EFFECTS OF BLENDED NPSB FERTILIZER RATES ON SELECTED SOIL PROPERTIES, YIELD AND YIELD COMPONENTS OF MAIZE (Zea *mays* L.) AT BANSHURE KEBELE IN BEDELE DISTRICT, SOUTH WESTERN ETHIOPIA

MSc THESIS

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MAY 2022
HARAMAYA UNIVERSITY, HARAMAYA

Effects of Blended NPSB Fertilizer Rates on Selected Soil Properties, Yield and Yield Components of Maize (*Zea mays* L.) at Banshure Kebele in Bedele District, South Western Ethiopia

A Thesis Submitted to the School of Natural Resources Management and Environmental Sciences, Postgraduate Program Directorate
HARAMAYA UNIVERSITY

In Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN AGRICULTURE (SOIL SCIENCE)

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May 2022
Haramaya University, Haramaya

APPROVAL SHEET

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This is to certify that we have read and evaluated the Thesis entitled ***“Effects of Blended NPSB Fertilizer Rates on Selected Soil Properties, Yield and Yield Components of Maize (Zea mays L.) at Banshure Kebele in Bedele District, South Western Ethiopia”,*** which is prepared under our guidance by Dechasa Mengistu Adugna. We recommended that it be submitted as fulfilling the Thesis requirements.

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As members of the Board of Examiners of the MSc Thesis Open Defense Examination, we certify that we have read and evaluated the Thesis prepared by Dechasa Mengistu Adugna and examined the candidate. We recommend that the Thesis be accepted as fulfilling the Thesis requirements for the degree of Master of Science in Soil Science.

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Final approval and acceptance of the Thesis is contingent upon the submission of the final copy of the Thesis to the Council of Graduate Studies (CGS) through the School Graduate Committee (SGC).

DEDICATION

I dedicate this Thesis to my father Mengistu Adugna and my mother Isey Gerbu for their incomparable support during my study from the beginning up to now.

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STATEMENT OF THE AUTHOR

I declare that this Thesis is my genuine work and that all sources of materials used for the preparation of this Thesis have been profoundly acknowledged. This Thesis has been submitted in partial fulfillment of the requirements for Master of Science (MSc) in soil science at Haramaya University and is to be deposited in the Haramaya University library and is made available for users under the rules of the library. I solemnly declare that this Thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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BIOGRAPHICAL SKETCH

The author was born on September 12, 1982 at Nunu Gondini Kebele, Wera Jarso district, North Shewa Zone, Oromia Regional State, Ethiopia. He attended his elementary, secondary and preparatory education at Meliyu Hamusi, Tulu Milki and Gerba Guracha schools respectively. After passing the Ethiopian General Secondary Education Certificate Examination (EGSECE), he joined Aksum University in 2003 E.C and graduated with the Degree of Bachelor of Science in soil resource and watershed management in July 2005.

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ACKNOWLEDGMENTS

Above all, I am grateful to the almighty God for His blessings and keeping my spirit up even in most difficult situations. My deepest thanks go to Dr. Lemma Wogi, my major advisor for his sustained and educative guidance, unreserved advice, suggestion and collaboration. His constructive comments, exemplary supports and professional involvement immensely contributed to the accomplishment from proposal preparation till complete write up of this Thesis. I also extended my heartfelt thanks to Dr. Abdissa Bekele, my co-advisor, for his careful scrutiny during the preparation of the proposal, important comments during field research and for reviewing the Thesis.

I would like to acknowledge Oromia Agricultural Research Institute for funding field experiment and laboratory works. I also wish to express my thanks to Bedele Agricultural Research Center and its staff for their cooperation during the field work and Haramaya University for giving me the opportunity to join the graduate program. I am also grateful to Mr. Amanuel Kajela for his support during field data collection and laboratory work. Last but not least, I extend my thanks to Mr. Alemayehu Abdeta and Mr. Bati Dube for their friendship and sharing of knowledge and experiences, relentless support and encouragement throughout my study.

LIST OF ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectroscopy
ADD	Agricultural Development Department
ANOVA	Analysis Of Variance
ATA	Agricultural Transformation Agency
BARC	Bako Agricultural research center
BDAO	Bedele District Agricultural Office
BMES	Bedele Meteorological Station
CEC	Cation Exchange Capacity
CIMMYT	International Maize and Wheat Improvement Center
CSA	Central Statistical Agency
DAP	Di-ammonium Phosphate
DNA	Deoxyribonucleic Acid
ETB	Ethiopian Birr
Ethio-SIS	Ethiopian Soil Information System
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
GDP	Gross Domestic Product
GFB	Gross Field Benefit
ICARDA	International Center for Agricultural Research in the Dry Areas
LDMA	Livestock Development and Marketing Agency
LSD	Least Significance Difference
MRR	Marginal Rate of Return
NFIU	National Fertilizer Input Unit
OC	Organic Carbon
OM	Organic Matter
PBS	Percentage Base Saturation
RCBD	Randomized Complete Block Design
RNA	Ribonucleic Acid
SAS	Statistical Analysis System
SSA	Sub-Saharan Africa
TVC	Total Variable Cost
USDA	United State Development of Agriculture

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ABSTRACT

Soil test based fertilizer recommendation concurrent to the actual limiting nutrients for a given crop helps to supply adequate and balanced plant nutrients for sustainable crop production without affecting soil health negatively. Blended NPSB fertilizer is a newly introduced fertilizer for crop production in the study area. However their optimum rate for maize crop production and their impact on selected soil property is not yet determined in the study area. Therefore a study was conducted to investigate the effects of blended NPSB fertilizer rates on selected soil properties, maize yield and yield components in Bedele district at Banshure Kebele during the 2021main cropping season. The experiment was laid out in randomized complete block design (RCBD) with three replication of the treatments (0, 25, 50, 75, 100, 150, 200, 250 and 300 kg ha^{-1}*) of blended NPSB fertilizer rates supplemented with the recommended nitrogen rate for maize production in Bedele District. Selected soil properties before and after trial were analyzed following standard laboratory procedure at soil laboratory of Bedele Agricultural Research Center. Soil analytical results before planting indicated that, the soils of the research sites had clay textural class, are moderately acidic (5.48 and 5.47), medium in OC content (2.04 and 2.12%), had low TN (0.17 and 0.18%), medium available P (1.67 and 1.77 mg kg*$^{-1}$*), low available S (9.26 mg kg*$^{-1}$*), low available B (0.3 and 0.36 mg kg*$^{-1}$*), medium CEC (20.94 and 22.64 cmol (+) kg*$^{-1}$*) and very low PBS (16.85 and 16.29%), for Alle and Abu respectively. The analysis of variance indicated that, the blended NPSB fertilizer rate highly significantly affected soil pH, available phosphorus, available boron, available sulfur, maize growth, yield and yield components. Moreover, the result showed that economically feasible grain yield (7173.6 kg ha*$^{-1}$*) and net benefit (74897.58 ETB ha*$^{-1}$*) with highest marginal rate of return of 2957% were obtained from the plot treated with 150 kg ha*$^{-1}$* of blended NPSB fertilizer rate. Therefore, based on the result obtained from this study, application of 150 kg ha*$^{-1}$* of blended NPSB fertilizer rate and recommended nitrogen can be tentatively suggested as economically profitable for the production of maize at the study area.*

Keywords: *Blended fertilizer, Soil fertility, grain yield, Economical feasibility*

1. INTRODUCTION

Agriculture is one of the largest components of the Ethiopian economy that contributes 34% to the country's gross domestic product (GDP) and 71% to employment (ATA, 2019). Crop production contributes up to 72% to the total agricultural GDP and over 75% to total export earnings (ATA, 2019). Declining of soil fertility is one of the major factors that reduced agricultural productivity and food security in Ethiopia similar to many Sub-Saharan African (SSA) countries (Sanchez, 2002).

The soils of Ethiopian highlands are deficient in most macro- and micro-nutrients as well as in organic matter (Elias, 2016). One of the major problems negatively affecting crop productivity in Africa including Ethiopia is rapid depletion of nutrients in smallholder farms (Achieng *et al*., 2010). According to Tekalign *et al*. (2001), low availability of nitrogen (N) and phosphorus (P) has been demonstrated to be a major constraint to cereal production, whereby N is deficient in almost all soils and (P) is deficient in about 70% of the Ethiopian soils. Soil degradation and nutrient depletion further aggravated due to the use of unbalanced fertilizer forms and rates based on site specific and crop nutrient demand (Hussain *et al*., 2006). Nutrient mining due to sub-optimal fertilizer uses coupled with unbalanced nutrients, favored the emergence of multi nutrient deficiency in Ethiopian soils and resulted in stagnant crop productivity (Wassie and Shiferaw, 2011).

Maize is one of the world's leading cereals, ranking second in production after wheat (FAOSTAT, 2019). It is the major staple food crop and source of cash in Ethiopia (Abera *et al*., 2013). Maize is used in Ethiopia directly for human consumption as food or for the preparation of local drinks; In addition, maize leaves are used for animals feed and dry stalks are used as fuel and for the construction of fences (Akalu, 2015). Ethiopia is the third largest maize producer in Africa next to Nigeria and Egypt (FAOSTAT, 2017). In Ethiopia maize is the second in area coverage next to teff, with total land area of 10,478,217 hectare being under cereals, of which maize covered about 17.68% (2,274,305.93 hectares) (CSA, 2020); and it is the major cereal crop of the study area covering about 40 % of the total area under production in Bedele district (BDAO, 2021). Despite the large area under maize production, the current national productivity is about 4200 kg ha^{-1} (CSA, 2020), which is far below the worlds average productivity of 5800 kg ha^{-1} (FAOSTAT, 2019).

In Ethiopia, di-ammonium phosphate (DAP) and urea have been the only chemical fertilizers used for crop production with initial understanding that nitrogen and phosphorus are the major limiting nutrients of Ethiopian soils (Bekabil and Hassan, 2006). However, plant growth and crop production require adequate supply and balanced amounts of all nutrients, but the use of only urea and DAP have totally neglected the use of micronutrients (Mengel and Kirkby, 1996). Since deficiency of macro and micronutrients are reported in tropical soils thereby necessitating the application of nutrient sources that reduce such deficiencies (Hassan *et al*., 2010) this can only be achieved if fertilizers are suitable to the soil condition and the nutrient contents fits to the needs of the crops.

It is so important to increase the productivity of crops along with desirable attributes through improved 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 (Ethio-SIS, 2016). Moreover, according to soil fertility survey report maps (Soil fertility Atlas), the depletion of nitrogen, phosphorous, sulphur, and boron is widely spread in Bedele district (Ethio-SIS, 2016). To overcome this problem of nutrient deficiency, Ethio-SIS recommended fertilizers such as NPS, NPSB, NPSZn, NPSZnB, NPSFeZn, and NPSFeZnB for Oromia region in general and NPSB for the study area in particular (Ethio- SIS, 2016).

Based on such evidence, DAP is gradually being substituted by blended NPSB fertilizer for crop production in the study area (BDAO, 2021). Even though new blended fertilizers such as NPSB (18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B) are currently being used by the farmers in the study area, there is no any study conducted on the effects of newly introduced blended NPSB fertilizer in relation to soil properties, maize yield and yield components. Therefore, there is a need to evaluate their effect on fertility related soil properties and develop site specific recommendation of the fertilizer rates to increase production and productivity of crops in general and that of maize in particular as it is the major cereal crop of the study area and its surroundings. Therefore, this study was initiated with the general objective to determine the optimum rate of blended NPSB fertilizer that increases maize yields with amending soil fertility at Banshure Kebele of Bedele District, South Western Ethiopia.

Accordingly, the specific objectives of the study were:

- To assess the effects of blended NPSB fertilizer rates on selected soil physicochemical properties.
- To evaluate the response of maize yield and yield components to different rates of blended NPSB fertilizer.
- To identify economically feasible NPSB fertilizer rate for the study area.

2. LITERATURE REVIEW

2.1. Origin and Uses of Maize

Maize originated in the western Hemisphere according to Fast and Caldwell (2000), and it was domesticated by America. It is an annual crop of great importance that belong to the family poaceae, it is used as a source of carbohydrate for both human (in developing countries), and animal feed worldwide due to its high feeding value (Unidie *et al*., 2012). It has a wide range of industrial application (Pingali *et al.*, 2001). Green Maize (fresh on the cob) is eaten as parched, backed, roasted, or boiled and plays an important role in filling the hunger gap after the dry season and it is used for animal feed and construction in many parts of the country (Tolessa *et al*., 2002). It has the highest yield potential among the cereals, and known globally as queen of cereals. The largest producer of maize is United States of America (USA) contributing about 36% of the total world maize production (FAO, 2018).

2.2. Maize Production and its Constraints in Ethiopia

Maize is one of the most important cereal crops in Ethiopia, ranking second in area coverage and first in total production (CSA, 2020). Although it is one of the strategic crops for the achievement of food security in the country, more than 90% of the production is handled by small scale farmers under rain fed growing condition (CSA, 2020). About 40% of the total maize growing area is also located in rain fall deficit areas, were it contributes less than 20% to the total annual production (Mandefro *et al*., 2002).

The low yield in these areas, like other sub-Saharan African countries, is mainly attributed to recurrent drought, low levels of fertilizer use and low adoption of improved varieties (CIMMYT, 2010). Inherently infertile soils, lack of agricultural inputs and over-exploitation of soils through mono-cropping with little nutrient inputs are the major factors to the decline in agricultural productivity (Kanonge *et al*., 2009). The most limiting nutrients in such soils are phosphorus and nitrogen (Nhamo *et al*., 2003).

2.3. Nutrient Requirement of Maize

Fertilizer usage plays a great role in the universal need to increase food production to meet the demands of the growing world population (Mitiku, 2008). Macronutrients include nitrogen (N), phosphorous (P), potassium (K), sulphur (S), magnesium (Mg) and calcium (Ca), which are needed in large amounts, and sufficient quantities have to be applied if the soil is deficient in one or more of them (FAO., 2013). The micronutrients or trace elements are iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), chlorine (Cl), Nickel (Ni) and boron (B) (Fageria, 2009). Being taken up in minute amounts, their range of optimal supply is very small (FAO, 2013). Macro-nutrients as well as micronutrients are of primary importance in our agriculture system, but due to unawareness of the farmers about the importance of applying micronutrients and unavailability, the soils are becoming low in micronutrients (Muhammad *et al*., 2009). Micronutrients are essential for plant growth and play great role in increasing crop yields as they improve plant nutrition and soil efficiency (Hamzeh and Florin, 2013).

2.3.1. Nitrogen

Nitrogen is one of the most important nutrients that affect the yield, and yield quality of maize; it is one of the key nutrients that limit crop growth of cereals in many production systems (Dandan and Yan, 2013). In maize production, it is a major yield determining factor, and its availability in sufficient quantity throughout the growing season is essential for optimum maize growth (Kogbe and Adediran, 2003). The application of essential plant nutrients particularly N in optimum quantity and right proportion (3-4 splits) through correct methods and times of application is the key to increase and sustain crop production (Harwinder and Hari, 2017).

Tagesse and Alemayehu (2020) reported that, the increments in yield of maize with increasing N rates up to 92 kg ha^{-1} might be attributed to the effective role of N as an essential constituent of chlorophyll on dry matter accumulation. According to their investigation, nitrogen applied at the rate of 92 kg ha^{-1} enhanced maize productivity and produced the maximum grain yield per nitrogen unit increase, and showed greatest agronomic efficiency.

2.3.2. Phosphorous

Phosphorus makes up 0.1 to 0.4% of the dry matter of the plant (FAO, 2013). The formation of seeds and fruits is especially depressed in plants suffering from phosphorous deficiency; thus not only yield but also poor quality seeds and fruits are obtained from phosphorous deficient plants (Fageria, 2009). The availability of soil phosphorous is affected by soil reaction and amount of phosphorous as well as other factors (Tisdale *et al*., 2002). In high rain fall area phosphorus fixation is high, in such strongly phosphate fixing soils, pH correction is also recommended since phosphate adsorption is especially high at low pH levels (Tisdale *et al*., 2002). Most of the P present in soils is in unavailable forms, and added soluble forms of P are quickly fixed by many soils (Tisdale *et al*., 2002). Plants absorb P in the form of $HPO4^{-2}$ and H_2P04^{-1}, depending on the pH of the growing medium, there is no efficient mechanism in the soil to retain H_2PO4^{-1} and $HPO4^{-2}$ ions in large quantities as exchangeable anions (Barker and David, 2007).

Due to deficiency of phosphorous fertilizer in the soil, many plants seedlings look stunted and older leaves may turn purple because of the accumulation of anthocyanins or purple pigments, as the result of which plants may produce only one small ear containing fewer smaller kernels than usual, and may result in often severely reduced grain yield (Jones *et al*., 2003). Obsa *et al.* (2021) reported that plants require adequate P from very early stage of growth for optimum production, and depressed maize yields may encounter when P supply is inadequate over the entire maize growth period. Enhanced early-season P nutrition in maize increased the dry matter partitioning to the grain at later development stage (Obsa *et al*., 2021).

2.3.3. Sulphur

Sulphur (S) has long been recognized as an essential element for plant growth and development and is classified as a macronutrient, crop responses to applied S have been reported in a wide range of soils in many parts of the world (Fageria, 2009). Sulphur (S) is required in similar amount as that of Phosphorus, and constitutes 0.2 to 0.5% dry matter accumulation in crop tissue (Ali *et al*., 2008). Besides, it is involved in various metabolic and enzymatic processes including photosynthesis and respiration (Rao *et al*., 2001). Sulphur (S) is as important as nitrogen (Brady and Weil, 2002). As a result, adequate supply of S is needed in order for plants to use N. This is because both nitrogen (N) and sulphur (S) are building blocks in protein and a deficiency of either results in shortages of chlorophyll, Rubisco (the enzyme which changes CO_2 into sugar), and nitrate reductase (an enzyme which converts plant nitrate into ammonia) (Brady and Weil, 2002).

2.3.4. Boron

Boron (B) is an essential micronutrient for plants, and plant requirements for this nutrient are lower than the requirements for all other micronutrients except molybdenum and copper. It is the only non-metal among the micronutrients and also the only micronutrient present over a wide pH range as a neutral molecule rather than an ion (Epstein and Bloom, 2005). Boron is an essential element for better utilization of macro-nutrients by plants and there is greater translocation of photo-assimilates from source to sink during growth period (Ali *et al.*, 2013). Boron is also involved in the transport of sugars across cell membranes and in synthesis of cell wall material; and it influences transportation through the control of sugar and starch formation (Singh *et al.*, 2015).

Boron-deficiency symptoms first become evident on the younger leaves, which change color and become hardened, malformed and necrotic (Dursun *et al.*, 2010). Deficiency of boron can also cause reduction in crop yield and inferior crop quality (Singh *et al.*, 2015). Deficiency of B is widely distributed than any other micronutrient, affecting reproduction and lowering the yield of crops (Shukla *et al.*, 2015). It is thought to be the part of plant cell wall, acting as structural component for its stability and integrity (Bassil *et al.*, 2004).

2.4. Plant Nutrient Depletion in Ethiopia

The fertility status of Ethiopian soils has been declining and continued to pose a challenge to crop production (Tilahun, 2007). Several studies both in and outside Ethiopia has been carried out on the subject of plant nutrient depletion (Amare *et al.*, 2013). This is due to continuous cropping (abandoning of fallowing), absence of manure application, total removal of crop residues and animal dung for fuel purpose, and absence of soil conservation practices coupled with low inherent fertility of the soils (Tilahun, 2007). Due to their low organic matter content, most of the soils in Ethiopian have low total N content, and there is a high crop response to nitrogen (N) fertilizers (Attah, 2010). On account of rapid nitrification, most of the N added as fertilizer containing NH_4 is subject to de-nitrification and leaching soon after application, ammonium fixation also affects fertilizer efficiency (Abera *et al.*, 2012). Most Ethiopian soils are deficient in P when analyzed by chemical methods, yet, with the addition of phosphorus (P) fertilizers; particularly field crop phosphorus (P) responses on the soils of the central highlands are low, even under improved drainage conditions (Tekalign *et al.*, 2002) owing to unbalanced fertilization.

Different studies conducted in Ethiopia in the past few years by various researchers have demonstrated that, most of Ethiopian soils have a very low level of P due to depletion or P fixation (Lalisa *et al*., 2010). Nitrogen and phosphorus are the most limiting nutrients for crop production in sub-Saharan Africa (Bationo *et al*., 2003). Recent studies have showed that elements like N, P, K, S and Zn levels as well as B and Cu are becoming depleted, and deficiency symptoms are being observed on major crops grown in different parts of the country (ATA, 2013). Furthermore, studies show that most Ethiopian soils are deficient in macronutrients (N, P, K and S) and micronutrients (Cu, B, and Zn) (EthioSIS, 2014).

2.5. Importance of Fertilizer in Crop Production

The steadily increasing world population demands ever-increasing food production, one of the major problems limiting crop production worldwide is nutrient deficiency (Sanchez, 2002). As much as 50% of the increase in crop yields worldwide during the twentieth century was due to the adoption of chemical fertilizers (Fageria, 2009). In the twenty-first century, chemical fertilizers played a great role in enhancing crop yields, which were declining mainly due to nutrient depletion, limited land and water resources available for crop production (Fageria *et al.*, 2008a).

Low levels of essential plant nutrients can reduce crop production, so that all essential plant nutrients that can hold back crop growth must be tested and determined for specific locations to the choice of proper fertilizers and the determination of appropriate rates of fertilizers (Sanchez, 2002). The use of manufactured P, K, S, and micronutrient fertilizers in conjunction with N fertilizers in a balanced fertilization program is a key part of a total crop production system that increases crop yields, and sustains soil productivity (Alley and Vanlauwe, 2009). Fertilizer is considered the most important input for the achievement of increased agricultural productivity, and food security status of farm households in Ethiopia (Fufa and Hassan, 2006).

2.6. Effects of Inorganic Fertilizers on Physicochemical Properties of the Soil

The use of balanced fertilizers and additions of organic matter are necessary to restore soil fertility and achieve high crop productivity in degraded soils, these can be achieved through applications of manure, other organic materials, inorganic fertilizers, lime, inclusion of legumes and crop rotations in the cropping systems, or a combination of these (Taye and Yifru, 2010).

Inorganic fertilizers have been the important tools to overcome soil fertility problems, and they are also responsible for a large part of the food production increases worldwide (Sanchez, 2002). Fekadu *et al*. (2018) conducted the experiment on the effects of organic and inorganic fertilizer on soil physical and chemical properties and observed nitrogen increment after harvest than pre-experiment soil total nitrogen. Similarly, Ullah *et al.* (2008) reported that chemical fertilizer increased organic carbon than cattle manure.

Czarnecki and Düring (2015) also reported that, addition of chemical fertilizers to soil influences the chemical composition of soil solution. Messiga *et al.* (2013) indicated that organic carbon tends to rise with increased nitrogen application. Tewolde *et al.* (2020) reported that application of blended NPSB fertilizer significantly increased some chemical properties of the soil such as total nitrogen (0.12%), available phosphorous (8.10 mg kg^{-1}), exchangeable sulfur (4.6 mg kg^{-1}) and exchangeable boron (0.33 mg kg^{-1}) by the application of 300 kg ha^{-1} blended NPSB supplemented with 46 kg ha^{-1} of N fertilizer. Similarily, Zeleke *et al.* (2020) reported that, application of blended NPSB fertilizer with supplemental nitrogen significantly increased the soil organic carbon, total nitrogen, available phosphorous, available sulfur and available boron content of the soil. In addition, Melkamu (2020) also reported that, application of blended NPSB fertilizer significantly increased the available phosphorous, available sulfur, available boron, total nitrogen and organic carbon content of the soil.

2.7. Effects of Inorganic Fertilizers on Yield and Yield Components of Maize

2.7.1. Grain yield

Maize grain yield can be described as a function of the rate and duration of dry matter accumulation by the individual kernels multiplied by the number of kernels per plant (Aweke and Muhaba, 2021). In simple terms, maize grain yield is a product of the number of cobs produced, and the average weight of the grain on the cobs. Thus, anything that affects one or both of these factors will significantly affect the final yield (Aweke and Muhaba, 2021). According to Hashemi *et al*. (2005), grain yield per unit area is the product of grain yield per plant and number of plants per unit area.

Field experiment was conducted in 2018-19 main cropping season under rain fed conditions at Bako, Oromia National Regional State to determine the optimum blended fertilizer rates with different plant population (Fufa et *al*., 2019). They obtained the highest grain yield of 9717 kg ha^{-1} from application of 150 kg ha^{-1} of blended NPSB fertilizer with 92N kg ha^{-1} in split application (Fufa *et al*., 2019). The increment in grain yield with the blended fertilizer that contained both macro and micro nutrients may be also an indicator of low soil fertility level in the respective study area (Kumar *et al*., 2017).

The findings of Melkamu (2020) indicated that, application of 150% N and P from NPSB blended fertilizer with 46 kg ha^{-1} of N were higher in grain yield by 36% compared to farmer's practice. This is due to the optimum application of N, P and S and their role in energy provision for seed formation and grain filling (Melkamu, 2020). Another recent research was conducted in Kambata Tambaro, souther Ethiopia by Tagesse and Alemayehu (2020) to investigate the effect of blended NPS fertilizer level on maize grain yield, they reported that the application of 200 kg ha^{-1} of blended NPS with 92 kg ha^{-1} of N gave the highest (8680 kg ha^{-1}) grain yield, whereas the lowest (2097 kg ha^{-1}) grain yield was obtained from the control plot (Tagesse and Alemayehu, 2020). The yield increase with the rate of NPS might be because of the fact that phosphate application is particularly useful in promoting good root system, which could favor the best utilization of the mineral nutrients from the soil (Martins *et al*., 2017).

2.7.2. Days to tasseling and silking

In maize (*Zea mays L*.) tassel initiation is the first visible sign that a plant has shifted from the vegetative to the reproductive stage of development, maize crop accumulates more heat units (thermal time) to tasseling, silking and physiological maturity with increasing the rate of N and vice versa (Amanullah *et al*., 2009). Sufficient nitrogen results in rapid growth, and hastens tasseling, while too little or no N resulted in slow growth and delayed tasseling (Gungula *et al*., 2003). Application of blended fertilizer significantly decreased days to silking as compared to control; and similarly, recommended NP fertilizers also significantly decreased days to silking as compared to control (Dagne, 2016).

Bati and Achalu (2021) also reported the decrease in days to tasseling and silking of maize with increasing P fertilizer rates up to (69 P_2O_5 kg ha^{-1}) might be attribute to the effective role of higher fertilizer use of the crop that leads to accelerated growth and ultimately to early tasseling instead of lengthy vegetative growth. They reported the longest (84.3 days) to reach 50%

tasseling from the control plot and the shortest (81.8 days) to 50% tasseling from plot supplied with (69 P_2O_5 kg ha^{-1}). Similar to the 50% days to tasseling, the longest (91.3 dyas) to 50% silking was also reported from the control plot and the shortest (88.4 days) to silking was recorded at application of P fertilizer at the rate of 69 P_2O_5 kg ha^{-1}.

2.7.3. Number of cobs per plot

Number of cobs per plot is determined by prolific ability of the Maize variety (Adefris *et al*., 2015) and the growth behavior of the crop which is dependent upon management practices and climatic factor. Mehta *et al*. (2005) reported that application of 60 kg P_2O_5 gave more number of maize cobs as compared to 40 kg P_2O_5 and control, this value indicated that the plant supplied with sufficient nutrients capacitated to hold two or more number of cobs.

2.7.4. Plant height

Plant height is a genetic trait. Thus, the number and length of the internodes determine the height of the stalk. In this way, plant height by maize can vary from 0.3 m to 7.0 m, depending on the variety and growing conditions (Gyenes-Hegyi *et al*., 2002). Adane *et al.* (2020) reported that, application of blended NPSZnB significantly increased plant height compared to the control plot. They recorded the tallest plant height 218 cm of maize by the application of 300 kg $ha^{-1}$of NPSZnB with 350 kg ha^{-1} of urea, while the lowest 120 cm plant height was recorded on the control plot. This might be due to increase in cell elongation and more vegetative growth as the result of the different nutrient contents of NPSZnB blended fertilizer. On the other hand, the shortest plant height in unfertilized plots might have been due to the low soil fertility level in growing media (Adane *et al*., 2020).

Plant height increased as N increased; this could be attributed to a mere fact that higher rates of N may have caused rapid cell division and elongation (Gul *et al*., 2015). Plant growth and development is reduced if any of nutrient elements is less than its critical value in the soil or not properly balanced with fertilization. Kinfe *et al*. (2019) reported that, blended fertilizer significantly increased plant height as compared to recommended NP and control plot. Similarly, Besufikad and Tesfaye (2019) concluded that mean plant height of maize increased as the rate of blended fertilizer increased.

2.7.5. Above ground dry biomass

Aboveground dry biomass is the total weight of maize measured including cobs after sun-dried that can be affected by the types and rates of fertilizers applied to the soil. Dassalegn *et al.* (2018) reported significantly higher biomass yield of Maize at a rate of 46 kg N ha^{-1} under blended fertilizer of PKSZnB as compared to negative control, standard control (92 kg N ha^{-1} and 69 P_2O_5 kg ha^{-1}). Similarly, Kinfe *et al*. (2019) reported the highest aboveground dry biomass yield of maize from the plot treated with 250 kg ha^{-1}of blended NPSZnB fertilizer rate. Mekuanent and Kiya (2020) reported that, the mean dry biomass yield of maize was significantly higher with 130.5 kg ha^{-1} of nitrogen.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location

Field experiments were conducted at two sites of Banshure Kebele, in Bedele district of Buno Bedele Zone, South Western Ethiopia in 2021 main cropping season. Bedele district is located between 8°14'30" and 8°37'53"N, and 36°13'17" and 36°35'05"E (Figure 1). The district is located at 483 km away from Addis Ababa on the road to Mettu.

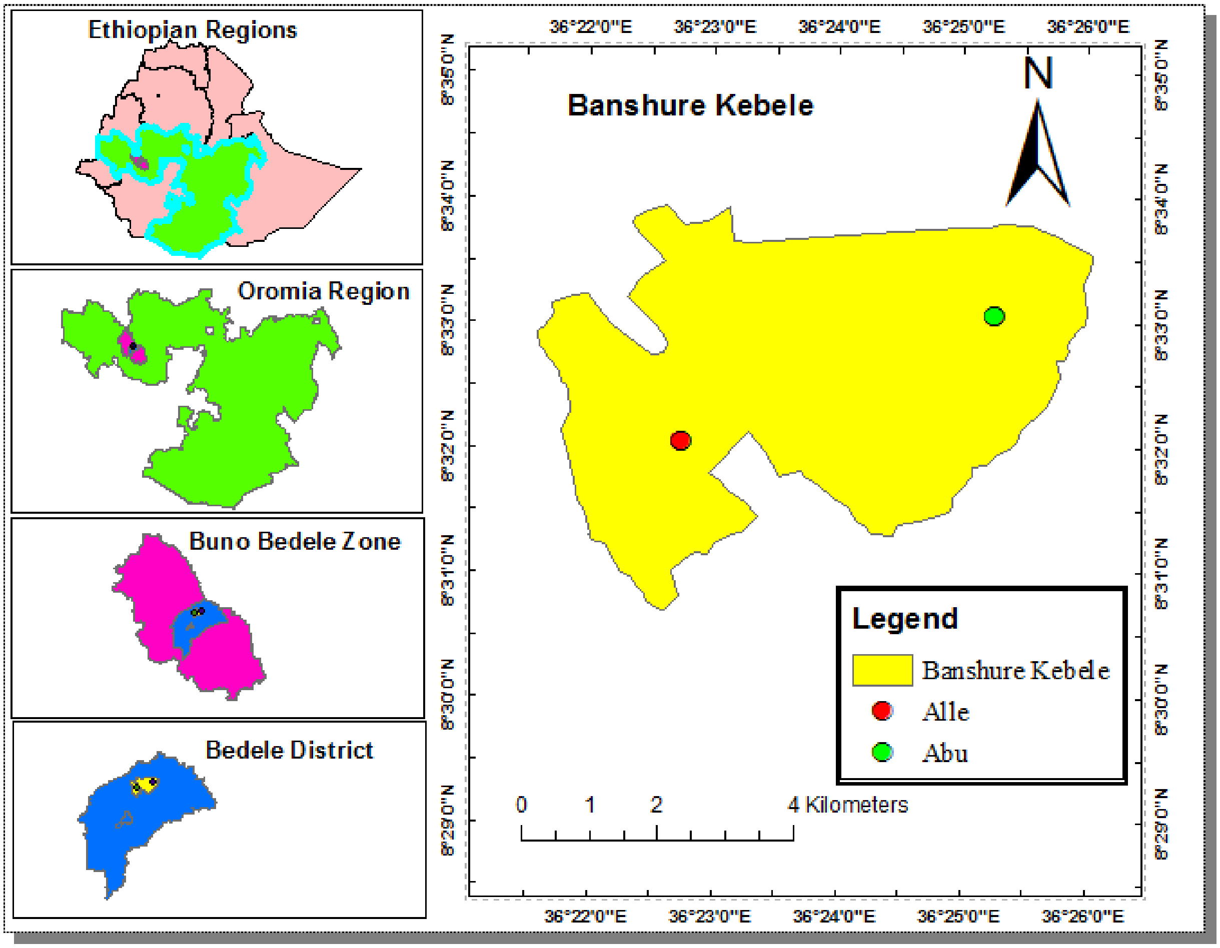

Figure 1: Location map of the study area

3.1.2. Climate

According to the sixteen-year (2005-2021) climate data recorded at Bedele Meteorological Station, the mean annual rainfall of the study area is 1942 mm and the mean monthly minimum and maximum temperature are 13 and 26 ^{0}C, respectively. The rainy season extends from April to October with the maximum rains in the months of May, June, July, August and September (Figure 2), whereby the mean monthly rainfall exceeds 301mm (BMES, 2021).

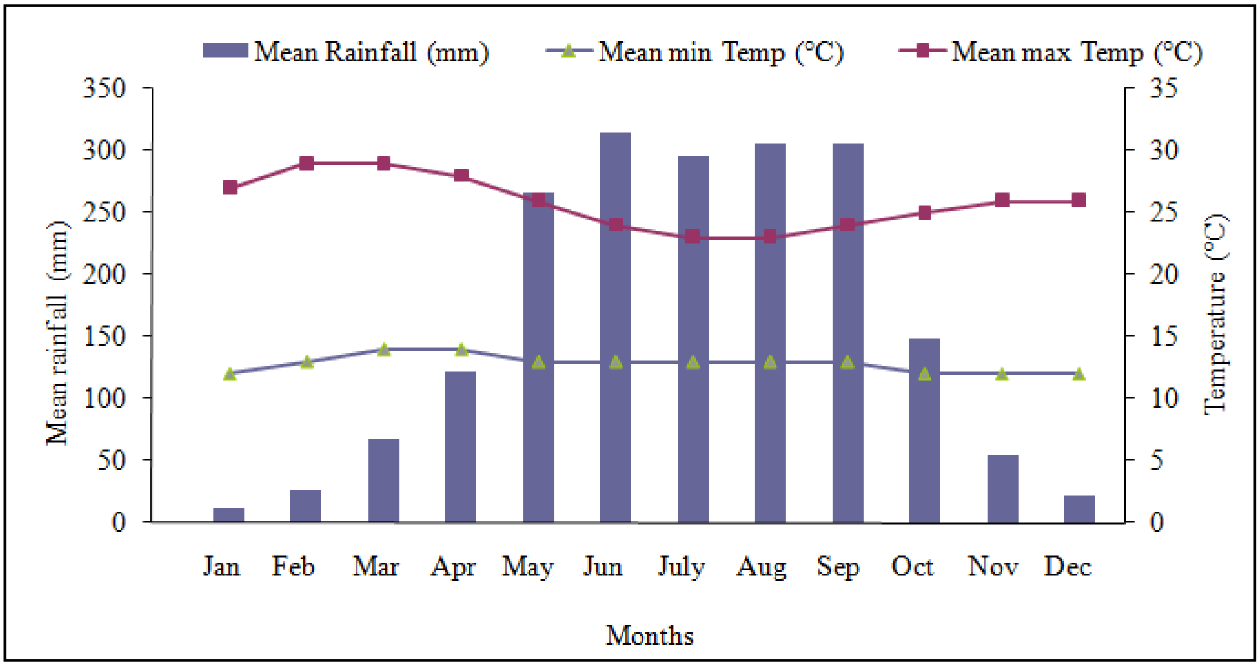

Figure 2. Mean rainfall and maximum and minimum temperature of Bedele district (2021)

3.1.3. Soil type and topography

According to Alemayehu (2015), the soil type of the study area belongs to the reference soil group of Nitisols. The soils are generally deep, well-drained and red tropical soils with diffuse horizon boundaries and a clay-rich nitic subsurface horizon (Driessen *et al*., 2001). Nitosols are predominantly derived from basic parent rocks through strong weathering, which are more fertile than most other red tropical soils (FAO-WRB, 2006). The area is characterized by undulating topographically. In general, Bedele district is characterized by lowland and midland, having an altitude ranging from 1013 to 2390 meters above sea level with humid climatic condition (BDAO, 2021).

3.1.4. Vegetation and Farming systems

Subsistence farming is the main livelihood of the community. Mixed crop-livestock farming system is predominant in the agricultural production of Bedele district. Most of the residents in the area are dependent on agriculture (LDMA, 2010), and crop and livestock are the important sources of income for all relatively wealthy community members (CSA, 2018). The concentrated common vegetation in the district is Bamboo, Gravilia robista, Cordia Africana and acacia species. The crops grown by smallholder farmers of the area include maize (*Zea mays*), teff (*Eragrostistef*), sorghum (*Sorghum bicolor*), barley (*Hordeumvulgare*), wheat (*Triticum spp*), rice (*Oryza sativa*) and different pulse crops, finger millet (*Eleusinecoracana*), fruits, different types of vegetables and spices.

Farmers in the district are using traditional plough drawn by oxen and maize is rotated with legume crops such as bean for maintaining soil fertility of cultivated lands and chemical fertilizers such as DAP and urea at the rates of 46 kg P_2O_5 ha^{-1} and 46 kg N ha^{-1} are applied for all types of crops grown in the district annually since 1995 when extension package program was launched around Bedele (BDAO, 2021). However, the yields are still low due to declining soil fertility and limited information on the right fertilizers with the right rates for the major crops grown in the district.

3.2. Experimental Site Selection

Bedele district was selected purposively for the experiment, because maize is the major crop grown widely in the district. Two specific experimental sites Alle and Abu were selected from model farmers in maize production based on the willingness of the farmers to provide their farmland for experimental purpose.

3.3. Soil Sampling and Analysis

After the experimental sites were identified, soil samples were collected from the experimental fields following zigzag pattern to increase precision (ICARDA, 2013). From each experimental field 15 disturbed soil samples were collected at depth of 0-20cm by using auger. For each site, one composite sample was prepared from the bulk samples for the determination of soil physicochemical properties of the soil before planting. Two undisturbed soil samples from both experimental sites for bulk density determination were taken by using core sampler following Jamison *et al*. (1950) method. Soil bulk density (ρb) was measured and determined by measuring the volume of undisturbed soil sample collected using a core sampler and the sample was weighed after oven-dried at a temperature of 105^{o}C. Then, the result was calculated by the formula as described by Jamison *et al.* (1950).

$$\rho\mathrm{b} = \frac{\text{Mass of soil in gram}}{\text{Volume of soil in cm}^3} \qquad (1)$$

The composite soil samples were air dried, ground using a pestle and mortar and allowed to pass through a 2 mm sieve for all parameters except organic carbon and total nitrogen and through a 0.5 mm sieve for organic carbon and total nitrogen. The collected samples were analyzed for selected physicochemical properties mainly for soil texture, soil pH, exchangeable basic cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+), cation exchange capacity (CEC), organic carbon (OC), total N, available P, available S, and available B at Bedele Agricultural Research Center Laboratory. Soil texture was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). Soil pH was determined in the supernatant suspension of a 1:2.5 soil to water ratio using a pH meter (Rhoades, 1982). Organic carbon was determined as described by Walkely and Black (1934). Exchangeable basic cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted with 1M ammonium acetate at pH 7, then exchangeable Ca^{2+} and Mg^{2+} were determined from the extracted solution with atomic absorption spectroscopy (AAS) method, whereas exchangeable K^+ and Na^+ were determined with flame photometer (Rowell, 1994). To determine the cation exchange capacity (cmol(+) kg^{-1} soil), the soil sample first was leached using 1 M ammonium acetate, washed with ethanol and the adsorbed ammonium was replaced by sodium (Na). Then, the CEC was determined titrimetrically by distillation of ammonia that was displaced by Na (Sahlemedhin and Taye, 2000). Percent base saturation was calculated by dividing the sum of the base forming cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+)) by CEC of the soil and multiplying by 100.

$$\text{PBS (\%)} = \frac{\text{Sum of exchangeable bases (Ca, Mg, Na and K)}}{CEC} * 100 \qquad (2)$$

Available phosphorus in soil was determined by the Bray-II (Bray and Kurtz, 1945) extraction method. Total nitrogen was analyzed by Kjedahl method as described by Bremner and Mulvaney

(1982). Available S was determined by KH_2PO_4 extractant (Johnson and Fixen, 1990). Available B was estimated by hot water extraction method (Havlin *et al*., 1999).

3.4. Description of Experimental Materials

3.4.1. Maize variety

Maize variety BH-661, which was released by Bako Agricultural Research in 2011 was used as a test crop. It performs well in altitudinal range of 1600-2200 masl with annual rainfall amount ranging from 1000-1500 mm. It can give grain yield of 95-120 and 65-85 q ha^{-1} under research station and farmers field, respectively (BARC, 2011).

3.4.2. Types of fertilizers

Blended NPSB fertilizer was used as a source of N, P, S and B. This Blended fertilizer contains 18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B. Urea was used as a supplementary source of nitrogen (46%).

3.5. Experimental Design and Treatments

The experiment was laid out in randomized complete block design (RCBD) with three replications. Treatments were nine levels of blended NPSB fertilizer rates, (0, 25, 50, 75, 100, 150, 200, 250 and 300 kg ha^{-1}) with 92 kg ha^{-1} of nitrogen which was recommended for maize production in Bedele district (Dagne, 2015). The treatment was decided standing from blanket recommendation 100 kg ha^{-1} which is commonly used by the farmers in the district for all types of crops. Urea was used as a supplementary source of nitrogen for all treatments.

The nine levels of blended NPSB fertilizer rates were compared to each other to determine the optimal rate. Since, nitrogen is the most limiting factor for plant growth and is found in low amount in blended fertilizer, urea was applied in split applications to all plots. The plot size was 3 m x 4 m ($12m^2$). The test crop was also planted in rows with 1m x 0.5 m x 0.8 m x 0.5 m spacing between blocks, plots, rows and plants respectively (BARC, 2011). The Maize variety of BH-661 was planted in 2021 cropping season at seed rate of 50,000 seeds/ha (BARC, 2011).

3.6. Management of the Experiment

The experimental fields were ploughed using local plough (Maresha) according to farmer's conventional farming practices. The fields were ploughed three times, before planting. The land was leveled and made suitable for crop establishment. All cultural practices were applied in accordance to the farmer's practices for maize production. Full rate of blended NPSB fertilizer was applied at planting as per the rates of the treatments and urea was applied in split applications to all plots 30 days after planting and at tasseling stage. Other necessary agronomic management practices such as weeding and pest control were carried out uniformly for all treatments.

3.7. Crop Data Collection

3.7.1. Phenological and growth parameters of maize

Days to 50% tasseling: days to tasseling was recorded based on number of days from planting up to when 50% of plants shed pollen.

Days to 50% silking: was recorded as the number of days require from planting to when 50% of the maize plant showed extrusion of silks in each plot. Both days to 50% tasseling and silking were determined based on visual observation.

Plant height (m): was measured from ground level to tassel of three (3) randomly selected plants from three central rows. A carpenter's (measuring) tape was used for measuring the height.

Cob length (cm): was measured from the point where the cob is attached to the stem to the tip of the cob from three (3) randomly selected plants in central net plot at crop harvest.

3.7.2. Yield and yield components of maize

Number of rows per cob: number of row per cob was counted from three cobs and the average was used for analysis.

Number of grain per cob: was calculated by counting the number of grains in three cobs of the three central rows of each sub-plot and their average was calculated.

Grain yield (kg ha^{-1}): was measured by husking and cleaning the grain from three central row plants (net plot area) and converted to kg ha^{-1}

Thousand grains weight (gm): was determined based on the weight of 1000 grains sampled from the sample used to determine grain yield of each treatment.

Aboveground dry biomass yield (kg ha^{-1}): of plants from the net plot area was harvested at physiological maturity and weighed after sun-dried to determine aboveground biomass yield

Stalk yield (kg ha^{-1}): was calculated by subtracting grain yield from the above ground dry biomass yield. Harvest index (%) was calculated as the ratio of grain yield to the above ground dry biomass yield expressed as percentage.

$$\text{HI (\%)} = \frac{\text{Grain yield (kg/ha)}}{\text{Above ground dry biomass (kg/ha)}} * 100 \qquad (3)$$

3.8. Post-Harvest Soil Sampling and Analysis

After harvesting, soil samples were taken from each plot at the depth of 0-20cm, whereby four soil samples were collected from each plot and one composite sample prepared. Accordingly, 54 composite samples were prepared for analysis of selected soil properties after harvest. The composite samples were air-dried, ground and passed through 2.0 mm and 0.5 mm diameter sieves before analysis. Analysis of the selected soil chemical properties were carried out for soil pH, organic carbon, total nitrogen, available phosphorus, available sulfur and boron as described under Section 3.3.

3.9. Statistical Data Analysis

After harvesting the data collected from both sites were pulled together and subjected to statistical analysis of variance (ANOVA) using SAS version of 9.3 (SAS, 2004). Significant difference between and among treatment means were assessed using Duncan’s multiple range taste (DMRT) at 0.05 level of probability (Gomez and Gomez, 1984).

3.10. Partial Budget Analysis

Economic analysis was made using the prevailing inputs at planting and for outputs at the time of crop was harvest. Partial budget was estimated for average yield of the different treatment combinations. At the time of harvest the market price of maize grain was 12 ETB kg^{-1}. The variable cost was calculated by multiplying the price of blended NPSB fertilizer (17.182 ETB ha^{-1}) with the amount of blended NPSB fertilizer rate applied to each treatment. The cost of other production practices like ploughing, planting and weeding were assumed to remain the same or insignificant among the treatments. Analysis of the marginal rate of return (MRR %) was carried out for non-dominated treatments, and the MRRs were compared to a minimum acceptable rate of return (MARR) of 100% to select the optimum treatment (CIMMYT, 1988). It was calculated by dividing the change in net benefit to the change in variable cost. The net benefit per hectare for each treatment is the difference between the gross benefit and the total variable costs. The average yield was adjusted downward by 10% to reflect the difference between the experimental field and the expected yield at farmer's fields and with farmer's practices from the same treatments (CIMMYT, 1988).

4. RESULTS AND DISCUSIONS

4.1. Selected Soil Physical Properties of Experimental Sites

4.1.1. Texture (Particle size distribution)

Soil texture analysis results of both sites were clay dominated and had the particles size distribution of 20% sand, 25% silt and 55% clay for Alle, and 19% sand, 22% silt and 59% clay for Abu (Table 1). Based on Bouyoucos (1962) classification, the textural classes of the soil of both sites were clay. The high clay content may indicate presence of high weathering activity due to high rainfall and warm temperature.

Steward *et al*. (1970) also stated that, high clay content may be due to high weathering which arises from the prolonged action or strong intensity of the weathering agents such as high rainfall and warm temperature, as a result of which the oxide of Al and Fe are formed. To improve the limitations that may occur due to the prevalence of such soil minerals, addition of adequate organic matter resources into the soil may improve the nutrient retention and availability for sustainable crop production.

4.1.2. Bulk density

Bulk densities of the experimental sites were 1.4 and 1.3 g cm^{-3} for Alle and Abu, respectively (Table 1) which is ideal for crop root penetration and aeration (Tekalign, 1991). This recorded bulk density was rated as medium and low for Alle and Abu respectively, based on the rating of bulk density by Hazelton and Murphy (2007) (Appendix Table 1). The medium to low bulk density might be due to the medium organic matter content of the experimental sites. Thus, the topsoil of the experimental sites seems to be well aggregated and without compaction problem that affect root growth, air and water movement in the soil and conducive for crop production.

White (2013) also stated that, values of top soil bulk density <1 g cm^{-3} for soils high in organic matter and 1.0 to 1.4 g cm^{-3} for well-aggregated mineral soils, are conducive for crop production. Likewise, Hunt and Gilkes (1992) stated that, for an optimal movement of air and water through the soil, low bulk density values of <1.5 gm cm^{-3} are desirable. Generally, according to Lal (1997) top soil bulk density value in the range of 0.7-1.84 g cm^{-3} is normal in relation to plant growth.

Table 1. Particle size distribution and bulk density values of soil of the experimental sites.

Parameters	Values	
	Site 1	Site 2
Sand (%)	20	19
Silt (%)	25	22
Clay (%)	55	59
Texture Class	Clay	Clay
Bulk density(gcm^{-3})	1.4	1.3

4.2. Selected Soil Chemical Properties

4.2.1. Soil pH

The pH values were 5.48 and 5.47 for Alle and Abu, respectively (Table 2). According to FAO (2006) classification, the soil reaction of both sites was moderately acidic. This might be due to climatic factors such as warm temperature and prolonged rainfall responsible for leaching of basic cations from the soil surface and may also be responsible for increment of soil acidity in the study area. The normal soil pH for maize is from 5 to 8, with a pH of 6-7 probably being an optimal for most varieties (Martins *et al.*, 2017). Likewise, FAO (2006) reported that the preferable pH range for most crops and productive soils are 4 to 8. Sahlemdhin (1999) also reported the pH of the soil between 5 and 7.55 is within a suitable range for crop production. Based on this evidences the topsoil reaction of the experimental sites can be considered as conducive for maize production.

4.2.2. Organic carbon

The results obtained from soil laboratory analysis indicated that, the soil organic carbon contents were 2.04 and 2.12% for Alle and Abu respectively (Table 2). According to Walkely and Black (1934) classification, the organic carbon contents of soil of both experimental sites were categorized as a medium (Appendices Table 2). The medium organic carbon contents of the surface soil could be related to organic matter addition due to crop residue decomposition in the soil surface, which are commonly left on the field.

4.2.3. Total nitrogen

The total nitrogen contents of the experimental sites were 0.17 and 0.18% for Alle and Abu, respectively (Table 2). According to FAO (2006) classification, the experimental soil contains low total nitrogen (Appendix Table 2). Indicating that, total nitrogen is a limiting factor for optimum crop growth and yields. This might be due to unbalanced application of N containing fertilizer and continuous cultivation of land resulting in the reduction of soil organic matter contents and total nitrogen. Likewise, Wakene and Heluf (2003) reported that, continuous cultivation reduced soil organic matter and total nitrogen content. Therefore, nitrogen containing fertilizers should be applied to supplement the nitrogen requirement of crop.

4.2.4. Available phosphorus

The laboratory analysis results of available phosphorus were 1.67 and 1.77 mg kg^{-1} for Alle and Abu, respectively (Table 2). According to Manjula and John (2012) rating, the soils of experimental area contains low available phosphorus (Appendix Table 3). Specifically, type and rate of organic and inorganic fertilizer utilized in cultivating land and P fixation is also the reason for low availability of phosphorous in the soil. This is in line with the research findings of Abera and Kefyalew (2017) who reported low amount of phosphorous content on soils that are cultivated repeatedly and due to removal of exchangeable basic cations through leaching in high rainfall areas which causes phosphorous fixation problem. Ethio-SIS (2014) suggests optimum phosphorus content for most Ethiopian soil as 15 mg kg^{-1} of soil. Based on this evidence, the available phosphorus in the soil of experimental sites is low and needs additional application of phosphorus containing fertilizer.

4.2.5. Available boron

Soil laboratory analyses results reveal that hot water available boron, which are considered as available to plants were 0.3 and 0.36 mg kg^{-1} for Alle and Abu, respectively (Table 2). According to the rating of Jones (2003), the available boron content of soil of the experimental sites were low (Appendix Table 3). This show that, the soil of the study area is deficient in boron content; this might be due to crop uptake, leaching and continuous application of fertilizers not containing boron. Similarly, Khadka et al. (2018) reported deficient available boron due to intense cultivation of crops without application of boron containing fertilizer. According to Ethio-SIS

(2014), the critical boron value for most Ethiopian soils is 0.8 mg kg^{-1} of soil and the results from the study area were below the critical value. So application of fertilizers containing boron is necessary to increase the boron content of the soil to the optimum level and to increase the productivity of the soil.

4.2.6. Available sulphur

The available sulphur content of the experimental soil had value of 9.26 mg kg^{-1} of sulfur for both Alle and Abu (Table 2). According to Ethio-SIS (2014) soil sulfur content rating, the sulfur content of soil of the experimental sites were very low (Appendix Table 3). Thus, the soils of experimental sites were considered as deficient in available sulphur content, which is unsatisfactory for optimum maize growth and yield. This might be due to crop uptake and continuous application of inorganic fertilizer not containing sulfur. Likewise, Khadka et al. (2018) reported intense cultivation of crops without application of sulphur containing fertilizer might be the cause of deficient status of available sulfur in the field. Thus, it is mandatory to apply sulphur containing fertilizer to improve soil fertility, crop growth and yield (FAO, 2008).

Table 2. Soil pH, organic carbon, total nitrogen, available phosphorus, available boron and available sulphur contents of the experimental sites

Parameters	Values	
	Site 1	Site 2
pH (1: 2.5 soil to water ratio)	5.48	5.47
Organic Carbon (%)	2.04	2.12
Total nitrogen (%)	0.17	0.18
Available phosphorous (mg kg^{-1})	1.67	1.77
Available Boron (mg kg^{-1})	0.3	0.36
Available Sulfur (mg kg^{-1})	9.26	9.26

4.2.7. Cation exchange capacity

The CEC of experimental soils were 20.94 and 22.64 cmol (+) kg^{-1} of soil for Alle and Abu, respectively (Table 3). The results obtained from both Alle and Abu were under medium range (Appendix Table 2). According to London *et al*. (1991), soil having CEC of 15 to 25 cmol (+) kg^{-1} of soil are categorized under medium range. The medium CEC of the soil might be due to high clay content of the soil, because the soil texture of the experimental sites was dominated by clay.

4.2.8. Exchangeable bases and percentage base saturation

The contents of basic cations (Ca, Mg, K and Na) in the soil were 1.26, 1.52, 0.59 and 0.16 cmol (+) kg^{-1} of soil for Alle, respectively and 1.39, 1.52, 0.6 and 0.18 cmol (+) kg^{-1} of soil for Abu, respectively (Table 3). As per the rating set by FAO (2006), the basic cations of the study area are classified as very low for Ca, medium for Mg and K and low for Na for both Alle and Abu sites (Appendix Table 4). The very low, low and medium values of basic cations at both study sites might be attributed to crop uptake and leaching of appreciable amounts of exchangeable basic cations like (Ca), Magnesium (Mg), potassium (K) and Sodium (Na) from the surface soil as the result of the high annual rainfall of the area. Similarly, Kidanu and Achalu (2018) also reported leaching of appreciable amounts of exchangeable basic cations from surface soil by excessive rainfall in soils of Wayu Tuka district, East Wolega Zone, Ethiopia.

Percent of base saturation of the soils of the experimental sites were 16.85 and 16.29 for Alle and Abu respectively (Table 3). The results were very low according to FAO (2006) classification. It is directly related with the exchangeable Ca, Mg, Na and K as described by Hazelton and Murphy (2007). Percent base saturation is closely related to soil pH as soil pH increases with base saturation, whereby base saturation of 70% to 80% represents generally soil with pH > 6.0 (Hazelthon and Murphy, 2007).

Table 3. CEC, exchangeable bases and PBS of soil of experimental sites

Parameters	Values	
	Site 1	Site 2
Cation exchange capacity cmol (+) kg^{-1}	20.94	22.64
Exchangeable Mg cmol (+) kg^{-1}	1.52	1.52
Exchangeable Ca cmol (+) kg^{-1}	1.26	1.39
Exchangeable K cmol (+) kg^{-1}	0.59	0.6
Exchangeable Na cmol (+) kg^{-1}	0.16	0.18
Percentage of base saturation (%)	16.85	16.29

4.3. Post Harvest Selected Soil Properties

4.3.1. Soil pH

The ANOVA analysis that, application of different rates of blended NPSB fertilizer significantly ($P<0.01$) affected the pH values of the soil. The highest mean value of pH (5.3) was recorded from the control plot, whereas the lowest value of pH (5.12) was recorded from the plot that received the highest rate of (300 kg ha^{-1}) blended NPSB fertilizer (Table 4). The result indicated that, as the rate of blended NPSB increased the pH of the soil slightly declined, which may be due to acid forming property of blended NPSB fertilizer incorporated to the soil. This result is in agreement with that of Melkamu (2020) who reported that pH of the soil decreased as the rate of blended NPSB and Urea applied to the soil is increased. To solve this problem, the use of combined application of lime along with blended NPSB fertilizer may be considered to increase soil pH to the optimum level in improving the soil richness status and to raise maize crop yield.

4.3.2. Organic carbon

Application of different rates of blended NPSB fertilizer did not significantly ($P >0.05$) affect the organic carbon content of the soil, but only numerical change was observed. The highest organic carbon content (3.85%) was recorded from the plot treated with highest fertilizer (300 kg ha^{-1}) rate, whereas the lowest organic carbon content (3.5%) was recorded from the control plot (Table 4). These results indicated that, application of blended NPSB fertilizer rates influenced the percentage of soil organic carbon content. In line with this study, Melkamu (2020) reported the highest value of soil organic carbon from the plot that received the highest blended NPSB fertilizer rate and the lowest from the control plots. Similarly, Zeleke *et al.* (2020) reported that the highest (2.16%) net increase of organic carbon was recorded from the plot treated with 200 kg ha^{-1} of blended NPSB fertilizer supplemented with 46 kg ha^{-1} of nitrogen and (0.71%) loss from the control plot.

4.3.3. Total nitrogen content

Total nitrogen content after harvest was not significantly ($p>0.05$) affected by application of different rates of blended NPSB fertilizer. This might be because nitrogen containing fertilizer is equally adjusted to all plots. However the mean values of total nitrogen recorded from all plots after trial was higher than the total nitrogen recorded before trials. This may be due to the residual effect of nitrogen containing fertilizer applied to the soil. In line with this study, Saha *et al*. (2003) stated that the nutrients added to the soil in the form of fertilizers are not being removed or utilized fully by the crops in one season. Moreover, Zeleke *et al*. (2020) reported the highest (0.066%) net increase of total nitrogen after application of 200 kg ha^{-1} blended NPSB fertilizer supplied with 46 kg ha^{-1} of nitrogen and a loss from the control plot.

4.3.4. Available phosphorus

The result obtained from this study revealed that, application of different rates of blended NPSB fertilizer highly significantly ($p<0.01$) affected the available phosphorus content of the soil. The highest residual phosphorus (4.81 mg kg^{-1}) was obtained from the plot that received the highest (300 kg ha^{-1}) NPSB fertilizer rate, whereas the lowest residual phosphorus (1.53 mg kg^{-1}) was recorded from the control plot (0 kg ha^{-1} NPSB) (Table 4). Except the control plot, the values of available phosphorus obtained after trial were higher than those recorded before the trial. This may be due to residual effect of phosphorus containing fertilizer applied, since phosphorus has low mobility and hence might have remained in the soil in appreciable amounts. The result recorded from this study agree with that of Tewolde *et al*. (2020), who obtained the highest residual soil phosphorus (8.3 mg kg^{-1}) from the plot supplied with 300 kg ha^{-1} of blended NPSB fertilizer rate. Similarly, Melkamu (2020) also reported the highest residual soil phosphorus from the plot supplied with the highest rate (250 kg ha^{-1}) of blended NPSB fertilizer and the lowest from the control plot.

4.3.5. Available sulphur

Application of different rates of blended NPSB fertilizer significantly ($P<0.01$) increased the available sulfur content of the soil. The maximum mean available sulphur (14.38 mg kg^{-1}) of the soil was recorded on plot that received the highest (300 kg ha^{-1}) blended NPSB fertilizer rate, whereas the lowest mean value of available sulfur (9 mg kg^{-1}) was recorded on the control plot (0 NPSB kg ha^{-1}) of fertilizer rate (Table 4). Except the control plot, all values of available sulfur obtained from this study after harvest was higher than the available sulphur content of the soil before the experiment was conducted. This study indicated that application of blended NPSB fertilizer rates brought changes in available sulfur content of the soil. This result is in line with that of Tewolde *et al*. (2020), who recorded the highest available sulfur on the plot that received 300 kg ha^{-1} of blended NPSB fertilizer rate supplemented with 46 kg ha^{-1} of N, whereas the lowest from the control plot. Moreover, Saha *et al*. (2003) reported that nutrients applied to the soil in the form of fertilizers are not removed or utilized fully by the crops in one season, so that the residual nutrients that remained from erosion, leaching and crop up take can be used for crop growth in the next cropping season.

According to Ethio-SIS (2014) soil classification for sulfur values, the results obtained from this study were in the low range and very low for the control plot (Appendix Table 3). It can be concluded that the present NPSB blended fertilizer rates can't meet sulfur requirements for the next cropping season, suggesting that additional application of sulfur containing fertilizer is necessary for best crop production.

4.3.6. Available boron

Application of different rates of blended NPSB fertilizer significantly ($p<0.01$) increased the available boron content of the soil. The maximum mean of available boron (0.77 mg kg^{-1}) of soil were recorded on the plot received 300 kg ha^{-1} of blended NPSB fertilizer rate, whereas the lowest (0.08 mg kg^{-1}) of available boron were recorded from the control plot (0 NPSB kg ha^{-1}) of fertilizer rate (Table 4). Generally the increasing trends were observed in case of available boron content of the soil from T1 to T9 as the rate of blended NPSB fertilizer rate increased upward.

According to Jones (2003) classification, the residual available boron content of the soil after harvesting was under low range except the control plot and the plot that received 25 kg ha^{-1} of blended NPSB fertilizer rate, which were under very low range (Appendix Table 3). This might be due to residual effect of boron containing blended fertilizer applied to the soil. According to Ethio-SIS (2014) critical boron value for most Ethiopian soils is 0.8 mg kg^{-1}of soil. Hence, available boron content of the soil after harvest was in low range, so that additional applications of boron containing fertilizer seems to be necessary to fulfill boron requirements of the crops in the next cropping season.

The result obtained from this study agreed with that of Tewolde *et al.* (2020), who reported the highest (0.334 mg kg^{-1}) residual Available boron from the plot that received the highest (300 kg ha^{-1}) blended NPSB fertilizer rate and the lowest (0.05 mg kg^{-1}) of available boron from the control plot. Likewise, Zeleke *et al*. (2020) reported the highest (0.2 mg kg^{-1}) net increase of available boron as a result of 200 kg ha^{-1} of blended NPSB +100 kg of Urea and the lowest (0.01 mg kg^{-1}) of available boron on the plot with 50 kg ha^{-1} of blended NPSB +100 Urea.

Table 4. Effects of blended NPSB fertilizer rates on selected soil properties

NPSB fertilizer rates (kg ha^{-1})	pH	OC (%)	TN (%)	Ava. P	Ava. S	Ava. B
0	5.30^{a}	3.50^{a}	0.30^{a}	1.52^{d}	9^{d}	0.08^{e}
25	5.29^{a}	3.57^{a}	0.30^{a}	1.83^{cd}	10.96^{c}	0.17^{de}
50	5.28^{a}	3.62^{a}	0.31^{a}	1.90^{bcd}	11.07^{c}	0.23^{d}
75	5.27^{ab}	3.73^{a}	0.32^{a}	2.12^{bcd}	11.31^{c}	0.41^{c}
100	5.26^{ab}	3.73^{a}	0.32^{a}	2.63^{bc}	11.46^{c}	0.48^{c}
150	5.25^{ab}	3.75^{a}	0.32^{a}	2.72^{bc}	11.89^{bc}	0.58^{b}
200	5.24^{ab}	3.77^{a}	0.32^{a}	2.86^{b}	12.60^{b}	0.61^{b}
250	5.18^{bc}	3.83^{a}	0.33^{a}	4.30^{a}	12.89^{b}	0.71^{a}
300	5.12^{c}	3.85^{a}	0.33^{a}	4.81^{a}	14.38^{a}	0.77^{a}
LSD(0.05)	0.09	0.70	0.06	0.98	1.13	0.09
CV (%)	1.52	16.23	16.11	30.71	8.34	17.50

pH=power of hydrogen, OC=Organic carbon, TN=Total nitrogen, Ava.P=Available phosphorus, Ava.B=Available boron, Ava.S=Available sulfur, CV=Coefficient of variance; LSD= Least significant difference at 5% level

4.4. Maize Phenological Growth, Yield and Yield Components

The major agronomic parameters and yield components measured for this study include days 50% to tasseling, days 50% to silking, number of cobs per plot, cob length, number of rows per cob, plant height, total above ground biomass yield, number of grains per cop, thousand grains weight, grain yield, harvest index and stalks yield. All the data on these parameters were recorded and analyzed statistically.

4.4.1. 50% Days to tasseling and silking

Regarding days to 50% tasseling and silking, there was significance difference ($p<0.05$) among blended fertilizer rates. The shortest length of time to tasseling and silking (76.66 and 83.66 respectively) were recorded from the treatment treated with 300 kg ha^{-1} of NPSB fertilizer (T9), followed by the treatment treated with 250 kg ha^{-1} of fertilizer (T8). On the other hands, the longest days to tasselling and silking (90 and 97, respectively) was recorded for maize grown on the control plot (Table 5). The higher fertilizer use leads the crop to enhanced growth and ultimately the crop tassel early instead of lengthy vegetative growth. In line with this result, Uwah *et al*. (2011) reported a reduction in number of days to 50% tasselling in maize with increased rates of blended fertilizers. Dagne (2016) also reported that, application of blended fertilizer hastened days to tasseling by 3.5% as compared to the recommended NP fertilizer, whereas it decreased days to tasseling by 9.2% as compared to control.

Table 5. Effects of blended NPSB fertilizer rates on days to 50% tasseling and silking

NPSB fertilizer rates (kg ha^{-1})	50% DT	50% DS
0	90^{a}	97^{a}
25	86.66^{ab}	93.66^{ab}
50	85^{abc}	92^{abc}
75	84.16^{abc}	91.16^{abc}
100	81.66^{abc}	88.66^{abc}
150	$80b^{c}$	$87b^{c}$
200	$80b^{c}$	$87b^{c}$
250	$78b^{c}$	85.33^{bc}
300	76.66^{c}	83.66^{c}
LSD(0.05)	8.9	8.9
CV (%)	9.28	8.55

DT=Days to tasselling, DS=Days to silking, CV=Coefficient of variance; LSD= Least significant difference at 5% level

4.4.2. Number of cobs per plot, cob length, rows per cob, grains per cob and thousand grains weight

The results of the study revealed that there was highly significant ($p<0.01$) difference among number of cobs per plot due to levels of blended NPSB fertilizer. The highest cob number (39) was counted from the plot that received 300 kg ha^{-1} of NPSB fertilizer rate, followed by cob numbers of 38, 37 and 37 from the plots that received 250, 200 and 150 kg ha^{-1} of blended NPSB fertilize rates respectively, whereas the lowest (25) cob number was recorded on the control plot followed by (27) cobs from the plot that received 25 kg ha^{-1} of blended NPSB fertilizer rate (Table 6). This might be due to the fact that plants that received optimum blended fertilizer were in a position to hold two or more cobs per plant. Number of cobs per plant is determined by prolific ability of the Maize variety (Adefris *et al*., 2015) and the growth behavior of the crop which is dependent upon management practices and climatic factor. In line with this study Fufa *et al*. (2019) reported the highest cob number from the plot that received the highest blended NPSB fertilizer rate. Accordingly, Besufikad and Tesfaye (2019) also reported the interaction of optimum plant population and fertilizer rate improve the number of cobs. Likewise, Mehta *et al*. (2005) reported that application of 60kg P_2O_5 gave more number of maize cobs as compared to 40kg P_2O_5 and control.

Regarding cob length, the result obtained from the study showed that there was highly significant ($p<0.01$) difference in cob length due to application of different rates of blended NPSB fertilizer. Accordingly, the longest (18.83 cm) cob was recorded from the treatment that received 300 kg ha^{-1} of blended NPSB fertilizer rate followed by (18.52 cm) from the plot that received 250 kg ha^{-1} of blended NPSB fertilizer; whereas the shortest (15.8 cm) cob length was recorded on the control plot followed by (16.61cm) from the plot that received 25 kg ha^{-1} fertilizer rate (Table 6). The increment in cob length might be due to an increase in cell elongation and more vegetative growth attributed to different nutrient content. The result obtained from this study is in line with that of Raouf and Ali (2016), who reported that increased amount of fertilizer, increased the length of cobs when compared to the control plot. Fufa *et al.* (2019) also reported the longest cob length record from fertilized plot than the control plot.

Regarding number of rows per cob, the results showed that ($p>0.05$) there was no significance difference among rows per cobs due to blended NPSB fertilizer rates (Table 6). This might be due to the fact that rows per cob in maize are formed at the early growth stage of maize, when there is less competition among plants for nutrients. This result agrees with the findings of Raouf and Ali (2016) who reported that the application of additional fertilizer did not significantly alter number of rows per cob.

Number of grains per cob is the prominent factor that influences yield in maize. The results from this study indicated that application of different rates of blended NPSB fertilizer highly significantly ($p<0.01$) affected the number of grains per cob. Accordingly, the highest number of grains (553) per cob was recorded on the plot that received 300 kg ha^{-1} of blended NPSB fertilizer followed by (539) grains recorded on the plot treated with 250 kg ha^{-1} of NPSB fertilizer; and the lowest number of grains (426) per cob was obtained from the control plot followed by (467) grains from the plot that received 25 kg ha^{-1} of blended NPSB fertilizer rate (Table 6). This might be due to the fact that plants provided with sufficient blended NPSB fertilizer rate may have higher capacity to efficiently utilize other nutrients from the growing media and produce bigger cobs that produce higher number of grains per cob. (Fufa *et al*., 2019) also reported the highest number of grains from the plot treated with the highest rate of blended NPSB fertilizer rate and the lowest from the control plot.

Regarding thousand grain weight, the result from this study showed that thousand grain weight was highly significantly ($p<0.01$) affected by application of different rates of blended NPSB fertilizer. Accordingly, the highest thousand grain weight 402.25 gm was obtained from the plot treated with 300 kg ha^{-1} of blended NPSB fertilizer rate followed by 386.35 gm from the plot that received 250 kg ha^{-1} of NPSB fertilizer rate. The lowest thousand grain weight, 295.32 gm, was recorded on the control plot, followed by 314.32 gm from the plot that received 25 kg ha^{-1} of blended NPSB rate (Table 6). The increment in thousand grain weight with increased rate of blended NPSB may be due to the fact that phosphorous fertilizer plays great role in root and shoot development and in grain filling of the crops. Similarly, Dagne (2016) found that application of blended fertilizer significantly increased thousand grain weights as compared to recommended NP and control plot.

Table 6. Effects of blended NPSB fertilizer rates on number of cobs per plot, cob length, number of rows per cob, number of grains per cob and thousand grains weight.

NPSB fertilizer rates (kg ha^{-1})	NCPP	CL(cm)	NRPC	NGPC	TGW (gm)
0	25^{e}	15.86^{g}	12.33^{a}	426.33^{f}	295.32^{g}
25	27de	16.61^{fg}	12.66^{a}	467.17^{e}	314.32^{fg}
50	29^{cd}	16.94^{ef}	13^{a}	473.00^{de}	331.75^{ef}
75	31^{bc}	17.33^{def}	13^{a}	490.33^{cd}	341.87^{de}
100	33^{b}	17.50^{cde}	13^{a}	496.33^{c}	348.03de
150	37^{a}	17.91^{bcd}	13^{a}	522.83^{b}	357.03^{cd}
200	37^{a}	18.19^{abc}	13.16^{a}	529.17^{b}	376.47^{bc}
250	38^{a}	18.52^{ab}	13.16^{a}	539.00^{ab}	386.35^{ab}
300	39^{a}	18.33^{a}	13.16^{a}	553.17^{a}	402.25^{a}
LSD(0.05)	2.85	0.83	0.97	20.71	20.36
CV (%)	7.38	4.07	6.49	3.56	4.99

NCPP=Number of cobs per plot; CL=Cob length; NRPC= Number of rows per cob; NGPC=Number of grains per cob; TGW=Thousand grains weight; CV=Coefficient of variance; LSD= Least significant difference at 5% level

4.4.3. Plant height

Plant height of maize was significantly ($p<0.01$) increased by the application of different rates of blended NPSB fertilizer. Accordingly, the longest plant (3.14 m) plant height was measured on the plot that received 300 kg ha^{-1} of blended NPSB fertilizer rate (T9) followed by (3.08 m) on the plot that received 250 kg ha^{-1} of NPSB fertilizer rate; whereas the shortest (2.49 m) plant height was recorded on the control plot followed by the (2.61 m) height recorded on the plot that received 25 kg ha^{-1} of blended NPSB fertilizer rate (Table 7). In general, this study indicated an increase in plant height with increased blended fertilizer rates from 0 to 300 kg ha^{-1}. The increment in plant height might be due to an increase in cell elongation and more vegetative growth attributed to different nutrient content. The result gained from this study agrees with that of Knife *et al.* (2019), who reported that, plant growth and development declines if any of the essential elements are less than their threshold values in the growing media or not adequately balanced with other essential plant nutrients.

Table 7. Effects of blended NPSB fertilizer rates on plant heights

NPSB fertilizer rates (kg ha^{-1})	PH (m)
0	2.49^{e}
25	2.61^{d}
50	2.68^{cd}
75	2.75^{bc}
100	2.85^{b}
150	3.02^{a}
200	3.03^{a}
250	3.08^{a}
300	3.14^{a}
LSD(0.05)	0.119
CV (%)	3.58

PH=Plant height; CV=Coefficient of variance; LSD= Least significant difference at 5% level

4.4.4. Grain yield, harvest index, stalk yield and total aboveground dry biomass yield

Mean grain yield of maize was significantly ($p<0.01$) increased by application of different rates of blended NPSB fertilizer. Accordingly, the highest grain yield 7272.5 kg ha^{-1} was obtained from the treatment treated with 300 kg ha^{-1} of blended NPSB fertilizer rate, followed by 7261.6 kg ha^{-1} from the plot that received 250 kg ha^{-1} of NPSB, whereas the lowest mean grain yield 1836.8 kg ha^{-1} was recorded on the control plot (T1) followed by 2496.5 kg ha^{-1} from the plot that received 25 kg ha^{-1} of NPSB fertilizer (Table 8).

The mean grain yield of maize 7272.5 kg ha^{-1} of the study area surpassed the national average yield 5800 kg ha^{-1} (FAOSTAT, 2019) and 4200 kg ha^{-1} (CSA, 2020). This might be due to combined effect of nutrients like nitrogen, phosphorus, sulfur and boron in blended fertilizer, which might have enhanced growth and development of the crop. Optimum fertilizer application nourishes and supplies nutrients required for good productivity. The optimum nitrogen, phosphorous, sulfur and boron levels might have helped in the efficiency of absorption and utilization of other required plant nutrients that ultimately increase the grain yield of maize.

Fayera *et al*. (2014) reported that, the increase in grain yield might be due to the effect of balanced nutrients in improving crops agronomic performance, thereby enhancing nutrient use efficiency. Smilarly, Jafar (2018) found better grain yield from application of blended fertilizer compared to recommended NP fertilizer and control plot. Moreover, Fufa *et al.* (2019) also reported the highest grain yield of maize from application of 150 kg ha^{-1} of NPSB fertilizer with 92 kg ha^{-1} of nitrogen in split application. Similar grain result was also reported by Onasanya (2009) in maize research, whereby up to certain levels of fertilizer rate, the yield of maize increased proportionally.

Result obtained from this study indicated also that the **%** HI was significantly ($p<0.01$) affected by application of different rates of blended NPSB fertilizer. The highest value of 53.25% HI was obtained due to the application of 150 kg ha^{-1} of blended NPSB fertilizer with recommended nitrogen. The second highest 46.55% HI was obtained from the plot treated with 200 kg ha^{-1} of NPSB fertilizer. The lowest value 25.9% HI was recorded on the control plot followed by 28.97% from the treatment that received 25 kg ha^{-1} of NPSB fertilizer (Table 8). High harvest index indicates the presence of good partitioning of biological yield to economic yield. Generally, harvest index (%HI) indicates the balance between the productive parts of the plant and the reserves, which form the economic yield. This result is in agreement with the finding of Awoke and Muhaba (2021), who reported that application of different rates of inorganic fertilizer levels had a significant effect on the maize harvest index.

Regarding stalk yield, analysis of variance showed that stalk yield was significantly ($p<0.01$) increased by application of different rates of blended NPSB fertilizer. The highest stalk yield 12578 kg ha^{-1} was obtained from the treatment treated with the highest blended fertilizer rate, whereas the lowest stalk yield 5424 kg ha^{-1} was recorded from the control plot (Table 8). Increasing blended fertilizer rates from 0 to 300 kg ha^{-1} significantly increased maize stalk yield. Plants grown on plots treated with higher rate of balanced nutrients might have been more initiated for vegetative growth, good photosynthesis and higher cell division that can in turn influence the stalk yield. Fagera *et al*. (2011) also reported the highest stalk yield of maize from the plot received highest fertilizer rate and the lowest from the control plot.

Regarding total aboveground dry biomass yield, application of different rates of blended NPSB fertilizer showed a significant ($p<0.01$) variation. Accordingly, the highest total aboveground dry biomass yield (19851 kg ha^{-1}) was obtained from the treatment supplied with 300 kg ha^{-1} of NPSB fertilizer rate (T9) followed by (17170 kg ha^{-1}) from (T8), which received 250 kg ha^{-1} of NPSB fertilizer rate. The lowest aboveground dry biomass yield (7261 kg ha^{-1}) was obtained from the control plot followed by 8328 kg ha^{-1} from the plot that received 25 kg ha^{-1} of NPSB fertilizer rate (Table 8). This may be due to sulfur that increases the formation of chlorophyll and encourage vegetative growth and boron that helps in nitrogen absorption.

These results are similar with those of Mekuanent and Kiya (2020), who observed a significant disparity in biomass yield of maize due to different blended fertilizer rates, whereby the highest blended fertilizer rate produced the highest above ground biomass yield; and the lowest biomass yield was gained from the treatment with the lowest fertilizer rate. The result of this study is in line also with the findings of Wubshet *et al.* (2017), which revealed that the application of 150 kg ha^{-1} of blended NPSB fertilizer rate increased the biomass yield over the control.

Table 8: Effects of blended NPSB fertilizer rates on grain yield, harvest index, stalk yield and above ground dry biomass yield

NPSB fertilizer rates (kg ha^{-1})	GY (kg ha^{-1})	(HI %)	SY (kg ha^{-1})	AGDBY (kg ha^{-1})
0	1836.8^{d}	25.91^{e}	5424^{d}	7261^{f}
25	2496.5^{cd}	30.52^{de}	6156^{cd}	8328^{ef}
50	2597.2^{cd}	28.97^{de}	6502^{cd}	9099^{ef}
75	3596.9^{c}	33.44^{cde}	6988^{cd}	10381de
100	4740.7^{b}	40.79^{bc}	7185^{cd}	11926^{cd}
150	7173.6^{a}	53.25^{a}	6208^{cd}	13215^{c}
200	7183.1^{a}	46.55^{ab}	8367^{cb}	15500^{b}
250	7211.6^{a}	42.79^{bc}	9908^{b}	17170^{b}
300	7272.5^{a}	37.16^{bcd}	12578^{a}	19851^{a}
LSD(0.05)	1126.1	9.78	2290.3	2212.6
CV (%)	19.14	22	25.5	15.17

GY=Grain yield; HI=Harvest index; SY=Stalk yield; AGDBY= Above ground dry biomass yield, CV=Coefficient of variance; LSD= Least significant difference at 5% level

4.5. Association between Maize Grain Yield, Yield Components and Soil Nutrients

A simple correlation analysis was done to consider the association of different agronomic parameters of the maize crop and soil nutrients. Both positive and negative associations between the parameters have been observed (Table 9). Grain yield exhibited positive and significant correlation with agronomic and yield components and negative correlation with 50% days to tasseling and silking. Grain yield was directly and significantly ($p<0.01$) positively correlated with number of rows per cob (0.289**) and significantly ($p<0.001$) positively correlated with above ground dry biomass yield (0.813***), number of cobs per plot (0.813***), cob length (0.626***), number of grains per cob (0.743***), thousand grains weight (0.838***) and harvest index (0.758***), whereas, it was significantly ($P<0.001$) negatively correlated with 50% days to tasseling (-0.398***) and silking (-0.398***).

This result indicated that, increased days to 50% tasseling and silking result in reduction of grain yield, while total above ground dry biomass yield, number of cobs per plot, cob length, number of grains per cob, thousand grains weight and harvest index have resulted in increasing maize grain yield. The results on the association of grain yield in this study agree with the findings of Gebreyesus (2008) who reported that, grain yield was positively and highly significantly associated with total above ground dry biomass and yield components of the crop.

Similar to above ground biomass and yield components, grain yield was significantly ($p<0.05$) positively correlated with soil organic carbon (0.323*) and total nitrogen (0.329*) as well as significantly ($p<0.001$) positively correlated with available phosphorus (0.601***), available boron (0.794***) and available sulphur (0.658***). The positive correlation between soil total nitrogen, available phosphorus, available sulphur and available boron indicates the soil nutrient status may affect grain yield and yield components directly. These findings were also in line with finding of Mahmood et al. (2017) who reported a significant positive correlation was found among grain yield, soil total nitrogen and available phosphorus. Furthermore maize grain yield has a positive and significant correlation with biological yield and yield components as well as with nutrient contents of the soil and it has negative correlation with 50% days to tassiling and silking (Table 9).

Table 9: Correlation coefficients among maize grain yield, yield components and available soil nutrients

	AGDB	NCPP	CL	NRPC	NGPC	TKW	DT	DS	GY	HI	pH	OC	TN	P	B	S
AGDB	1.00															
NCPP	0.725***	1.00														
CL	0.584***	0.749***	1.00													
NRPC	0.332**	0.081ns	0.266ns	1.00												
NGPC	0.737***	0.857***	0.869***	0.198**	1.00											
TKW	0.754**	0.829***	0.759***	0.289**	0.803**	1.00										
DT	-0.296**	-0.421***	-0.702***	-0.159ns	-0.521***	-0.491***	1.00									
DS	-0.296**	-0.421***	-0.703***	-0.159ns	-0.521***	-0.491***	1.000***	1.00								
GY	0.813***	0.813***	0.626***	0.289**	0.743***	0.838***	-0.398***	-0.398***	1.00							
HI	0.264ns	0.579***	0.490***	0.120***	0.489***	0.609***	-0.428***	-0.4278***	0.758***	1.00						
OC	0.290*	0.188ns	0.043ns	0.191ns	0.031ns	0.242ns	0.258ns	0.258ns	0.323*	0.188NS	-0.312*	1.00				
TN	0.297*	0.194ns	0.055ns	0.199ns	0.021ns	0.245ns	0.273*	0.273*	0.329*	0.191ns	-0.323*	0.992***	1.00			
P	0.626***	0.68***	0.681***	0.121ns	0.669***	0.689***	-0.616***	-0.616***	0.601***	0.390***	-0.397***	0.029ns	0.036ns	1.00		
B	0.879***	0.840***	0.760***	0.294*	0.841***	0.787***	-0.444***	-0.444***	0.794***	0.404***	-0.471***	0.165ns	0.177ns	0.660***	1.00	
S	0.807***	0.663***	0.588***	0.448***	0.659***	0.732*	-0.227ns	-0.228ns	0.658***	0.247*	-0.447***	0.313*	0.325*	0.506***	0.762***	1.00

AGDB=Above ground dyr biomass, NCPP=Number of cobs per plot, CL=Cob length, NGPC=Number of grains per cob, TKW=Thousand kernels weight, DT=Days to tassiling, DS=Days to silking, GY=Grain yield, HI=Harvest index, pH=Soil pH, OC=Organic carbon, TN=Total nitrogen, P=Available phosphorus, B=Available boron, S=Available sulfur, NS, *, ** and ***, Non-significant, Significantly different at 0.05, 0.01, 0.001 probability levels respectively.

4.6. Economic Feasibility of NPSB Fertilizer Rates for Maize Production

Economic analysis for each treatment was performed and income computed based on the current local market price of maize in study area. Net benefit was calculated by subtracting the total variable cost (TVC) from the gross field benefit (GFB) for each treatment. All variable costs were calculated excluding the price of other agronomic practices such as cost of seed, land preparation, sowing, weeding and harvesting since all those practices are uniform to all plots. The grain yield was adjusted downward by 10% to reflect the difference between the experimental field and the expected yield at farmer's field with farmer's practices from the same treatments (Agegnehu and Rezene, 2006).

Dominance analysis led to the selection of treatments ranked in increasing order of total variable costs (Table 10). For each pair of ranked treatments, the percent marginal rate of return (MRR) was calculated. The MRR (%) between any pair of un-dominated treatments was the return per unit of investment in fertilizer. Analysis of marginal rate of return (MRR) was carried out for non-dominated treatments and the MRRs were compared to a minimum acceptable rate of return (MARR) of 100% to select the optimum blended NPSB fertilizer rate (CIMMYT, 1988). The highest net benefit of 74897.58 ETB ha^{-1} with the highest marginal rate of 2957% was obtained from the plot treated with 150 kg ha^{-1} of blended NPSB fertilizer rate (T6). On the other hand, the lowest net benefits 19837.44 ETB ha^{-1} was obtained from the control plot. So that application of 150 kg ha^{-1} of blended NPSB fertilizer rate with the recommended N was economically feasible for maize production in the study area.

Table 10: Partial budget analysis of blended NPSB fertilizer rate for maize production

NPSB (kg ha^{-1})	Av.yld (kg ha^{-1})	Adj.yld (kg ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
0	1836.8	1653.12	19837.44	0	19837.44	0
25	2496.5	2246.85	26962.2	429.55	26532.65	1558
50	2597.2	2337.48	28049.76	859.1	27190.66	153
75	3596.9	3237.21	38846.52	1288.65	37557.87	2413
100	4740.7	4266.63	51199.56	1718.2	49481.36	2775
150	7173.6	6456.24	77474.88	2577.3	74897.58	2957
200	7183.1	6464.79	77577.48	3436.4	74141.08	D
250	7211.6	6490.44	77885.28	4295.5	73589.78	D
300	7272.5	6545.25	78543	5154.6	73388.4	D

Av.yld= Average yield, Adj.yld=Adjusted yield, GFB=Gross field benefit, TVC=Total variable cost, NB=Net benefit, MRR=Marginal rate of return

5. SAMMARYAND CONCLUSION

Soil test based fertilizer recommendation that is based on actual limiting nutrients for a given crop will help to supply adequate plant nutrients. To avoid the deficiency of nutrient caused by blanket recommendation of DAP and Urea, Ethio-SIS tested the soils of Ethiopia and gave recommendation based on the actual limiting nutrients at Regional, Zonal, district and Kebele levels. Based on the limiting nutrients, blended NPSB fertilizer is recommended for Bedele district, even though the optimum rate of this fertilizer for major crops grown in the district was not known. Field experiment was conducted during the 2021 main cropping season (June to November months) in Bedele district on two farmer's fields with the objectives of assessing the effect of blended NPSB fertilizer rates on selected soil properties, maize yield and yield components, and to identify the economically feasible rate of blended NPSB fertilizer for optimal yield of maize. The treatments consisted of nine levels of blended NPSB (0, 25, 50, 75, 100, 150, 200, 250, 300 kg ha^{-1}) fertilizer rates. The experiment was laid out as a randomized complete block design with three replications. Maize variety named 'BH-661' was used as a test crop. The fertilizer materials used were urea (46%N) and blended NPSB (18.9%N, 37.7%P_2O_5, 6.95% S and 0.1%B).

All necessary data from test crop and soil data before and after harvesting were collected and analyzed using SAS software 9.3 versions. Analysis of results revealed that application of the different blended NPSB fertilizer rates highly significantly affected soil pH, Available phosphorus, Available sulfur and Available boron content of the soil; whereas soil organic carbon and total nitrogen were not significantly affected by application of blended NPSB fertilizer rates. The highest residual Available phosphorus (4.81 mg kg^{-1}), Available sulfur (14.38 mg kg^{-1}) and Available boron (0.77 mg kg^{-1}) of soil were recorded from the plot that received the highest (300 kg ha^{-1}) blended NPSB fertilizer rate. The lowest pH (5.12) value was recorded from the plot that received 300 kg ha^{-1} NPSB, which may be due to acid forming tendency of the NPSB fertilizer that needs yet further investigation.

Similarly all the necessary maize yield and yield components were recorded and analyzed using SAS software. Accordingly, economically feasible grain yield (7173.6 kg ha^{-1}) and the highest harvest index (53.25%) were recorded from the plot treated with 150 kg ha^{-1} of blended NPSB fertilizer rate with the recommended nitrogen 92 kg $ha^{-1}N$ for maize production in the district. The longest plant height (3.14 m), the highest above ground dry biomass (19851 kg ha^{-1}), number of cobs per net plot (39), cob length (18.83 cm), number of row per cob (13.16), number of grains per cob (553), thousand grains weight (402.25 gm) and stalk yield (12578 kg ha^{-1}) were recorded at NPSB rate of 300 kg ha^{-1}; which were statistically significant. Number of rows per cob was not significantly influenced by application of blended NPSB fertilizer rates.

The partial budget analysis revealed that application of 150 kg ha^{-1} of blended NPSB fertilizer rate gave the best economic net benefit of (74897.58 ETB ha^{-1}) with the marginal rate of return of 2957%. Therefore, it can be concluded that application of 150 kg ha^{-1} of NPSB fertilizer with the recommended nitrogen (92 kg $ha^{-1}N$) can be tentatively recommended for production of maize in the study area and other areas with similar agro-ecological conditions without affecting the soil properties negatively. However, since the experiment was conducted for one cropping season on two locations, repeating the experiment over seasons and locations using BH-661 maize and other improved varieties seems inevitable to make conclusive recommendation.

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7. APPENDICES

Appendix Table 1. Ranges of soil pH and Bulk density

Soil reaction class	Soil pH range*	Bulk density class	Bulk density range***(g/cm^3)
Very strongly acidic	<4.5	Very low	< 1
Strongly acidic	4.5 to 5.2	Low	1 – 1.3
Moderately acidic	5.2 to 5.9	Medium	1.3 – 1.6
Slightly acidic	6.0 to 6.6	High	1.6 – 1.9
Neutral	6.7 to 7.3	Very high	>1.9
Moderately alkaline	7.4 to 8.0	-	
Strongly alkaline	>8.0	-	

Source *FAO, 2006, ***Hazelton and Murphy (2007)

Appendix Table 2. Ranges of soil OC, TN and CEC

Ratings	Organic carbon (%)*	Total nitrogen (%) **	Cat ion exchange capacity (CEC) (Cmol/kg)***
Very low	<0.89	<0.01	-
Low	0.89 to 1.5	0.01 to 0.2	<15
Medium	1.5 to 3	0.2 to 0.5	15 to 25
High	>3	0.5 to 1.0	25 to 40
Very high	-	>1.0	>40

Source *Walkley and Black (1934), **FAO (2006), ***Landon, et al. (1991)

Appendix Table 3. Ranges of Available phosphorous, Available boron and Available sulfur

Ratings	Available phosphorus (mg/kg)*	Available boron (mg/kg)**	Available sulfur (mg/kg)***
Very low	-	-	<9
Low	0 to 2	<0.5	10 to 20
Medium	-	0.5 to 1	-
Acceptable	3 to 5	-	-
Optimum	6 to 10	-	20 to 80
High	11 to 18	1 to 2	>80
Very high	>19	-	-

Source *Manjula *et al.* (2012), **Jones (2003), ***Ethio-SIS (2014)

Appendix Table 4. Ranges of exchangeable bases and PBS

Ratings	Exch. Ca^{2+}	Exch. Mg^{2+}	Exch. K^+	Exch.Na^+	PBS (%)
Very low	<2	<0.5	<0.1	<0.1	<25
Low	2 to 5	0.5 to 1.5	0.1 to 0.3	0.1 to 0.3	25 to 50
Medium	5 to 10	1.5 to 3	0.3 to 0.6	0.3 to 0.7	50 to 75
High	10 to 20	3 to 8	0.6 to 1.2	0.7 to 2.0	75 to 100
Very high	>20	>8	>1.2	>2.0	>100

Source FAO (2006)

Appendix Table 5. ANOVA Table showing mean square values of selected soil chemical properties as influenced by application of blended NPSB fertilizer rates

Source	DF	Mean square					
		Soil pH	OC (%)	TN (%)	Avai.P (mg/kg)	Avai.S (mg/kg)	Avai.B (mg/kg)
Replication	2	0.033**	1.24*	0.0093*	2.20^{ns}	7.23**	0.00070^{ns}
Rates	8	0.021**	0.085^{ns}	0.97^{ns}	7.61**	13.43**	0.35**
Error	16	0.0063	0.36	0.0026	0.71	0.95	0.0062
CV (%)		1.52	16.23	16.11	30.71	8.34	17.50

pH=Power of hydrogen ion, OC=Organic carbon, TN=Total nitrogen, Avai.P=Available phosphorus, Avai.S=Available sulfur, Avai.B=Available boron, CV=Coefficient of variance, *=significance, **=Highly significance, ns=Non significance

Appendix Table 6. ANOVA Table showing mean square values of phenological and growth parameters of maize as influenced by application of blended NPSB fertilizer rates

Source	DF	Mean square			
		50% DT	50% DS	PH (m)	CL (cm)
Replication	2	57.40^{ns}	57.40^{ns}	0.10**	0.74^{ns}
Rates	8	121.64*	121.64*	0.31**	5.47**
Error	16	54.59	54.59	0.01	0.50
CV (%)		8.97	8.27	3.58	4.07

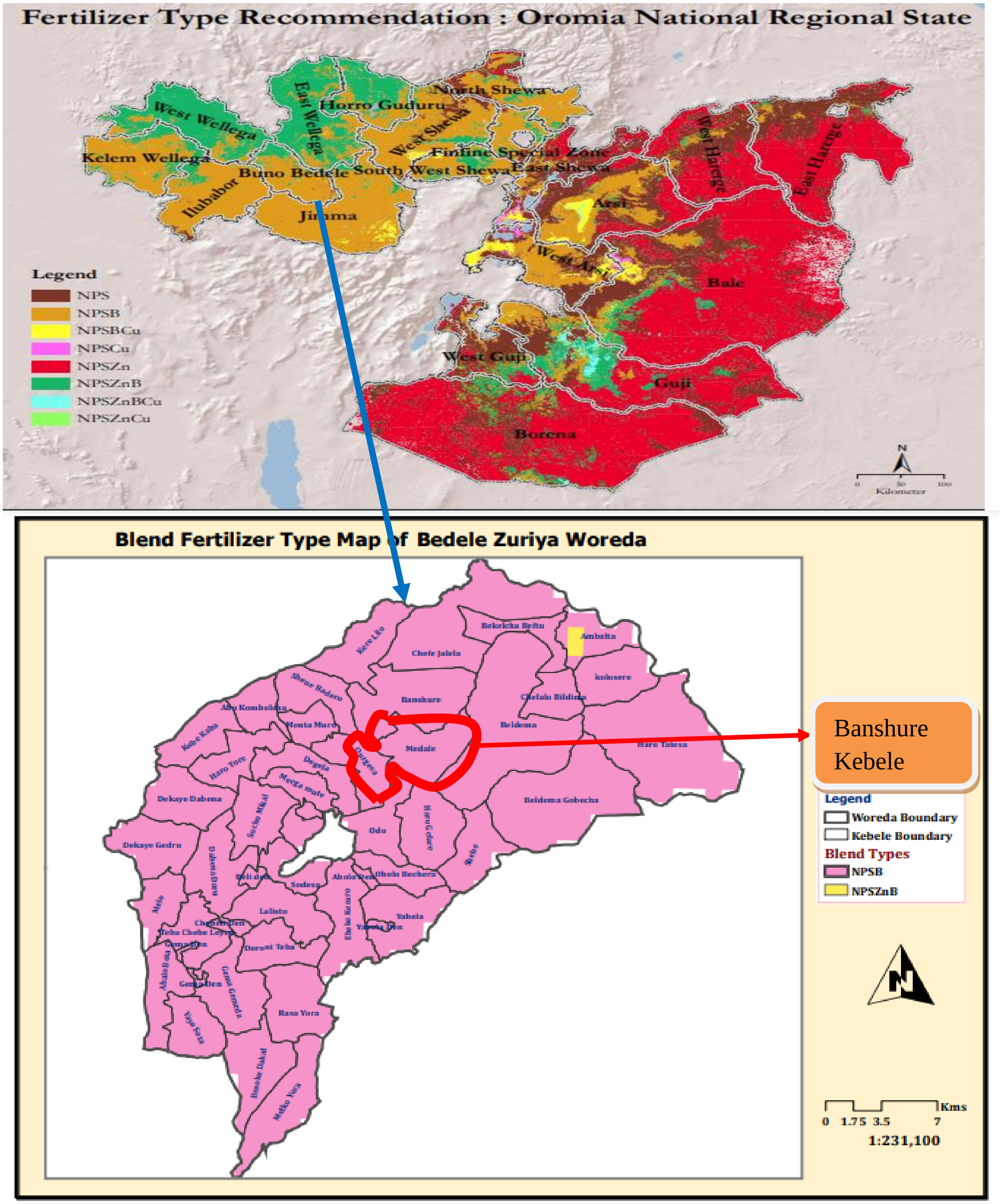
DT=Days to tasseling, DS=Days to silking, PH=Plant height, CL=Cob length, CV=Coefficient of variance, *=significance, **=Highly significance, ns=Non significance

Appendix Table 7. ANOVA Table showing mean square values of yield and yield components of maize as influenced by application of blended NPSB fertilizer rates

Source	DF	Mean square							
		NCPP	TAGDB (kg ha^{-1})	NRPC	NGPC	TGW (gm)	GY (kg ha^{-1})	SY (kg ha^{-1})	HI (%)
Replication	2	8.38^{ns}	742573.7^{ns}	1.38^{ns}	1184.29*	1375.55*	2991453.2*	2098838.5ns	270.88*
Rates	8	167.58**	109937582.7**	0.45^{ns}	9794.74**	7100.03**	32654968.5**	30837970.8**	480.65**
Error	16	6.03	3611331	0.70	316.48	305.95	880414.4	3869111.3	70.62
CV (%)		7.38	15.17	6.49	3.56	4.99	19.14	25.53	22.28

NCPP=Number of cobs per net plot, TAGDB=Total above ground dry biomass, NRPC=Number of rows per cob, NGPC=Number of grains per cob, TGW=Thousand grains weight, GY=Grain yield, SY=Stalk yield, HI=Harvest index, CV=Coefficient of variance, *=significance, **=Highly significance, n s=Non significance.

Appendix Figure 1. Recommended fertilizer for Bedele district by Ethio-SIS (2016)



Source:-Ethiopian soil information system (2016)