table 15. Grain and straw sulfur plant tissue nutrient content and uptake of maize at Asossa district.

<table>
<thead>
<tr>
<th>Treatment (Nutrients ha⁻¹)</th>
<th>S Concentration ( % )</th>
<th>S uptake ( Kg ha⁻¹ )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grain</td>
<td>Straw</td>
</tr>
<tr>
<td>Control</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td>100 Kg TSP&amp;200 Kg Urea</td>
<td>0.05</td>
<td>0.06</td>
</tr>
<tr>
<td>125 Kg TSP &amp; 250 Kg Urea</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td>150 Kg TSP &amp; 300 Kg Urea</td>
<td>0.03</td>
<td>0.07</td>
</tr>
<tr>
<td>100 Kg NPSB Kg +73.9 N</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>150 Kg NPSB Kg +110.8 N</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>200 Kg NPSB Kg +147.8 N</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td>100 Kg NPSZnB + 75.1 N</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td>150 Kg NPSZnB + 112.6 N</td>
<td>0.034</td>
<td>0.06</td>
</tr>
<tr>
<td>200 Kg NPSZnB + 150.2 N</td>
<td>0.04</td>
<td>0.06</td>
</tr>
</tbody>
</table>

The amount of S in a cereal crop at harvest can range between 7 and 30 kg ha⁻¹, depending on both S supply and yield level, although most crops contain nearer to 15 kg ha⁻¹ (Withers et al., 1997). Therefore the S uptake and concentration of the studied area were below the optimum uptake and concentration for the cereals. The low up take and concentration of S might be due to poor soil fertility of studied area and below recommended rate of sulfur fertilizer present in blended fertilizer. This result is line with (Arshad et al., 2010), who found application of S increased the grain S concentration at high but not at low S. At the maximum N and S up take (T10 ) the N:S was 20 : 1 and this indicated that the deficiency of S can be observed in grain. This result is in line with (Aulakh et al., 1980) who found adequate N: S ratio has been found to be 7.5:1 in grains, above which deficiency of S can be observed.
Aulakh et al. (1977) found N : S ratio of 15.5:1 in plant tissue of mustard to be critical, above which the inadequacy of S may cause drastic reduction in grain yield. Generally according to Blake-Kalff et al. (2003), an optimal N:S ratio should range from 10 to 15:1, depending on a maize variety and, thus N : S ratio of the studied area was above the range that indicated the deficiency of S in plant tissue and soil.

4.8.5. Physiological efficiency grain and apparent recovery of biological yield of maize

The highest mean of apparent recoveries of N and P recorded were 28.05% and 14.70% , respectively. The apparent N recovery decreased with increasing rate of blended fertilizer application (Table 18), however P recovery decreased with increasing rate of blended fertilizers were inconsistence. The maximum (28.05%) and minimum (7.27%) apparent recoveries of N were obtained at 100 kg NPSB +73.9 N kg ha$^{-1}$ and 100 kg TSP & 200 kg Urea ha$^{-1}$, respectively. There was a decrease in the apparent recovery of fertilizer N at each successive increment of fertilizer so that the highest recovery always occurred at lowest increment of fertilizer (Doyle and Holford, 1993). Similarly the maximum (14.70%) and minimum (0.92%) apparent recoveries of P were obtained at 100 kg NPSZnB + 75.1 N kg ha$^{-1}$ and 100 kg TSP & 200 kg Urea ha$^{-1}$, respectively (Table 18). The blended fertilizer had improved the N and P recovery over recommended N and P might be the contribution of macronutrient (S) and micronutrient (B and Zn) present in blended fertilizer increased the availability of macro nutrients. The N and P apparent recovery is in line with the findings of Sandana (2016) which indicate that the level and types of nutrient fertilization affects the nutrient availability in soil and at high contents of soil nutrients and their availability more nutrients might be taken up by plants. In general, fertilizer N recovery by rice is never too high due to various types of losses including denitrification, volatilization and leaching losses (Brady and Weil, 2002).
Table 16. Mean of apparent recovery, physiological efficiency and agronomic use efficiency of maize.

<table>
<thead>
<tr>
<th>Treatment (Nutrients ha(^{-1}))</th>
<th>AR %</th>
<th>PE Kg ha(^{-1})</th>
<th>AUE Kg kg(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>100 Kg TSP&amp;200 Kg Urea</td>
<td>0.92</td>
<td>7.27</td>
<td>818.60</td>
</tr>
<tr>
<td>125 Kg TSP &amp; 250 Kg Urea</td>
<td>1.84</td>
<td>8.03</td>
<td>540.51</td>
</tr>
<tr>
<td>150 Kg TSP &amp; 300 Kg Urea</td>
<td>3.23</td>
<td>9.63</td>
<td>431.92</td>
</tr>
<tr>
<td>100 Kg NPSB Kg +73.9 N</td>
<td>9.14</td>
<td>28.05</td>
<td>847.02</td>
</tr>
<tr>
<td>150 Kg NPSB Kg + 110.8N</td>
<td>10.77</td>
<td>24.54</td>
<td>663.15</td>
</tr>
<tr>
<td>200 Kg NPSB Kg + 147.8 N</td>
<td>7.73</td>
<td>17.02</td>
<td>639.54</td>
</tr>
<tr>
<td>100 Kg NPSZnB + 75.1 N</td>
<td>14.70</td>
<td>25.43</td>
<td>498.74</td>
</tr>
<tr>
<td>150 Kg NPSZnB + 112.6 N</td>
<td>12.20</td>
<td>22.98</td>
<td>572.58</td>
</tr>
<tr>
<td>200 Kg NPSZnB + 150.2 N</td>
<td>12.20</td>
<td>22.64</td>
<td>492.49</td>
</tr>
</tbody>
</table>

Where, AR = Apparent recovery; PE = physiological efficiency; AUE = Agronomic fertilizer use efficiency

The small number of grain and straw nutrient concentration and uptake of P might be due to the P fixation by acidity, and Al toxicity of the experimental site. Low available P of these soils could be one of the major soil fertility limiting factors in the study area, which limit the nutrient use efficiency of experimental site as was also confirmed by soil characterization of the studied area (Table 5). This result is line with (Kirsten, 2014), who found phosphorus availability to plants is determined by the chemical characteristics of the soil and the P fertilizer source.
The physiological efficiency of N and P were influenced by the application of blended fertilizer rates, types and recommended N and P (Table 18). The highest (114.22 kg kg\(^{-1}\)) and lowest (51.77 kg kg\(^{-1}\)) values of physiological efficiency of N were recorded at application rate of 150 kg NPSB + 110.8N kg ha\(^{-1}\) and 100 kg TSP & 200 kg Urea ha\(^{-1}\), respectively. Craswell and Godwin (1984) explained physiological efficiency of crop and they found high physiological efficiency on N usage cereal achieved when high portion of N taken up is used for grain formation. Physiological N use efficiency (Singh et al., 1998) or N use efficiency for grain production (Borrell et al., 1998) refers to the additional yield produced for each additional kg of fertilizer N uptake and is determined as the ratio of net grain yield produced due to the applied fertilizer to the net uptake from applied fertilizer N.

The highest (847.02 kg kg\(^{-1}\)) physiological efficiency of P at a blended fertilizer rate of 100 kg NPSB kg +73.9 N kg ha\(^{-1}\), mean while the lowest value of (431.92 kg kg\(^{-1}\)) was obtained at 150 kg TSP & 300 kg Urea ha\(^{-1}\) (Table 18). According to Dobermann (2005) the physiological efficiency values should commonly range between 30 to 60 kg kg\(^{-1}\). If the obtained results are above these common values, it could be concluded that the farm was under well managed system and the reverse is true, if the results obtained are below the common values. The physiological efficiency of the experimental site was above the common values for both N and P physiological efficiency. Generally the physiological efficiency of P was high as compared to N this might be due to relatively higher yield produced with low uptake of P as compared with N of uptake.
4.8.6. Agronomic fertilizer use efficiency of maize grain

Agronomic fertilizer use efficiencies of maize were influenced by blended fertilizer rates and recommended N and P (Table 17). The agronomic fertilizer use efficiency of maize was varied from 2.5 to 19.64 kg ha\(^{-1}\) at harvest stage of maize. The highest agronomic fertilizer use efficiency (19.64 kg kg\(^{-1}\)) was obtained under application of 100 kg NPSB + 73.9 N, while minimum value of agronomic fertilizer use efficiency (2.5 kg kg\(^{-1}\)) was recorded from 100% recommended N and P. Therefore, it seems that recommended N and P could not be an adequate application level regarding nourishing of this hybrid maize, perhaps due to limitation in the numbers of essential nutrients applied.

Karim and Ramasamy (2000) suggested that higher fertilizer use efficiency which is always associated with low fertilizer rate, cultural practices meant for 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 use of nutrient and by decreasing nutrient losses from the soil-plant system. The blended fertilizer applied improved agronomic fertilizer use efficiency by 682.47% as compared to recommended N and P fertilizers.

Mengel et al. (2006) agronomic fertilizer use efficiency value for a nutrient should not be less than 5. This result therefore shows that the rates of recommended N and P of studied ranged from 2.51 to 4.7 kg kg\(^{-1}\) which is less than the minimum standard AE according to Mengel et al. (2006). Values of AE were lower than 5 for recommended N and P that may be due to nutrient imbalance of recommended N and P and this indicates that higher rate of N and P were not well utilized though a limiting nutrient. On the other hand, the agronomic efficiency for blended fertilizer types and rates of studied area were within the optimum rage (12.54 to
19.64 kg kg\(^{-1}\)). This result is similar with (Dobermann, 2005) who reported that agronomic fertilizer use efficiency should be within the ranges of 10 to 30 kg kg\(^{-1}\).

4.8.7. Association of nutrient uptake and recovery with maze grain

The analysis of simple correlation showed that certain nutrient uptake and recovery was positively and significantly associated with grain yield of maize. Grain yield was positively and strongly correlated with grain N uptake (r=0.95**), grain P uptake (r=0.93**), grain S uptake (r=0.92**), recovery of N (r=0.69**) and recovery of P (r=0.69**) in a grain (Table 17). This form of relationship is an indication of the high contribution of N, P and S uptake, and their recovery through fertilizer application in influencing growth and increasing grain yield. While potassium grain uptake had positive and non-significant (r = 0.35\(^{ns}\)) relation with grain yield of maize.

Similarly correlation coefficient had showed highly significantly and positively strong association of P recovery with K grain uptake (r=0.59**), N grain uptake (r= 0.61**), P grain uptake (r= 0.68**), S grain uptake (r= 0.69**) and N recovery (r=0.87**). N recovery had strong and positive correlation with grain N uptake (0.6**), grain P uptake (0.55**) and grain S uptake (0.67**), respectively. However, it had positive and non-significant coloration with grain K uptake (0.25\(^{ns}\)). Grain S uptake showed positively strong correlation with grain N uptake (r= 0.90**) and p uptake (r= 0.85**) respectively, while it had positive and non-significant with grain K uptake.
Table 17. Association of simple correlation of nutrient uptake and recovery with grain yield of maize.

<table>
<thead>
<tr>
<th></th>
<th>GKU</th>
<th>GNU</th>
<th>GPU</th>
<th>GSU</th>
<th>RN</th>
<th>RP</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNU</td>
<td>0.44ns</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPU</td>
<td>0.6**</td>
<td>0.97**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GSU</td>
<td>0.22ns</td>
<td>0.90**</td>
<td>0.85**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RN</td>
<td>0.25ns</td>
<td>0.60**</td>
<td>0.55**</td>
<td>0.67**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>RP</td>
<td>0.59**</td>
<td>0.61**</td>
<td>0.68**</td>
<td>0.62**</td>
<td>0.87**</td>
<td>1</td>
</tr>
<tr>
<td>GY</td>
<td>0.35ns</td>
<td>0.95**</td>
<td>0.93**</td>
<td>0.92**</td>
<td>0.69**</td>
<td>0.69**</td>
</tr>
</tbody>
</table>

Where, GKU = grain potassium uptake GNU = grain nitrogen uptake, GPU, = grain phosphorous uptake, GSU = grain sulfur uptake, RN = recovery of nitrogen, RP = recovery of phosphorous and GY= grain yield and ** = P- value at ≤ 0.01.

4.9. Partial Budget Analysis

The net benefit curve is allows to mark out an efficient set of technologies for recommendation. The application of 150 kg NPSB + 110.8N kg ha⁻¹ had the highest net-benefit of 32321.4 ETB, followed by 200 kg NPSZnB + 150.2 N, 150 kg NPSZnB + 112.6 N, 200 kg NPSB + 147.8 N and 100 kg NPSB +73.9 N kg ha⁻¹ which also had a total of 31,845.6, 30,478.1, 29,430.5 and 27,945.7 ETB net benefit respectively. The lowest net benefit was obtained by the application of the 100% recommended N and P with total of 14,891 ETB followed by 125% recommended nitrogen and phosphorous and control with net benefit of 15,528.5 and 16,080 ETB the respectively. Furthermore 150% recommended nitrogen and phosphorous also had lower net benefit of 16,595.5ETB. The increased production of the crop due to the application of inputs might or might not be beneficiary to farmers (CIMMYT, 1988). Therefore, partial budget analysis (CIMMYT, 1988) was employed to estimate the net benefit, dominance analysis and marginal rate of return that could be obtained from various alternative treatments (CIMMYT, 1988). The profitability of
the study showed that application of 150 kg NPSB + 110.8N kg ha\(^{-1}\) and 150 kg NPSZnB + 112.6 N kg ha\(^{-1}\) which provided the relatively high net benefit (32,321.4 and 30,478.1ETB) respectively, was the peak to apply fertilizers. The total costs that vary increased over the optimum level, the net benefit obtained reduced as the result of higher variable costs associated with lower earnings.

Table 18. Partial Budget Analysis of blended fertilizer application rates and types on maize at Asossa Zone

<table>
<thead>
<tr>
<th>Treatments</th>
<th>VC (ETB ha(^{-1}))</th>
<th>Yield kg ha(^{-1})</th>
<th>GR (ETB ha(^{-1}))</th>
<th>TGR (ETB ha(^{-1}))</th>
<th>NB (ETB ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Straw</td>
<td>Grain</td>
<td>Straw</td>
<td>Grain</td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>0</td>
<td>4400</td>
<td>2996</td>
<td>1100</td>
<td>14980</td>
</tr>
<tr>
<td>T2</td>
<td>3,073</td>
<td>5019</td>
<td>3342</td>
<td>1254</td>
<td>16710</td>
</tr>
<tr>
<td>T3</td>
<td>3622.5</td>
<td>5227</td>
<td>3569</td>
<td>1306</td>
<td>17845</td>
</tr>
<tr>
<td>T4</td>
<td>4639.5</td>
<td>5762</td>
<td>3959</td>
<td>1440</td>
<td>19795</td>
</tr>
<tr>
<td>T5</td>
<td>2721.3</td>
<td>6870</td>
<td>5790</td>
<td>1717</td>
<td>28950</td>
</tr>
<tr>
<td>T6</td>
<td>3937.6</td>
<td>7776</td>
<td>6863</td>
<td>1944</td>
<td>34315</td>
</tr>
<tr>
<td>T7</td>
<td>5106.5</td>
<td>6871</td>
<td>6564</td>
<td>17178</td>
<td>32820</td>
</tr>
<tr>
<td>T8</td>
<td>2825.6</td>
<td>6524</td>
<td>5473</td>
<td>1631</td>
<td>27365</td>
</tr>
<tr>
<td>T9</td>
<td>3971.9</td>
<td>7020</td>
<td>6539</td>
<td>1755</td>
<td>32695</td>
</tr>
<tr>
<td>T10</td>
<td>5293.4</td>
<td>7439</td>
<td>7056</td>
<td>1859</td>
<td>35280</td>
</tr>
</tbody>
</table>

N. B: Prices - Urea= 8.24 birr/kg, NPSB = 11.02, NPSZnB = 11.7, TSP=12.75 birr/kg, Price of Maize=5 birr/kg, Price of straw= 0.25 birr/kg, Seed=10 birr/kg & Labor cost =30 birr/person/day for 8 hours, TC=Total cost, Gross return (Return from Grain & straw yield) = price /kg\(^{*}\) yield in kg and Net return = gross return – Total cost, VC = variable cost, GR= growth return, TGR = total growth return from straw and grain, NB = net benefit.
Figure 3. Net benefit curve of maize as influenced by blended fertilizer types and rates in Asossa district

4.9.1. 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 (CIMMYT, 1988). The % MRR between any pair of undominated 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 19. Dominance analysis of blended fertilizer and recommended N and P application in Asossa district during 2016/17.

<table>
<thead>
<tr>
<th>Treatments (Nutrient ha⁻¹)</th>
<th>VC(ETB ha⁻¹)</th>
<th>NB(ETB ha⁻¹)</th>
<th>MRR%</th>
<th>B:C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>16080</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>100 Kg NPSB + 73.9 N</td>
<td>2721.3</td>
<td>27945.7</td>
<td>436.0</td>
<td>10.3</td>
</tr>
<tr>
<td>100 Kg NPSZnB + 75.1 N</td>
<td>2825.6</td>
<td>26170.4</td>
<td>D</td>
<td>9.3</td>
</tr>
<tr>
<td>100 Kg TSP &amp; 200 Kg Urea</td>
<td>3,073</td>
<td>14891.0</td>
<td>D</td>
<td>4.8</td>
</tr>
<tr>
<td>125 Kg TSP &amp; 250 Kg Urea</td>
<td>3622.5</td>
<td>15528.5</td>
<td>D</td>
<td>4.3</td>
</tr>
<tr>
<td>150 Kg NPSB + 110.8N</td>
<td>3937.6</td>
<td>32321.4</td>
<td>5329.4</td>
<td>8.2</td>
</tr>
<tr>
<td>150 Kg NPSZnB + 112.6 N</td>
<td>3971.9</td>
<td>30478.1</td>
<td>D</td>
<td>7.7</td>
</tr>
<tr>
<td>150 Kg TSP &amp; 300 Kg Urea</td>
<td>4639.5</td>
<td>16595.5</td>
<td>D</td>
<td>3.6</td>
</tr>
<tr>
<td>200 Kg NPSB + 147.8 N</td>
<td>5106.5</td>
<td>29430.5</td>
<td>D</td>
<td>5.8</td>
</tr>
<tr>
<td>200 Kg NPSZnB + 150.2 N</td>
<td>5293.4</td>
<td>31845.6</td>
<td>D</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Where VC = variable cost, NB = net benefit, MRR% = marginal rate of return, D = dominated, B:C ratio = benefit cost ratio.

The dominance analysis showed that the net benefit of all treatments were dominated except application of 100 kg NPSB + 73.9 N kg ha⁻¹ and 150 kg NPSB + 110.8N kg ha⁻¹ (Table 20). This result indicated that the net benefit was decreased as the total cost that varies increased beyond undominated fertilizer treatments application. Therefore, no farmer may choose other dominated treatments in comparison with the undominated treatments. This also helps to avoid the dominated treatment in further estimate of marginal rates of return.
4.9.2. Marginal rate of return

Economic analysis revealed that maximum marginal rate of return was recorded with application of 150 kg NPSB + 110.8 N kg ha\(^{-1}\) (5329.4\%), followed by 100 kg NPSB +73.9 N kg ha\(^{-1}\) (436.0\%). The marginal rates of those treatments were well above the 100\% minimum (CIMMYT, 1988). According to CIMMYT (1988) experience and empirical evidence, for the majority of situations indicated that the minimum rate of return acceptable to farmers would be between 50 and 100\%. In the present study the treatments that had above 100\% marginal rate return was recommended for the farmers, with treatments that had small number of variable cost. This treatment was 150 kg NPSB + 110.8 N kg ha\(^{-1}\).

The % MRR between any pair of undominated treatments denotes the return per unit of investment in fertilizer expressed as a percentage. The results of undominated treatments indicated that for each one birr invested in purchase or production of fertilizers that was possible to recover one birr plus an extra of 4.36 birr ha\(^{-1}\) and 53.29 birr ha\(^{-1}\) as the fertilizer application changed from unfertilized plot to 100 kg NPSB +73.9 N kg ha\(^{-1}\) and 150 kg NPSB + 110.8N kg ha\(^{-1}\) respectively. Passing from the first treatment that had the lowest costs that vary to the end treatment which had the highest cost that vary, the marginal rate of return obtained was above the minimum acceptable marginal rate of return. In this study, 100\% was considered as minimum acceptable rate of return for farmers” recommendation. Accordingly, the study revealed that application of 150 kg NPSB + 110.8N kg ha\(^{-1}\) was considered as the best for recommendation. The best recommendation for treatments subjected to marginal rate of return is 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 tentative recommendation (CIMMYT, 1988).
Table 20. Marginal rate of return analysis of blended fertilizer and recommended N and P application for maize in Asossa district during 2016/17.

<table>
<thead>
<tr>
<th>Treatments (Nutrient ha⁻¹)</th>
<th>VC(ETB ha⁻¹)</th>
<th>NB(ETB ha⁻¹)</th>
<th>MRR%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>16080</td>
<td>0</td>
</tr>
<tr>
<td>100 Kg NPSB +73.9 N</td>
<td>2721.3</td>
<td>27945.7</td>
<td>436.0</td>
</tr>
<tr>
<td>150 Kg NPSB + 110.8N</td>
<td>3937.6</td>
<td>32321.4</td>
<td>5329.4</td>
</tr>
</tbody>
</table>

Where VC = variable cost, NB = net benefit, MRR% = marginal rate of return, D = dominated, B:C ratio = benefit cost ratio.
5. SUMMARY AND CONCLUSIONS

In recent years, crop productivity in Ethiopia in general and in Benshal-gul Gumuz region in particular has shown a declining trend, in spite of the best use of improved varieties. The most possible causes of this decline is soil fertility depletion and the continuous use of the traditional fertilizer, which have limited number of essential plant nutrient. In addition, due to high rainfall, soil erosion is a severe problem in sloping areas where vegetative cover is very low. Therefore the study was designed to determine the response of growth, yield and nutrient use efficiency of maize (Zea mays L.) to different blended fertilizer rates and types in Asossa district. The present study was conducted in Benishangul Gumuz Regional State, at Asossa Agricultural Research Center station in the 2016/2017 main cropping season under rain fed field conditions.

Two soil pedons were opened from adjacent land uses (uncultivated and cultivated) to characterize and classified the soil of study area. Accordingly, both pedons had low base saturation (less than 50 percent) in all of its parts between 20 cm and 100 cm from the soil surface and qualified for dystric concept at the subunit level. It also had a humic soil property which is having organic carbon content of greater than 1 percent as weighted average over a depth of 100cm from the soil surface and recognized meeting a humic qualifier at third unit level of classification. Therefore, soils represented by both pedons were classified as Humic-dystric Nitisols.

Application of blended fertilizers hastened days to tasseling silking and maturity by 10, 7 and 15 days, respectively as compared to N and P combined supply. Application of blended fertilizer had significantly affected the plant height and ear height as compared N and P combined supply and the control. Application of blended fertilizer increases the cob weight
by 128.2% over the control plot while non-significant difference was observed between the blended fertilizer formulas. The analysis of variance of treatment on ear length, 100 kernels weight, number of kernels per row revealed highly significant (P≤ 0.01) difference among fertilizer rates and types.

The fertilizer rates and types on biological yield, grain yield, straw yield and harvest index revealed highly significant difference (P≤ 0.01), however there was no significant differences between the two blended fertilizer types. Maximum grain yield 7056.2 kg ha⁻¹ was recorded with T10 (200 kg NPSZnB + 150.2 N), while minimum grain yield 2996.0 kg ha⁻¹ was recorded from control treatment. This maximum grain yield was followed by T6, T7 and T9 with corresponding grain yield of 6863.4, 6563.8 and 6538.7 kg ha⁻¹ respectively, where these treatments were statistically at par with each other. The maximum maize straw was recorded with T6 (7886.7 kg ha⁻¹), while minimum value (4400.9 kg ha⁻¹) was recorded with control treatment. Accordingly, the study revealed that application of 150 kg NPSB + 110.8N kg ha⁻¹ and 150 kg NPSZnB + 112.6 N kg ha⁻¹ as the best rates recommended for maize production at Assosa area.

Blended fertilizer had improved nutrient concentration, uptake, agronomic efficiency, physiological efficiency and apparent recovery of maize as compared to recommended N and P. The improvements of uptake and nutrient use efficiency of maize by blended fertilizer might be due to the contribution of macro and micro nutrients present in blended fertilizer. Improving nutrient efficiency is an appropriate goal for all involved in agriculture, and the fertilizer industry, with the help of agronomic studies at different agro-ecologies. However, effectiveness cannot be sacrificed for the sake of efficiency. Much higher nutrient efficiencies could be achieved simply by sacrificing yield, but that would not be economically effective
or viable for the farmer, or the environment. The profitability of the study showed that application of 150 kg NPSB kg + 110.8N and 150 kg NPSZnB + 112.6 N kg which provided relatively high net benefit (32321.4 and 30,478.1ETB) was the best rates to apply. Marginal rate of analysis from undominated treatments indicated that for each one birr invested in purchase or production of fertilizers that was possible to recover one birr plus an extra of 4.36 birr ha⁻¹ and 53.29 birr ha⁻¹ as the fertilizer application changed from unfertilized plot to 100 kg NPSB +73.9 N kg ha⁻¹ and 150 kg NPSB + 110.8N kg ha⁻¹ respectively.

The best recommendation for treatments subjected to marginal rate of return is 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 high net benefit, relatively low variable cost together with an acceptable MRR becomes the tentative recommendation. Therefore we recommend the treatments (150 kg NPSB + 110.8N kg ha⁻¹ ) that have high marginal rate of return, high net benefit and relatively small total cost of production for maize production in Asossa zone. But based on yield data, net benefit and relatively small total cost of production the farmer of Asossa district can also use 150 kg NPSZnB + 112.6 N when NPSB formula were not available on the market. The rate of sulfur in the blended fertilizer was less than the requirement for cereal crop and the blending fertilizer company must work toward balancing the ratio of sulfur with other macronutrient. The exchangeable potassium of Asossa area is below the critical level and will be corrected only by application of potassium fertilizer, so potash fertilizer are needed to address the key nutrient deficiencies in the tested soils. However, since the experiment was conducted only for one season and one site, repeating the trial at different sites as well as in the same trial site would be important in order draw sound recommendation.
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Appendix table 1. Description of the soil site and soil pedon opened at cultivated research farm of profile NO.2.

- **Location:** Asossa, Amba12 /Asossa
- **Coordination:** N 10° 2’ 30’’ E 34° 34’ 18’’
- **Soil type:** Humic-dystric Nitisols
- **Surrounding land form:** Medium gradient Hill
- **Slope and Position:** middle slop or back slop
- **Elevation:** 1546m above sea level
- **Drainage:** Well drained
- **Land use/vegetation:** Crop Agriculture, mixed farming and fallow land
- **Moisture condition:** Moist
- **Erosion**
  - a. At site: Medium
  - b. surrounding: Strong
- **Described by:** Bakala Anbessa

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth(cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0-20</td>
<td>Dark redish brown (5 YR 2.5/1 ) moist and dark redish brown (2.5 YR 2.5/2) dry; heavy clay; Structure one moderately very coarse granular, structure2 strongly coarse granular; dry slightly hard, moist very firm; sticky; plastic; many medium roots; gradual smooth boundary.</td>
</tr>
<tr>
<td>AB</td>
<td>20-45</td>
<td>Dusky red (10 R 3/3) moist and dusky red (10 R 3/3) dry; clay; structure one moderately very coarse granular; structure two moderately coarse granular; dry soft; moist very friable; very sticky; very plastic; few very fine roots; clear smooth boundary.</td>
</tr>
<tr>
<td>Bt₁</td>
<td>45⁺</td>
<td>Dark redish brown (2.5 YR 2.5/3 ) moist and dark red (2.5 YR 3/6) dry; heavy clay; structure one weakly very coarse prismatic; structure two moderately fine angular blocky; dry soft; moist very friable; very sticky; very plastic; few very fine roots.</td>
</tr>
</tbody>
</table>
Appendix table 2. Description of the soil site and soil profile opened at uncultivated research farm of profile NO.1.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth(cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap</td>
<td>0-20</td>
<td>Reddish black (2.5YR 2.5/1) moist and dark reddish brown (2.5YR 3/3) dry; loam; Structure one strongly very coarse, structure2 strongly coarse granular; dry very hard, moist very hard; slightly sticky and plastic; medium common pores; many medium roots; gradual smooth boundary.</td>
</tr>
<tr>
<td>AB</td>
<td>20-45</td>
<td>very dusk red (2.5 YR 2.5/2) moist and dusky red (10 R 3/3) dry; clay; structure one moderately coarse granular; structure two moderately coarse granular; dry friable, moist very friable; very sticky, very plastic; common fine roots; clear smooth boundary.</td>
</tr>
<tr>
<td>Bt1</td>
<td>45-100</td>
<td>dusky red (10 R 3/4) moist and dark red (2.5 YR 3/6) dry; heavy clay; structure one weakly very coarse prismatic; structure two moderately fine angular blocky; dry soft, moist very friable; very sticky, very plastic; medium common pores; common fine roots; clear smooth boundary.</td>
</tr>
<tr>
<td>Bt2</td>
<td>100*</td>
<td>dark redish brown (2.5 YR 3/4) moist and finally to red (2.5 YR 4/6) dry; heavy clay; structure one weakly very coarse prismatic; structure two moderately fine angular blocky; dry hard, moist firm; very sticky, very plastic; few very fine roots.</td>
</tr>
</tbody>
</table>
### Appendix table 3. Soil morphological characteristics of the pedons in the study area.

<table>
<thead>
<tr>
<th>Profile No.</th>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Boundary</th>
<th>Roots</th>
<th>Drainage</th>
<th>Biological activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>0-20</td>
<td>Diffuse</td>
<td>Smooth</td>
<td>Medium</td>
<td>Many</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Few</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Termite Ants</td>
</tr>
<tr>
<td></td>
<td>BA</td>
<td>20-35</td>
<td>Gradual</td>
<td>Smooth</td>
<td>Fine</td>
<td>Common</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Few</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Termite Ants</td>
</tr>
<tr>
<td></td>
<td>Bt1</td>
<td>35-100</td>
<td>Gradual</td>
<td>Smooth</td>
<td>Fine</td>
<td>Common</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Few</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Termite</td>
</tr>
<tr>
<td></td>
<td>Bt2</td>
<td>100+</td>
<td>Fine</td>
<td>Very few</td>
<td>Well drained</td>
<td>Few</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Termite</td>
</tr>
<tr>
<td>P2</td>
<td>A</td>
<td>0-20</td>
<td>Diffuse</td>
<td>Smooth</td>
<td>Medium</td>
<td>Many</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Few</td>
</tr>
<tr>
<td></td>
<td>BA</td>
<td>20-45</td>
<td>Gradual</td>
<td>Smooth</td>
<td>Fine</td>
<td>Very few</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Few</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Termite Ants</td>
</tr>
<tr>
<td></td>
<td>Bt</td>
<td>45+</td>
<td>Fine</td>
<td>Very few</td>
<td>Well drained</td>
<td>Few</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Termite</td>
</tr>
</tbody>
</table>
**Appendix table 4.** Analysis of variance showing mean squares for phonological and grow the traits of maize supplied with different blended fertilizer rate and types of application.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Df</th>
<th>DM</th>
<th>DS</th>
<th>DT</th>
<th>EH</th>
<th>PH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>3.33</td>
<td>3.33</td>
<td>3.33</td>
<td>24.61</td>
<td>87.15</td>
</tr>
<tr>
<td>Treatments</td>
<td>9</td>
<td>233.33**</td>
<td>120.00**</td>
<td>120.00**</td>
<td>531.90**</td>
<td>1402.14**</td>
</tr>
<tr>
<td>Error</td>
<td>18</td>
<td>3.33</td>
<td>3.333</td>
<td>3.33</td>
<td>96.70</td>
<td>362.66</td>
</tr>
</tbody>
</table>

CV% | 1.39 | 2.38 | 2.74 | 10.93 | 8.78 |

Where, DM = days to 50% maturity; DS = days to 50% silking; DT = days to 50% tasseling; EH = ear height; LN = leaf number per ten plants; PL = plant height. NS, *, ** and *** = non-significant, significantly different at 5%, 1%, and 0.1%, respectively.

**Appendix table 5.** Analysis of variance showing mean squares for yield and yield components of the traits maize supplied with different blended fertilizer rate and types of applications.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Df</th>
<th>CD</th>
<th>CW</th>
<th>EL</th>
<th>HSW</th>
<th>NCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>0.08066</td>
<td>314551</td>
<td>0.44433</td>
<td>1.1420</td>
<td>0.02033</td>
</tr>
<tr>
<td>Treatments</td>
<td>9</td>
<td>0.08706ns</td>
<td>1.381E+07***</td>
<td>5.86978**</td>
<td>22.5164**</td>
<td>0.00237 **</td>
</tr>
<tr>
<td>Error</td>
<td>18</td>
<td>0.11943</td>
<td>365182</td>
<td>1.41989</td>
<td>6.1877</td>
<td>0.00404</td>
</tr>
</tbody>
</table>

CV% | 11.12 | 8.32 | 8.61 | 5.66 | 5.54 |

Where, CW = cob weight; CD = cob diameter; EL = ear length; HSD = hundred seed weight; NCP = number of cob per plant. NS, *, ** and *** = non-significant, significantly different at 5%, 1%, and 0.1%, respectively.
Appendix table 6. Analysis of variance showing mean squares for yield and yield components of the traits maize supplied with different blended fertilizer rate and types of applications.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Df</th>
<th>NCR</th>
<th>NRC</th>
<th>BY</th>
<th>HI</th>
<th>SY</th>
<th>GY</th>
<th>CV%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>1.1373</td>
<td>0.55033</td>
<td>1635668</td>
<td>0.01281</td>
<td>2517614</td>
<td>171853</td>
<td>9.90</td>
</tr>
<tr>
<td>Treatments</td>
<td>9</td>
<td>40.3911**</td>
<td>0.28504ns</td>
<td>1.643E+07**</td>
<td>0.00407**</td>
<td>1751786**</td>
<td>7597403**</td>
<td>2.95</td>
</tr>
<tr>
<td>Error</td>
<td>18</td>
<td>9.9855</td>
<td>0.19404</td>
<td>421175</td>
<td>0.00090</td>
<td>171430</td>
<td>195626</td>
<td>6.85</td>
</tr>
</tbody>
</table>

CV% 9.90 2.95 6.85 5.50 9.72 8.48

Where, BY = biological yield; NCR = number of cornels per row; NRC= number of row per cornels; SY = straw yield; GY = grain yield; HI = harvest index . NS, *, ** and *** = non-significant, significantly different at 5%, 1%, and 0.1%, respectively.

Appendix table 7 The annual rainfall, maximum and minimum temperature of experimental area during 2017

<table>
<thead>
<tr>
<th>Month</th>
<th>Rainfall</th>
<th>Maximum temperature</th>
<th>Minimum temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0</td>
<td>32.5</td>
<td>11.2</td>
</tr>
<tr>
<td>February</td>
<td>0</td>
<td>29.8</td>
<td>13.2</td>
</tr>
<tr>
<td>March</td>
<td>18.2</td>
<td>33.2</td>
<td>13.8</td>
</tr>
<tr>
<td>April</td>
<td>50</td>
<td>29.5</td>
<td>14.2</td>
</tr>
<tr>
<td>May</td>
<td>131.9</td>
<td>23.5</td>
<td>14.4</td>
</tr>
<tr>
<td>June</td>
<td>270.4</td>
<td>23.5</td>
<td>13.3</td>
</tr>
<tr>
<td>July</td>
<td>178.8</td>
<td>23.9</td>
<td>15.9</td>
</tr>
<tr>
<td>August</td>
<td>241.6</td>
<td>23.7</td>
<td>15.8</td>
</tr>
<tr>
<td>September</td>
<td>333.8</td>
<td>25.5</td>
<td>15.5</td>
</tr>
<tr>
<td>October</td>
<td>154.7</td>
<td>25.9</td>
<td>15.5</td>
</tr>
<tr>
<td>November</td>
<td>1.6</td>
<td>27.5</td>
<td>12.6</td>
</tr>
<tr>
<td>December</td>
<td>0</td>
<td>30.5</td>
<td>12.3</td>
</tr>
</tbody>
</table>
Appendix figure 1. Blended fertilizer type of Amba 12 kebele and Asossa Woreda