EFFECT OF MINERAL FERTILIZER ON YIELD AND YIELD COMPONENTS OF TEFF [(*Eragrostis tef (*Zucc.*) Trotter*] IN TEMBARO DISTRICT, SOUTHERN ETHIOPIA

MSc. THESIS

BY:

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NOVEMBER 2019

JIMMA, ETHIOPIA

Effect of Mineral Fertilizer on Yield and Yield Components of Teff [(*Eragrostis tef* (Zucc.) *Trotter*] in Tembaro District, Southern Ethiopia

MSc. Thesis

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Submitted to Jimma University College of Agriculture and Veterinary Medicine, Department of Natural Resources Management, in Partial Fulfillment of the Requirements for Degree of Master of Science in Soil Science

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November 2019
Jimma, Ethiopia

DEDICATION

This thesis manuscript is dedicated to my mother W/o Wochame Anito and my father Ato Arfito Feka. My great brother Abera Arfito who is still fresh in my memory and deserves great credit for my current achievement.

STATEMENT OF THE AUTHOR

By signing below, I declare that this thesis is a result of my own genuine work. I have followed all ethical principles of scholarship in data collection, data analysis, and write-up of the thesis. All scholarly matters that are included in the thesis have been given recognition through citations. I affirm that I have cited and referenced all sources used in this document. Every serious effort has been made to avoid any plagiarism in the preparation of the thesis.

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Place: Jimma University

Date of Submission: ________________

BIOGRAPHICAL SKETCH

The author, Abeje Arfito Feka, was born on 19th March 1982 in Semen Abukuna kebele in Tembaro District, (South Nations Nationalities and Peoples Regional State) SNNPS. When he reached a school age; he attended 1st to 8th grades at Ambukuna elementary and junior secondary school. He pursued secondary and preparatory education at Mudula Secondary and Preparatory School in the Tembaro District.

After completing secondary education in 2008, he joined Hawassa University to pursue his study for the Degree of Bachelor of Science in Agriculture (Plant and Horticulture sciences) in July 2010.Immediately after his graduation, he was employed by Tembaro Worada Agriculture and Natural Resource development office and served there as a Coffee, Tea and Spices Expert for two years and as an Agronomist for four years.

Then, he joined Jimma University College of Agriculture and Veterinary Medicine in September 2016 for his M.Sc. degree in Soil Science.

ACKNOWLEDGEMENTS

First and for most, I would like to thank and give praise to the Almighty God for providing me with the opportunity to pursue my M.S.c learning and for keeping me and my family healthy to finish this work.

This research would have not been possible without the contribution of many individuals. I am highly thankful to my advisers Abebayehu Aticho and Dr. Tesfaye Shimber, for their keen interest, constant supervision, valuable guidance, consideration, encouragement, and constructive criticisms from the inception of the research proposal to the completion of the write up of the thesis. They shared with me their accumulated professional experience and were cooperative, without which the success of this work would have not been achieved.

I am very much thankful to Ato Esmael Shamebo, head of Tembaro woreda agricultural and Natural Resource development office, for his information and materials support. It is also worth to thank DAs in my study site.

I am indebted to my father Ato Arfito Feka and my mother W/o Wochame Anito who have never been to school but brought me to this end. I am also thankful to my brothers, Abera Arfito, Abrham Arfito, Temesegen Arfito and my sisters Tedelech Arfito and Ayelech Arfito for all the encouragement they gave me during my study. I am also grateful to Mudula Mekaneyesus church leaders and members, whohelped me in pray day and night to God for my study to come to this end.

Last but not least, I am most deeply grateful to my wife w/ro Betsit Yoseph and my child Asebosh Abeje, for helping me strive towards the realization of my potentials and all the inconveniences they have encountered during my absence and their wonderful support and patience during my stay away from home.

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LIST OF ABBREVIATIONS AND ACRONMYS

AE	Agronomic Efficiency
AJY	Adjusted Yield
ANOVA	Analysis of Variance
AR	Apparent Recovery
ATA	Agricultural Transformation Agency
BOFED	Bureau of Finance and Economics Development
CEC	Cation Exchange Capacity
CIMMY	International wheat and maize Improvement center
CSA	Central Statistic Agency
CV	Coefficient of Variation
DAP	Di-ammonium Phosphate
Ethio-SIS	Ethiopian Soil information system
FAO	Food and Agriculture Organization of the United Nations
GAY	Gross Average Yield
GFB	Gross Field Benefit
ha	Hectare
LSD	Least Significant Difference
M.a.s.l	Meter above Sea level
MB	Marginal Benefit
MC	Marginal Cost
MRR	Marginal Rate of Return
NB	Net Benefit
NPSB	Nitrogen, Phosphorus, Sulfur and Boron
NUE	Nitrogen Use Efficiency
RCBD	Randomized complete block design
SNNPS	Southern Nation Nationalities and Peoples Regional States
SOM	Soil organic matter
TSP	Triple super phosphate
WARDO	Worada Agriculture and Rural Development office
WFEO	Worada Finance Economy Plan Office

Effect of mineral fertilizer on yield and yield components of teff [(*Eragrostis tef* (Zucc.)Trotter] in Tembaro District, Southern Ethiopia.

ABSTRACT

Low soil fertility and limited nutrient supply is one of the causes for low teff production and productivity at national level and in the Tembaro district. The overall objective of this study was, therefore to evaluate different rates of mineral fertilizer to optimize teff yield in Tembaro district. To realize this objective, a field experiment was conducted during the main cropping season of 2018. The treatments consisted of factorial combinations of control, five DAP and urea rates (50 kg DAP+50 kg urea/ha, 75 kg DAP+75 kg urea/ha, 100 kg DAP+100 kg urea/ha, 125 kg DAP+125 kg urea/ha and 150 kg DAP+150 kg urea/ha) and five rate blended fertilizers, containing different proportions of N, P, S and B (61kg NPSB +44.5 kg urea/ha,91.5 kg NPSB+66.75kg urea/ha,122 kg NPSB+89 kg urea/ha,152.5 kg NPSB+111.25 kg urea/ha and 183 kg NPSB+133.5 kg urea/ha. The experiment was laid down in Randomized Complete Block Design with four replications on farmer's field. Accordingly, the soils have pH of 5.33-5.42, with44-46% clay, 28-32% silt and 28-32% sand, 0.119-1.3% TN,13.94-15.22mg/kg available S,8.21-9.11mg/kg available P,0.71-0.75mg/kg available B,0.96-1.2% OC,1.66-2.07% OM,5.7-6.8cmol(+)/kg Exchangeable Ca,2.9-2.3cmol(+)/kg Exchangeable Mg,0.79-0.81cmol(+)/kg Exchangeable K,0.06-0.09cmol(+)/kg Exchangeable Na, 49.7-50.6% PBS and 19.8-23.6cmol(+)/kg CEC at (Semen Ambukuna) and (Belela) experimental sites, respectively before sowing. The textural class of soil at both experimental sites was clay. Generally, one year mineral fertilizer application blended (NPSB) plus urea and DAP plus urea fertilizers) may be slightly decrease the soil fertility status both experimental area after harvested except available P soil slightly increased in both experimental sites as compared to before sowing. Effect of fertilizer was also significant ($p<0.05$) for all growth parameters, yield, yield components, except total number of leaves. Fertilizer and location interact to significantly affecting 90% maturity, leaf area, number of tillers and apparent recovery efficiency of P. The maximum grain yield of teff (2426kg/ha) was recorded for183kg NPSB+133.5kg Urea/ha and statistically similar with application of 100kg DAP+100kg urea/ha and 152.5kg NPSB+111.3kg urea/ha, while the minimum value (470.8kg/ha) was obtained from the control plots at study area. The maximum mean grain yield (1655.28kg/ha) was obtained at Belela, while the lowest mean yield (1596.72kg/ha) was recorded at Semen Ambukuna. Therefore, recommended the treatment (100 Kg DAP + 100 kg ha-^{1}) since it produced high marginal rate of return and relatively small total cost of production, for teff production in Tambaro area. Furthermore, based on yield, net benefit and relatively low total cost of production the farmer of Tambaro area also can use 152.5 kg NPSB + 111.3 kg urea in case of absence of DAP in market. However, it was suggested that further research across all soil types, in different years and locations may be required to draw a sound recommendation for teff production in the area. This study provides insights for smallholder farmers to incorporate recommended rate of N and P fertilizer for soil fertility amendment for boosting teff production.

Key Words: DAP and Urea Fertilizers, NPSB, Partial Budget Analysis, Soil Fertility Status.

1. INTRODUCTION

1.1 Background

Soil fertility maintenance is a major concern in tropical Africa, particularly with the rapid population increase, which has occurred in the past few decades. Improving food production and soil resources in the smallholder farm sector of Africa has become an enormous challenge (Smaling and Braun, 1996; Dagne, 2016). Soil fertility is a primary constraint affecting agricultural production in sub-Saharan Africa (SSA) (Guta *et al*., 2014; Tadele, 2017).Soil fertility assessment is an important asset to increase crop production and productivity (Gete *et al.*, 2010*).* Declining soil fertility is one of the major challenges to crop production and productivity, especially for cereals (Amsal andTanner, 2001).Soil nutrient depletion is becoming one of the major challenges of agricultural production of the smallholder farmer in country (Abebayehu *et al*., 2011).

Ethiopia is one of the fourteen sub-Saharan countries with highest rates of nutrient depletion (yu, 2006), due to lack of adequate synthetic fertilizer input, limited return of organic residues and manure, and high biomass removal, erosion, and leaching rates. Soil nutrient mining due to sub optimal fertilizer use on one hand and unbalanced fertilizer use on the other have favored the emergence of multi nutrient deficiency in Ethiopian soils that in part might have contributed to fertilizer factor productivity decline experienced over recent past (Wassie and Shiferaw, 2011). Many small holder farmers do not have access to synthetic fertilizer because of high price of fertilizers, lack of credit facilities, poor distribution, and other socio-economic factors.

Fertilizer usage plays a major role in the universal need to increase food production to meet the demands of the growing world population. Fertilizer application resulted in marked crop yield increases, which for most crops was more than hundred percent (Mengel and Kirkby, 1996). Nitrogen (N) is deficient in almost all soils and phosphorus (P) is deficient in about 70% of the soils in Ethiopia (Tekalign *et al.*, 2001). Low availability of nitrogen and phosphorus has been demonstrated to be major constraint to cereal production. In Ethiopia, smallholder farmers generally apply low amounts of mineral fertilizers to crops (Morris *et al*., 2007). As most research works focus on NP requirements of crops, information on various sources of fertilizers, including K, S, Zn and B and other micronutrients, is quite limited. Application of other sources of nutrients beyond urea and Di-ammonium Phosphate (DAP), especially those containing K, S, Zn and other micro-nutrients could increase crop productivity (CSA, 2017).

The imbalanced fertilization of crops may result in low uptake of some beneficial nutrients and consequently decline in grain yields. As there has been little information on the impact of different types of fertilizers except for nitrogen and phosphorous (64kg N and 46 kg P_2O_5 per ha), an atlas of soil fertility map was developed at country level, indicating that about seven nutrients (N, P, K, S, Cu, Zn and B) are deficient in the soils of SNNP regional state (ATA, 2015). Except for nitrogen and phosphorus, the effect of blended fertilizers including those deficient nutrients on the overall performance and productivity of teff is also unknown. Based on the Ethio-SIS (Ethiopian soil Information System) soil analysis report of 2015, SNNP region lucks S and B, in addition to the low level of P. According to Tadela and Alemu (2016), available P is below critical values for most of the studied sites in the region. This, situation brought about formulations of blended fertilizers, such as NPSB, for different soil types and crops in the country in general, and in SNNP region in particular. However, the amount of P in blended NPSB fertilizers is lower than that in the same rate of DAP. Thus, there is a need to supplement blended fertilizer with additional Psources.

Tef [*Eragrostis tef* (Zucc.*)* Trotter] is a small cereal grain indigenous to Ethiopia. It is the most important cereal grain of country most probably domesticated thousands of years ago before the birth of Christ (Seyfu, 1997). As a result of this, it is a part of the society's culture, tradition and food security. Tef has got both cultural and economic value for Ethiopian farmers with more than six million households' life depending on the production of tef.

Teff yields are decreasing in many parts of the highlands of Ethiopia (CSA, 2012), which could be the result of plant lodging, decline in soil fertility due to high soil erosion and others, and unbalanced chemical fertilizer application. The low teff crop productivity could be due to a complex interaction among the environments, lack of appropriate management practices, biotic and abiotic stresses. Of these, soil fertility problem is one of the major causes of temporal and spatial yield variability (Brhan, 2012).Teff growing area occupies about (7085 ha) of the total acreage of all the major cereals grown and teff 2752.5 ha which is 39% of the production area covered by teff in 2018 cropping season in district. Teff is one of the major cereal crops produced for the purpose of both market and consumption. The average yield of teff in 2018 cropping season was only 1.35 ton ha^{-1} which also is very low as compared with yield potential of teff in the Tambaro (WAO, 2018).Some of the factors contributing to the low yield of teff are low soil fertility and lack of adequate mineral fertilizer application, weeds, erratic rainfall distribution and drought particularly in the low altitudes areas, lack of high yielding cultivars, erosion, lodging and water-logging (Ermias *et al*.,2007).

1.2. Statement of Problem

Ethiopian soil lacks most of the macro and micronutrients that are required to sustain optimal growth and development of crops (Hailu, 2014). In the study area, soil degradation and low agricultural productivity per unit area, as a result of erosion and soil fertility depletion are becoming the major challenges for smallholder farmers. The Soil fertilization programs in the Ethiopia agriculture have been limited to urea and Di-ammonium Phosphate (DAP) over the past five decades. The fertilizer recommendation being used to produce the crop in the area is not in accordance with the specific soil and agro-ecological requirements. Therefore, adequate knowledge on the different rates of blended fertilizer at large-scale farm level is essential in tackling specific and local problems of agricultural production, particularly productivity of teff study area. Excluding nitrogen and phosphorus, the four effect of other plant nutrient on yield and yield components of teff are not identified. This blended NPSB (18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B) fertilizer is currently available and widely used by the farmers in the study area. However, detailed information about the different rate of NPSB nutrients for sustainable agriculture and maximization of teff production to the potential level is still limited. Hence, the present study was initiated with the following objectives.

General Objective

The study was generally aimed at evaluating different rates of mineral fertilizers to optimize teffyield in Tembaro district of SNNP region.

Specific Objectives

- To assess the basic soil fertility parameters of teff growing area.
- To evaluate NPSB nutrient required for optimum growth, yield components, yield and nutrient use efficiency of teff in the study area.
- To determine economically optimum rates of NPSB nutrients for teff crop production in the study area.

Hypotheses: HI

- Application of different rates of NPSB nutrients changes teff yield and yield components and nutrient use efficiency in Tambaro District.
- Application of different rates of NPSB nutrients can determine optimum rates to teff producing farmers.
- The basic soil fertility parameters can affect the teff production in study area.

Hypotheses: Ho

- Application of different rates of NPSB nutrients doesn't changes teff yield, yield components and nutrient use efficiency in Tembaro District.
- Application of different rates of NPSB nutrients doesn't determine optimum rates to teff producing farmers.
- To assess the basic soil fertility parameters don't affect the teff production in study area.

2. LITERATURE REVIEW

2.1. Production and Agro-ecology of Teff

Tef *(Eragrostis tef*) is predominantly grown in Ethiopia as a cereal grain. It is widely grown in both high potential and marginal production areas. Ethiopia is one of the richest centers of crop origin contributing numerous important crops to the world such as *Eragrostis tef*and other related species Cufodontis (1974). Teff is adapted to environments ranging from drought stress to water logged soil conditions. Maximum tef production occurs at altitudes of 1700–2400 m, growing season rainfall of 450–550 mm, with a temperature range of 10–27°C. Tef can grow under wide and diverse agro-ecologies. Even though there are areas where the crop is grown during the short rainy season (*Belg*), tef is mainly cultivated during the main rainy season (*Meher*). The length of the growing period (LGP) ranges from 60 to 180 days (depending on the variety and altitude) with an optimum of 90 to 130 days (Deckers *et al*., 2001). It can be planted, broadcast or sown at 15-20 kg/ha in rows, no deeper than 1 cm, and subsequently rolled (Tefera and Belay,2006;Ecocrop, 2016). Its rapid growth outcompete weeds. It suffers few diseases and pests attacks. Tef is considered as a low risk grain because its vulnerability to pest and diseases is very low (Fufa *et al*. 2011; Minten *et al*. 2013).

Tef is well adapted to a wide range of soil types. It has the ability to perform well in black soils and, in some cases, in low soil acidities. Tef is normally grown on soils of neutral pH, but it has been observed that it tolerates soil acidity below pH 5. Differences exist between cultivars for response to saline conditions. In addition, tef has the capacity to withstand waterlogged, rainy conditions, often better than other cereal grains except rice (ATA, 2013).

The low yield is due to low soil fertility status which is a result of continuous cropping, overgrazing, soil erosion, and complete removal of field crop residues without any soil amelioration activities and low or no input of fertilizers (Seyfu, 1993).

2.2. Soil Fertility Status in Ethiopia

Soil is the most important resource required for Agricultural production **(**Khanif, 2010**)**. The fertility status of Ethiopian soils has also declined and continued to decline posing a challenge to crop production. This is due to, continuous cropping, reduced manure application, removal of crop residues and animal dung for fuel wood and erosion coupled with low inherent fertility of the soils (Tilahun *et. al*, 2007).

The nutrient mining of Ethiopian soils might be caused by the losses of soil organic matter, macronutrient and micronutrient depletion; topsoil erosion; acidity; salinity; and deterioration of other soil physical properties. Due to their low OM content, most of the soils in Ethiopian have low total N content and there is a high crop response to N fertilizers in these areas (Attah, 2010). On account of rapid nitrification, most of the N added as fertilizer containing NH_4 is subject to leaching or denitrification soon after application. Ammonia fixation also affects fertilizer efficiency (Girma *et al.,* 2012). Most Ethiopian soils are deficient in P when analyzed by chemical methods, yet, with the addition of P fertilizers, field crop P responses on these soils, particularly in the central highlands are low, even under improved drainage conditions (Tekalgn *et al*., 2002) owing to unbalanced fertilization. Different studies conducted in Ethiopia in the past few years by various researchers have demonstrated that most Ethiopian soils have very low level of P due to depletion and/or P fixation (Lalisa *et al.*, 2010).

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

2.3. Nutrient Requirement of Teff

The soil fertility involves examining the forms in which plant nutrients occur in the soil, how these become available to the plant, and factors that influence their uptake (FAO, 2006; Haftom *et al*., 2009). This in turn leads to a study of the measures that can be taken to improve soil fertility and crop yields by supplying nutrients to the soil-plant system. This is usually done by adding fertilizers, manures and amendments to the soil but sometimes by supplying nutrients directly to the plant parts by means of sprays. A mineral element is considered essential to plant growth and development if the element is involved in plant metabolic functions and plant cannot complete its life cycle without the element, if usually the plant exhibits a visual symptom indicating a deficiency in specific nutrient, it can be corrected or prevented by supplying that nutrient (Patricia and Lisette Van, 2008; Brhan, 2012). Fertilizer usage plays a major role in the universal need to increase food production to meet the demands of the growing world population (Mitiku, 2008). Fertilizer application resulted in marked crop yield increases, which for most crops was more than hundred percent. The extent to which fertilizers are used still differs considerably between various regions of the world (Tekalign *et al*., 2000; Tulema *et al., 2007*); Brhan, 2012).

Most of the Ethiopian soils contain low nutrient content due to erosion and absence of nutrient recycling. In addition, most of the areas used for production of grains especially tef, wheat and barley fall under the low fertility soils (Hailu and Seyfu, 2001). Low availability of nitrogen and phosphorus has been demonstrated to be major constraint to cereal production. The quantity of fertilizer nutrients required for optimum crop production depends on the inherent capacity of the soil to supply adequate levels of nutrients to growing plants, the yield potential of the crop variety grown and the availability and cost of fertilizers and climatic conditions prevailing during the crop growing season (Refissa, 2012).

2.4. The Need for Blended Fertilizers

Blending fertilizer is defined as the mechanical mixing of two or more granular fertilizer materials to produce mixtures containing nitrogen (N), phosphorus (P), potassium (K) and other essential plant nutrients. It allows small batches of high analysis soil and crop specific fertilizers to be mixed and transported in an economical manner contributing additional profit for farmers and improving the environment because it provides balanced fertilization (James, 1997).

Since fertilizers were introduced to Ethiopia in the Freedom from Hunger Campaign, virtually all fertilizers used in Ethiopia are limited to Di-ammonium phosphate (DAP) and Urea. However, recent completed research and soil tests through the Ethiopian Soil Information System Project revealed that Ethiopian soils are deficient in various other nutrients that are not provided by DAP and Urea (ATA, 2013).

Furthermore, Ethiopia's crop yields have been constrained by a very limited set of imported fertilizers. Therefore, the blending fertilizers here in Ethiopia, smallholder famers will not only have access to an expanded range of soil nutrients, they will actually be able to request custom blended formulas tailored to their specific soil needs.

2.5. Nature of nitrogen fertilizer and its roles in crop production

The atmosphere is made up of 79% N by volume as inert N_2 gas that resists reacting with other elements to create a form of N most plants can use (Foth, 1984). However, the amount of micro-element in available forms in the soil is small, while the quantity withdrawn annually by crops is comparatively large (Brady and Weil, 2002). It is one of the most widely distributed elements in nature. It is present in the atmosphere, the lithosphere and the hydrosphere (FAO, 2013). It is a very mobile element circulating between the atmosphere, the soil and living organisms. Globally, rapid population growth in developing countries increase demand of food supply which cause an increasing of N fertilizer consumption by 60 to 90 percent by the year 2025 (Ortiz-Monasterio *et al.*, 1997).

2.5.1. Role of nitrogen fertilizer in plant system

Nitrogen is the essential element applied in the largest amounts among the soil nutrients for growth and development. The quantity of nutrients required to optimize or sustain crop production depends on the inherent capacity of the soil to supply adequate levels of nutrients to the growing plants, the yield potential of the crops, the variety grown and the availability and cost of fertilizers. Among the macro nutrients, N is first in limiting sustainable crop production (Tisdale *et al.,* 2002).Generally, N is involved in cell multiplication, giving rise to the increase in size and length of leaves and stems, especially the stalks of grains and grasses; increases in chlorophyll contents, giving the leaves their dark green color; plays a part in the manufacture of proteins in the plant and is part of many compounds in the plant, including certain types of basic acids and hormones (Ortiz-Monasterio *et al*., 1997).

Optimum, rate of N increases photosynthetic processes, leaf area production, dark-green color in plants, promotes leaves, stem and other vegetative part's growth and development as well as net assimilation rate (Ahmad *et al*., 2009; Rafiq *et al*., 2010; Bloom, 2015; Hemerly, 2016). Moreover, it also stimulates root growth. It supply Excessive causes higher photosynthetic activity, weak stem the risk lodging, dark green color, reduced productive tillers, reduced product quality, delayed in maturity, increase in susceptibility to insect pest and diseases and build-up of nitrate which is harmful to animals (Brady and Weil, 2002). Its deficiency causes stunted plant growth, development of thin spindly stem, low protein and high sugar content and chlorosis as deficiency symptoms on older leaves which could progress to necrosis under severe conditions. However, adverse effects on annual plants caused by early-stage lack of N cannot usually be corrected by late application of N (Yang *et al*., 2000; IAEA, 2003).

2.5.2. Role of nitrogen fertilizer in the soil

Nitrogen is a very mobile element circulating between the atmosphere, the soil and living organisms. N_2O and NO are the forms of N lost through denitrification and the $NH4^+$ and NO_3^- are the forms of nitrogen can be taken up by the plants or microorganism (immobilization; the conversion of inorganic plant available N (NH_4^+ or NO_3^-) by soil microorganisms to organic forms), however NH_4^+ can be adsorbed or fixed to the soil particle, or oxidized to NO_3^- (Tisdale *et al*., 1995).

Nitrogen occurs in soils in both organic and inorganic compounds of which plants absorb N in its cationic form (NH_4^+) and anionic form (NO_3^-) and obtain readily available N forms from different sources. Nitrogen in the soil can be in different forms and in large quantity, even beyond the demand of some crops. According to Jenkinson (1973), more than 90% of N is found in the form of organic matter but is not readily available to plants. Its availability can be facilitated only through decomposition by soil microorganisms. Inorganic N exists in the form of NH_4^+, NO_3^-, NO_2, NO and the elemental nitrogen (N_2), while the organic forms include protein, amino acids, amino sugars and other complexes.

2.5.3. Teff response to nitrogen fertilizer

Nitrogen (N) is one of the most yield-limiting nutrients for crop production in the world. It is also the nutrient element applied in the largest quantity for most annual crops (Thompson and

Huber, 2007). The increase in use of nitrogen (N) fertilizers for enhancing the agricultural production has been under consideration for the last fifty years (Hirel *et al*., 2007).

Tef responds to N application with remarkable changes in all its yield and yield components. The farm fertility management trial on teff carried out at Holetta agricultural research center in year 2000 at Welmera (Lemlem *et al.*, 2002). According to Debnath *et al.* (2011) indicated that increasing plant height teff increase with N and P at the rates of 64 kg N/ha and 69 kg P/ha on Nitosols. The straw yield and other agronomic parameters such as biomass yield, plant height, days to maturity and dead heart count were highly and positively correlated with the increasing levels of N at the farmer's field on Kobo Vertisol (Temesgen, 2001). Different studies in various environments and times reported that tef responds highly to higher N fertilizer rates. Similarly, Legesse (2004) found that, high yield components were recorded in response to application of high N rate of 69 kg N ha^{-1}. As applied N rates increased, the grain uptake also increased which was also reflected in the plant height, yield and yield components like panicle length, panicle weight, grain yield, straw yield and biomass yield and application of p had shown no significant effects on crop phenology, growth, lodging, and yield and yield components of teff on vertisols (Legesse, 2004). Similarly, Mulugeta (2003) found that application of high rates of N fertilizer (90 kg ha^{-1} N) increased the number of fertile panicles of tef.

Similarly, Berhane (2015) reported that application of high N rate result high amount of biomass yield in sorghum. Application of N has been found to influence grain yield of crops. Mitiku (2008); Haftom*et al*. (2009) indicated that application of high N fertilizer rate (69 kg N ha^{-1}) was the best to obtain high total biomass yield, straw yield and grain yield. Another result reported that high straw and total above ground biomass and grain yields were recorded when high (90 kg ha^{-1}) N was added (Tekalign *et al*., 2000). Successive increase in N rates increased dry matter accumulation and straw yield of tef (Tekalign *et al*., 2000; Mulugeta, 2003).

Most Ethiopian soils are deficit in nutrients, especially nitrogen and phosphorus and fertilizer application has significantly increased yields of crops (Tekalign *et al*., 2001). Temesegen (2001) also reported that the application of different levels of N fertilizer affected grain, straw and biomass yield significantly on farmer's field where increasing N fertilizer rate consistently increased tef grain yield from 1620 kg ha^{-1} in the control treatment to 1950 kg ha^{-1} in the treatment where the highest rate of N (69 kg ha^{-1}) was applied. According to Brhan (2012), crop response to N is greatly reduced when P is limiting. When both N and P were adequate, crop recovery of fertilizer N was approximately 75% compared to about 40% without adequate P fertilizer. Adequate N and P fertilizer was optimize yield and profitability and was maximize the fertilizer N recovery, whilst minimizing the environment impact of fertilizer N use. In soils, N fertilizer stimulated uptake of P application (Alemayehu, 2014). This indicated that, for good crop yield, there should be desirable ratio of plant nutrients. Optimum application of nitrogen for the plant is important also for the uptake of the other nutrients (FAO, 2000).

2.6. Nature of phosphorous fertilizer and its roles in crop production

Phosphorus (P) has long been known to be an essential element in the nutrition of plants. It plays key role in cellular energy transfer, respiration, and photosynthesis (Price, 1970). Phosphorus is an important plant nutrient required by the plants for growth and development making up about 0.2% of a plant's dry weight. A good supply ofPhas been associated with increased root growth and a stiff stalk to resist lodging (Miller and Donhue, 1995). 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).

2.6.1. Role of phosphorus fertilizer in plant system

Phosphorus plays an important role in energy storage and transfer in crop plants. Phosphorus is a component of many cell constituents and plays a major role in several key processes, including photosynthesis, respiration, and energy storage and transfer, cell division, and cell enlargement (Price, 1970). Adequate phosphorus is needed for the promotion of early root formation and growth. Phosphorus also improves crop quality and is necessary for seed formation (Mullins, 2009).

Plants deficient in phosphorus are stunted and in contrast to those lacking nitrogen, are often dark green. Plant P uptake is influenced by P supply, characteristics of the soil and P requirement of crop plants. When P was withheld at early growth period of the plant, tillering and secondary root development was hindered. Early tillering was significantly higher and plants developed both root systems due to adequate P fertilization than only primary or adventitious roots under P deficient conditions (Strongh and Soper, 1974).

In early stages of development, crop plants absorb phosphorous faster from fertilizer than from soil and hence a high proportion of the total P absorbed by young plants is derived from the fertilizer. Minimum number of tillers was due to the deficiency of P that directly altered the normal pattern of tiller emergence by inhibiting the emergence of leaves on the main stem and reducing the rate of tiller emergence (Daniel *et al*., 1998).

2.6.2 Role of phosphorus fertilizer in soil

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 HPO_4^{-2} and $H_2PO_4^{-2}$ depending on the pH of the growing medium although there is no efficient mechanism in the soil to retain $H_2PO_4^-$ and HPO_4^{-2} ions in large quantities as exchangeable anions (Barker and David, 2007).

2.6.3 Teff response to phosphorous fertilizer

Tef responds to P application with remarkable changes in all its yield and yield components. According to Assefa (2016) also indicated the as the rate of NP increasing, the number of days elapsed to heading was shortened. The farm fertility management trial on teff carried out at Holetta agricultural research center in year 2000 at Welmera (Lemlem *et al.*, 2002). However, Sate (2012) reported that plant height of teff significantly affected by application of $P_2O_5$and N with blended fertilizer. The finding disagreement with of Shiferaw (2012), who reported that there was no significance difference among treatments for total number and productive tiller in teff as the rate of N/P_2O_5 was increased from zero to 64/46 kg/ha. Similar, result was also obtained by Tana and Lemma (2015), who indicated that no significant difference in total and productive of tillers plant^{-1}among different blended fertilizers in wheat. In barley, Tigre *et al*. (2014) also reported no significance difference between application of 46N and 69 P_2O_5 kg/ha in total tillers.

According to Alemayehu (2014) reported that total biomass 586 to 1016 kg/ha, harvest index 0.14 to 0.22, panicle weight 0.49 to 0.73g, and seed weight 0.25 to 0.38 mg when P rate was increased from 0 to 9 kg $P_2O_5/m^{2.}$. Grain yield increased from 84 to 218kg/ha when P rate was increased from 0 to 9 g P_2O_5/m^2 (Alemayhu, 2014). According to Brhan (2012), experimental results of N and P fertilizer trial on teff showed that grain yield could be substantially improved with the application of N and P fertilizers. As expected, teff yield response varies accordingly across locations based on the soil fertility status and moisture conditions. For example, under waterlogged and leached *Vertisols* conditions, maximum teff yield was found with the application of 90 kg N /ha. According to Ayalew *et al*. (2011), who indicated that mean yield continuously increased with increased levels of P from 0 to 30 kg/ha, but declined with further P application. Most Ethiopian soils are deficit in nutrients, especially nitrogen and phosphorus and fertilizer application has significantly increased yields of crops (Tekalign *et al*., 2001).

Adequate N and P fertilizer was optimize yield and profitability and was maximize the fertilizer N recovery, whilst minimizing the environment impact of fertilizer N use. In soils, N fertilizer stimulated uptake of P application (Alemayehu, 2014). According to Brhan (2012), crop response to N is greatly reduced when P is limiting.

2.7. Nature of sulfur fertilizer and its roles in crop production

Sulfur (S) has long been recognized as at least 17essential elements for plant growth and development and is classified as a macronutrient. Crop responses to applied sulfur have been reported in a wide range of soils in many parts of the world (Fageria, 2009). Sulfur (S) 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).Their deficiency results in stunted growth, reduced plant height, tillers, spikelets and delayed maturity. Sulfur deficient plants have also less resistance under stress condition (Doberman and Fairhurst, 2000).

According to Habtegebrial and Singh (2006), the deficiency of Sin soils is partly exacerbated by the fact that the Ethiopian agriculture mainly emphasizes on the use of high analysis NP fertilizers that contain little available S, continuous mono cropping, seldom application of organic wastes, and the complete removal of crop residues. In addition, organic S must be mineralized to sulfate-S to be taken up by crop plants. Therefore, the lower the organic matter content of the soil the more likely S deficiency is to occur.

According to Depending upon available S levels, the wheat yield can increase from 0 to 42%, usually obtaining the best response with S application between 10 and 20 kg ha^{-1}, even though higher supplies of S (49-60 kg ha^{-1}) have been reported for highly calcareous soils in India (Pompa *et al.*, 2009).

According to Alemu *et al*. (2016), who reported that available S ranged between 3 and 63ppm and nearly 98% of the agricultural soils of the Kembata Tembaro District had below optimum sulphur values. There are three main sources of sulfur availability to plants. These sources are organic matter, soil minerals and sulfur gases in the atmosphere and also small amount of S is supplied by irrigation water. Sulfur occurs primarily in the sulfate ($SO4^{-2}$) form in the soil (Abraha, 2013).

2.7.1 Teff response sulfur fertilizer

Fageria *et al*. (2011) also indicated that application of S enhanced the photosynthetic assimilation of N in crop plant. Hence, application of N and S increased the net photosynthetic rate which in turn increased the dry matter and grain yield as 90% of dry weight considered to be derived from products formed during photosynthesis. Sulfur additionally enhances efficiency of use of supplementary nutrients of plants, chiefly N and P (Rafiq *et al*., 2016). One of the major nutrients essential for plant growth, root nodules formation of legumes and plant protection mechanism is sulfur. Sulfur application up to 60 kg ha^{-1} can make nitrogen and phosphorus efficient (Sarfaraz *et al*., 2014).

2.8. Role and availability of micronutrient in the soil

The micronutrients or trace elements are iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), chlorine (Cl) and boron (B) (FAO, 2000; Barker and David, 2007; Fageria, 2009). They are part of the key substances in plant growth and are comparable with the vitamins in human nutrition. Being taken up in minute amounts, their range of optimal supply is very small (FAO, 2000). Their plant availability depends primarily on the soil reaction. Micronutrients are essential elements that are used by plants in small quantities. Yield and quality of agricultural products increased with micronutrients application; therefore human and animal health is protected with feed of enrichment plant materials. There is more than 90% of superoxide dismutase in chloroplasts, which about 4 to 5 percent of it is in mitochondria (Sharifianpour *et al*., 2013).

2.8.1. Nature of boron fertilizer and its roles in crop production

Boron is an essential element for better utilization of macro-nutrients by plants and there by greater translocation of photo-assimilates from source to sink during growth period (Ali *et al*., 2013). Boron (B) is an essential micronutrient for plants, and plant requirements for this nutrient are lower than the requirements for all other nutrients except molybdenum and copper. It is the only non-metal among the micronutrients and the only micronutrient present over a wide pH range as a neutral molecule rather than an ion (Epstein and Bloom, 2005).

Two types of B deficiencies are encountered in agricultural soils. One is a natural deficiency, due to a lack of boron in the soil-forming minerals, and the other is an induced deficiency, the result of over liming or other adverse environmental conditions (Fageria, 2009). Boron is required for normal development of reproductive tissues and deficiency results in low grain set and poor seed quality. Most the cereals crops like wheat and rice with small B requirement can suffer from impaired seed set due to B shortage at a critical growth stage (Shorrocks, 1997).

2.8.2. Teff response boron fertilizer

Boron is involved in N and P metabolism, in plants poorly supplied with B, NO_3^- N accumulated in the roots, leaves, and stems, showing that NO_3^- reduction and amino acid synthesis were inhibited. Boron is mainly associated with cell wall pectin, and physical characteristics of the growing cell wall were altered under B deficiency (Brown and Hu, 1997). Plants absorb boron in the form H_3BO_3, and it moves to plant root mainly by mass flow and diffusion. Uptake of B in crop plants is mainly determined by yield level. Variation in B uptake was about 99% in rice and 97% in dry bean with increasing plant age. This variation in B uptake may be associated with increasing dry matter of shoot in both crop species (Fageria and Barbosa, 2006). The decrease in B uptake at harvest was associated with translocation of this element to grain. Boron recovery under field conditions by annual crops is generally in the range of 5 to 15% the year of application, and for most annual crops, uptake of 100 to 200 g B ha^{-1} of applied B could be expected to be sufficient (Shorrocks, 1997).

Boron is one least mobile micronutrients in plants, and the deficiency symptoms appear first young growing parts and merstematic tissues, such as new leaves, roots and flower buds (power and Prasad, 2010). According to Debnath *et al.* (2014) application of B at the rate of 0.75 to 3.0 kg/ha found no significant difference on plant height of wheat. The researcher reported that the application of boron on wheat yield and yield attributes like grain yield, straw yield and thousand seed weight are statically influenced.

2.9. Effect of blended fertilizer on agronomic attributes.

Blended fertilizer is defined as the mechanical mixture of two or more granular fertilizer materials containing N, P, K and other essential plant nutrients in defined proportions (James, 1997).Tef responds to blended fertilizer application with remarkable changes in all its yield and yield components. Studies on the response of tef to NPSB fertilizer, by different authors showed that increased application resulted in increased production.

According to State Tana and Lemma (2015), who indicated that no significant difference in total and productive of tillers plant^{-1}among different blended fertilizers in wheat. According to Brhan (2012) reported that application of blended fertilizer brought significant difference in yield and growth parameters. Application of blended fertilizer with Cu and Zn significantly increased leaf area of maize as compared to blended fertilizer, recommended NP + Cu + Zn, recommended NP and control (Dagne, 2016).

The treatment which received blended fertilizers under row planting responded more significantly to plant height, panicle length, seed weight/panicle by 260, 133 and 65% respectively, than the control plots on both *Vertisols* and *Nitosols* (Brhan, 2012). Similarly, the study Shiferaw (2012) who reported that above ground dry biomass yield was significantly affected by application of blended fertilizer and DAP + Urea. According to Wakjira (2018) who reported that harvest index obtained from blended fertilizer might be attribute of sufficient quantity of nutrients particularly p for translocation to sink.

Blended fertilizer (Zn and B micronutrients combined with NPK macronutrients improve nutrient concentration, and uptake and enhancing yield of teff (Feyera *et al*., 2014). According to Lemlem (2012), reported that the main effect of blended fertilizer, DAP and urea fertilization significantly increased the N, P, K, Zn, Mg and S concentration of teff grains in both Regosols and Vertisols. Similarly Feyera *et al*. (2014), reported that the agronomic performance was improved through application of blend of macro with micronutrient in an appropriate form in fertilizer in nutrient deficient soil, as a result enhanced nutrient use efficiency of teff which increased the grain productivity.

According to Feyera *et al*. (2014), report that greater solubility in the soil, total nutrient uptake and fertilizer use efficiency, and the inclusion of micronutrients in its formulation, application of 200 kg of 14N $21P_2O_5$ $15K_2O$ 6.5S 1.3Zn 0.5B blended + 23 kg N ha^{-1} fertilizer brought higher yield (2147.7 kg ha^{-1}), compared to NPK fertilizer has been practiced at the study area. Therefore, this blended fertilizer can be recommended for teff production particularly in the study area as well as it greatly benefit farmers where deficiencies of micronutrients in the soil significantly reduce the productivity of the crops. According to Gebrekidan *et al.* (2015), in both vertisols and regosols significantly increases nutrient uptake than the other trials because yield is high. Therefore, application of blended fertilizer and row seeding rate increases yield and yield components than DAP and Urea because it contains many mineral elements such as N, P, K, Mg, Zn and S. And nutrient uptake is high in plots with blended fertilizer and banded trials because, nutrient uptake is the product of nutrient concentration and grain yield. Nutrient concentration on *Vertisols* significantly increased N (53.2%), P (52.3%), Zn (38.3%), Mg (137.2%) and S (79.44%) relative to the control.

3.1.1. Climate

The study area consists of three distinct agro-climatic zones, *“Kola*” (10%), *“Wayne-Degas”* (85%) and “*Degas*” (5%) at Semen Ambukuna and “*Kola*” (90%), *“Wayne-Degas”* (10%) at Belela. The average annual temperatures of Semen Ambukuna and Belela Kebele are 21.5^{o}C and 25.24^{o}C with mean annual precipitation of 1275.32mm and 1141.92mm, respectively (Appendix Tables 11 and 12). The areas have bimodal rainfall distribution such as “*Belg*” and “*Meher*” “*Belg*” is the short rainy season that lasts between March and May. The “*Meher*” season, which is the longest rainy season, lasts between June and September. Rain that occurs during the “*Meher*” season is very intensive and long. Most crop production takes place during the “*Meher*” (May to September) season. The dry months in the area extends from middle of October to end of March and May is also included in dry season. The altitude of the study sites in Semen Ambukuna and Belela Kebele is about 1705 and 1450 m.a.s.l, respectively (WARDO, 2018).

3.1.2. Population

The total population of the study district is 190,350, from these female108,302;male 89,272 and total population of Semen Ambukuna 5800; male 2500; female 3300; total population of Belela 5632; male 2453; female 3179 (Tembaro woreda finance and economy plan office, 2018) . The area is characterized by high population density. Thus, land holding is as low as an average of 0.25ha per household (WFEO, 2018).

3.1.3. Farming Systems

The existing farming system in the area is mixed agriculture, i.e., intensive and continuous crop cultivation and animal husbandry. The common land use types in the area can be categorized in to cultivated land, villages, grazing land and some other miscellaneous lands such as roads and stony lands. There are two cropping seasons in the area. The major crops grown in the area include maize (*Zea mays* L.), wheat (*Triticum aestivum* L.), barley (*Hordemv ulgare*L.), and teff [*Eragrotis tef (Zucc.) Trotter*], sorghum (*Sorghum bicolor* L.), chickpea (*Cicerarietinum* L.), root and tubers, including enset (*Ensete ventricosum*) and potato (*Solanum tuberosum*). Fruits such as avocado (*Persea americana*), mango (*Mangifera indica*), banana (*Musa paradisiaca*) and papaya (*Carica papaya*); and stimulants, such as coffee (*Coffee arabica*) and khat (*Catha edulis*) are also grown in the area (WARDO, 2007).

3.1.4. Vegetation

Until the down fall of the Derge regime, Tembaro district was known by its natural forest, mainly found in the periphery of Omo River and near the main town of the district, commonly known as the 'Lamo' natural forest. It also has plantation forests in degraded areas. According to the surrounding elder's descriptions, 40 years ago the area was covered by indigenous trees such as poducarpus and juniperus species. Small patches/pockets of the remaining high forests are found now in the area with common species of *Cordia africana*, *Prunus africana, Albizia gumnifera*, Eucalyptus species, Ficus species, *Croton macrostachus, Gravelia robusta,* Acacia species, and other various native vegetations (WARDO, 2007).

3.1.5. Soil

The common soil in the district is Nitisols (SNNPR BoFED, 2004). It is also the predominated soil type in the study area with a traditional name of (Bsha buch) meaning red soil. This soil type occurs in high rainfall areas on flat to slopping terrains. It is dark reddish brown to dark red in color, with deeply developed clay illuviation horizon of high structural stability. Nitisols are well drained, porous with high water holding capacity, and said to be the best agricultural soils with clay-to-clay loam texture and characterized by strongly acidic to moderately acidic reaction and low soil P (Tadela and Alemu, 2016). Nitisoils (alfisoils) develop on a wide range of parent materials: volcanic, metamorphic, and granite, sandstones and limestone (Mesfin, 1998; Brady and Weil, 2002).

3.2. Treatments, Experimental Design and Plot Management

A factorial experiment consisting of the eleven treatments a control and each five different rates of DAP + Urea and blended fertilizers (NPSB) + Urea was laid down at two locations (Semen Ambukuna and Belela) (Table 1). The fertilizer materials used in the experiment Di-ammonium (46% P_2O_5 and 18% N), urea (46 % N) and blended NPSB (18.9% N, 37.7% P_2O_5, and 6.95% S and 0.1% B). The experiment had each five rates of NPSB (61, 91.5, 122,152.5 and 183 kg ha^{-1}), DAP (50, 75,100,125 and 150kg/ha) and Urea (50, 75,100,125 and 150kg/ha) which were derived on basis of the national blanket recommendation for teff.

The experiment was carried out in a randomized complete block design (RCBD) with four replications, 44 plots each experimental sites. The gross plot size for the trial was 8.6mx 28m

(240.8 m^2) and each plot had an area of 1.4 m × 2 m (2.8 m^2) with net plot of 0.8 m x 1.5 m (1.2 m^2), Spacing between blocks, plots and rows were 1m, 0.5m and 20cm, respectively. An experimental unit consisted of seven rows, where the two rows were used as border effects and five rows as net plot with 1.2 m^2 (0.8 m × 1.5 m) area. After the layout, the plots were leveled manually; and each treatment was randomly assigned to the experimental plots within a block (replication).

The experimental fields were prepared by using oxen plough in the conventional way, where the fields were ploughed three times before planting. The other crop management practices were applied uniformly to all plots as per the recommendation for the crop. The experiment was conducted at two locations at farmer's field in the study area during the 2018/2019 cropping season. Seed of variety Kuncho (Dz-Cr-387) were drilled at the rate of 5.0 kg/ha in 20 cm apart rows (Tareke and Nigusse, 2008). While of urea applied in two splits. Full rates of DAP and NPSB were applied at sowing, while half top dressed 14 days after sowing and the remaining half after tillering or 37 days.

Table 1. Detail treatment set up of the experiment.

Treatment cod	Treatments	Rate of each blend type			
		N	P_2O_5	S	B
T1	Control	0	0	0	0
T2	50kg DAP + 50 kg Urea	32	23	0	0
T3	75kg DAP + 75 kg Urea	48	34.5	0	0
T4	100kg DAP + 100kg Urea	64	46	0	0
T5	125kg DAP + 125kg Urea	80	57.5	0	0
T6	150kg DAP + 150kg Urea	96	69	0	0
T7	61kg NPSB + 44.5 kg urea ha^{-1}	32	23	4.24	0.06
T8	91.5 kg NPSB + 66.75 kg urea ha^{-1}	48	34.5	6.36	0.09
T9	122 kg NPSB + 89 kg urea ha^{-1}	64	46	8.48	0.12
T10	152.5 kg NPSB + 111.3 kg urea ha^{-1}	80	57.5	10.59	0.15
T11	183 kg NPSB + 133.5 kg urea ha^{-1}	96	69	12.72	0.18

In the experiment, 100kg DAP + 100kg urea and 122kg NPSB + 89kg urea were used as base line to calculate NPSB rated for the treatments. Hence,

100kg DAP =46kg P_2O_5, 100kg NPSB=37.7kg P_2O_5, therefore,

100kg NPSB =37.7kg P_2O_5

Y Kg NPSB =46kg P_2O_5

100kg NPSB x $46P_20_5/37.7P_2O_5$=122kg NPSB}……………………………………………[1]

Calculating from 100kg NPSB =18, 9 kg N and 122 kg NPSB =XKg N

18.9 kg N x 122 kg NPSB/100kg NPSB =23.0kg N

Then, 100kg DAP + 100kg urea=64kg N, 64kg of N-23kg of N=41kg of N or 89kg urea fertilizer}……………………………………………………………………………………...[2]

Therfore,122kg NPSB + 89kg urea were used as base line blended fertilizer rate.

3. 3. Data collection

3.3.1 Soil sampling and analysis

Pre-planting and after harvesting soil samples was taken randomly in a diagonal pattern from the experimental sites at depth of 0-20 cm. Fifteen sub-samples were taken by an auger from the whole experimental field and combined to form one composited sample before planting and eleven composite samples after harvesting from each experimental site. Then, the collected samples were air-dried at room temperature under shade and ground to pass through a 2mm sieve for laboratory analysis of soil pH, and available phosphorus. Small of this 2 mm sieved material allowed passing through 0.2mm sieve for soil organic carbon (OC) and total nitrogen. The composite soil samples were analyzed for selected physicochemical properties mainly textural analysis (sand, silt and clay), soil pH, total nitrogen (N), available Sulphur (S), organic carbon (OC), available phosphorus (P), cation exchange capacity (CEC), exchangeable potassium, magnesium and calcium and besides available P, TN, OC ,CEC and pH of the soil samples collected after harvest were determined using the appropriate laboratory procedures at Wondo Gent and Areka Soil Laboratories using the standard analytical procedures.

The pH of the soils was measured by potentiometrically. Organic carbon (OC) was determined by the wet combustion procedure of Walkley and Black as outlined by Van Ranst *et al*. (1999). Organic matter content of the soil was calculated by multiplying the organic carbon percentage by 1.724 following the assumptions that OM is composed of 58% carbon.

Total nitrogen content of the soil was determined by wet-oxidation procedure of Kjeldahl method (Bremner and Mulvaney, 1982).

Available phosphorus was determined using the Bray II method (Bray and Kurtz, 1945) as the experimental soil is acidic.

Exchangeable cations (Ca, Mg, Na and K) content and cation exchange capacity (CEC) of the soils were determined by ammonium acetate (pH 7) method using the percolation tube procedure (Van Reeuwijk, 1993).

The percent base saturation of the soils was calculated as the percentage of the sum of the basic exchangeable cations (Ca, Mg, K and Na) to the CEC (Bohn *et al.*, 2001). The contents of extractable micronutrients were determined using Mehlich-III soil test extraction procedure. Available S was determined by monocalcium phosphate extraction method or turbidimetric estimation (Hoeft *et al*., 1973). Available B was determined using hot water method (Havlin *et al*., 1999).

3.3.2 Plant tissue analysis

Plant samples collected at harvest were partitioned into vegetative and grain parts for the determination of N and P concentrations in the grains and straw. The samples were collected from each treatment with in a replication. The straw samples were washed with distilled water to clean the samples from contaminants such as dust. Then, samples were oven dried at 70 °C to a constant weight, ground and sieved through 0.1 mm sieve size and saved for laboratory analysis.

Nitrogen content of the samples was determined using micro-Kjeldahl Method (Bremner and Mulvarey, 1982). About 0.3g of each grain and straw samples were taken for analysis of N uptake in the grain and straw, which was determined after multiplying nitrogen content of the grain and the straw by the respective yields. Total nitrogen uptake was calculated as the sum of grain N uptake and straw N uptake and expressed on ha basis (Hussain *et al*., 2011).

Similarly, 0.3g of finely ground samples was digested with 2:1 mixture of nitric (HNO_3) and perchloric acids ($HC1O_4$). Then, phosphorus in the solution was determined calorimetrically using molybdate and metvanadate for color development (Sahlemedehin and Taye, 2000). Grain and straw P uptake was calculated by multiplying P content with the respective straw and grain yield ha^{-1}.

Apparent fertilizer N and P recovery was calculated using the following formula [(UN - Uo) / n] x 100; where UN stands for nutrient uptake at ‘n’ rate of fertilizer nutrient and Uo stands for nutrient uptake at control (no fertilizer nutrient). Agronomic nutrient use efficiency and apparent recovery efficiency (AR) were calculated by the formula developed by Fageria and Baligar (2003).

$$AR = \frac{\text{TU fertilizized treatment} - \text{TU control}}{\text{Fertilizer applied per ha}} * 100 \ldots [3]$$

Agronomic N and P use efficiencies (AE) were calculated by using procedures described by Craswell and Godwin (1984) as:

$$\text{AE} = \frac{\text{Grain yield of fertilizer treatments} - \text{grain yield of control treatment}}{\text{Fertilizer applied kg per ha}} \text{kg} \ldots [4]$$

3.3.3Phenologicaldata

Days to 50% heading: was determined by counting the number of days from sowing to the time when 50% of the plants started heading.

Days to 90% physiological maturity: was determined as the number of days from sowing to the time when 90% of plants reached maturity based on visual observation.

3.3.4 Growth parameters

Plant height (cm): was measured from the base of the main stem to the base of the fully opened top leaf until panicle emergence. Later on, it was measured from the base of the plant to the collar of flag leaf for 20 randomly selected plants from the net plot.

Panicle length: The length of panicle from the node where the first panicle branch emerged to the tip of the panicle was measured for randomly selected 20 culms in the net plot area.

Leaf area (LA cm^2): was estimated as leaf length × maximum leaf width × 0.73 for 20 randomly selected plants from the net plot area, where physiologically well performing medium two leaves were considered per plant and 0.733 was used as a correction factor for teff and the mean value was taken as LA per plant for each plot (Mckee, 1964).

Number of leaves per plant: Only fully developed leaves were counted weekly. Leaves were considered fully developed when the leaf collar was easily recognizable.

Number of tillers per plant: The average number of tillers per plant was counted excluding the main shoot for 20 randomly selected plants from the net plot area.

Number of productive tillers: The number of productive tillers was determined by counting the tillers that produced panicles in pre tagged 20 plants.

3.3.5 Yield and yield components

Grain yield: Grains obtained from each unit plots were sun dried and weighed carefully and finally converted to kg ha^{-1}. Seed moisture content was determined using seed moisture tester. Then, grain yield of each treatment was adjusted to the standard moisture level the conversion factor for each treatment to get the adjusted yield using the following formula (Biru, 1979):

$$\text{Conversion factor (C.F)} = {}^{100-Y}\!/_{100-X} \quad \text{......[5]}$$

Where, Y is actual moisture content and X is the standard moisture content to which the yield is to be adjusted (for cereals the standard moisture content is 12.5%).

Adjusted yield = C.F * Recorded grain yield from each Plots…………………………………..[6]

Above ground dry biomass (kg ha^{-1}); above ground dry biomass yield was measured from plants harvested from the net plot area after sun drying for one week.

Straw yield (kg/ha.**);** Straw obtained from each unit plot was dried in sun and weighed to obtained the final straw yield per plot and converted to kg/ha.

Harvest index (HI); was calculated as the ratio of the total grain yield to the total above ground biomass yield harvested from each plot.

HI=Grain yield/ Total biomass x 100 (Fleischer *et al*., 1989)………………………………[7]

Dry root mass(qt/ha): was counted at physiological maturity from thee randomly selected rows of 0.6 m in length from the net plot as converted to m^2 and measured after sun drying for one week.

3.4. Economic Benefit Analysis of Fertilizer Use

Economic analysis was performed to evaluate the economic feasibility of the treatments by using partial and marginal analyses. Gross income was estimated from the average grain yield and straw yield (kg ha^{-1}) multiplied by the respective average open market price (Birr kg^{1}). The economic analysis, the average yield was adjusted downwards by 10%, taking in to consideration that farmers obtain 10 % less than the yield achieved in an experimental field (CIMMYT, 1988). The average open market price for teff seed (157 ETB/ha) the official prices of urea (1216.91 ETB ha^{-1}), DAP (1196.40 ETB ha^{-1}), and blended fertilize NPSB (1280.35 ETB ha^{-1}) at both experimental sites were used for the analysis. Five workers for DAP, urea and seed application and five workers for blended fertilizer, urea and seed application were considered per hectare. The wage rate per worker was 60 Birr per day. Cost of land preparation, field management, harvesting, transportation, storage, post-harvest handling, and others were not included in the calculation because these activities were applied equally for all the treatments. The economic analysis was based on the formula developed by CIMMYT (1988) and given as follows:

Gross average yield (GAY) in kg ha^{-1} was an average yield of each treatment.

Adjusted yield (AJY) was the average yield adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. Hence,

$$AJY = GAY - (GAY * 0.1) \qquad [8]$$

Gross field benefit (GFB) was computed by multiplying field /farm gate price that farmers reconceived for the crop when they sale its adjusted yield. Thus,

$$GFB = AJY * fiel\ or\ farmgate\ \ price\ of the\ crop \qquad [9]$$

Total variable cost (TC) included current price of DAP (birr kg $^{-1}$), urea (birr kg^{-1}), NPSB (birr kg^{-1}) and teff seed, and application costs of DAP, urea and blended fertilizer.

Net benefit (NB) was calculated by subtracting the total costs from the gross field benefit for each treatment, i.e.

$$NB = \text{ Gross income} - \text{total variable cost (Shah } et\ al., 2011) \qquad [10]$$

Marginal cost (MC) = change in costs between treatments.

Marginal benefit (MB) **=** change in benefits between treatments.

Dominance analysis was carried out by first listing all the treatments in their order of increasing costs that vary (TVC) and their net benefits (NB) were then put aside. Any treatment that has higher TVC but net benefit that was less than or equal to the preceding treatment (with lower TVC but higher net benefits) was considered as a dominated treatment (marked as “D”).

$$Marginal\ rate\ ofreturun(MRR\ \%) = (\frac{MB}{MC})100 \qquad [11]$$

Marginal rate of return was computed to measure the effect on net return of an additional capital invested in a new technology, compared to the control

3.5 Data Analysis

Data was collected on plot basis, checked for meeting all the assumptions of (ANOVA) and subjected to analysis of variance (ANOVA) using SAS Version 9.3 statistical software (SAS Inc, 2013). Mean separation for treatment differences was carried out using the least significant difference (LSD) test at $P \leq 0.05$ level.

The model of RCBD

$\chi ij = \mu + \tau i + \beta j + Eij$.. [12]

Where χij = observation of the ith treatment in the jth block.

μ = overall mean

τi = ith treatment effect ($\mu i - \mu$)

Bj = jth block effect ($\mu j - \mu$)

Eij = effect of the ith treatment in thejth block ($\chi ij - \mu i - \mu j + \mu$)

i = 1... t, j = 1...

4. RESULTS AND DISCUSSION

4.1 Selected Soil Physico-chemical Properties of the Experimental Sites before Sowing

Analytical results of the soil before sowing of teff indicated that texture of the soil was dominated by clay fraction, as it contains 44% clay, 28% silt and 28% sand at experimental site one (Semen Ambukuna) and 46% clay, 22% silt and 32% sand at experimental site two (Belela). According to the soil textural class determination triangle, soil of the study area was found to be clay (Table 2). This result was in line with the findings of Tadela and Alemu (2016) who reported that textural class of the soils around the study area is clayey. Soil texture is an important soil physical property as it determines water infiltration, water holding capacity of the soil, the ease of tilling, the amount of aeration, and also influences soil fertility (Gupta, 2004). Hence, the clay content observed in the present study might indicate the good water and nutrient holding capacity of the soil of the study area.

Table 2 Particle size distribution and texture of soils of the study area

particle size distribution	Experimental Site one (Semen Ambukuna)	Experimental Site two (Belela)
	Measured values	
Sand (%)	28	32
Silt (%)	28	22
Clay (%)	44	46
Textural class	Clay	Clay

Soil organic carbon content ranged between 0.96% for Site one and 1.2 % for Site two, which was low in both cases (Table 3). According to Tekalign *et al*. (1991), organic carbon content of <0.08% is rated as very low, 0.08 - 2.59% as low, 2.59 - 5.17% as moderate and > 5.17% as high. In agreement with the present result, Tadela and Alemu (2016) have indicated that the status of organic matter (OM) of *Nitisols* of the study area was low to medium for agricultural use. Such a low amount of organic matter in the soil could be related to different factors, such as environmental or climatic and soil conditions, vegetation cover, and history of cultivation and soil or farmland management practices. The decline of soil OM and, thus, low level of total nitrogen in the study area could be attributed to lack of any OM amendment and total removal of crop residues from farm lands for animal feed and residue burning after harvest. Laboratory results show that application of organic fertilizers, such as green manure and farmyard manure would help increase soil OM contents in the study areas. In line with this, it has been reported that the most cultivated soils of Ethiopia were poor in their organic matter content due to low amount of organic materials applied to the soils and complete removal of biomass from the field (Tesfaye and Sahlemedhin, 2002;Yihenew, 2002).

Total nitrogen content of the soils in the study is also fall in the low range (Table 3), as the classification by Havline *et al*. (2013) shows that total nitrogen contents of the surface soils in some parts of Ethiopia were rated as low, as < 0.1% regarded as very low, 0.1 - 0.15% as low, 0.15 - 0.25% as medium and > 0.25% as high. The low soil nitrogen content in the study area could be due to loss of nitrogen from the soil system through leaching, denitrification, volatilization, crop removal, soil erosion and runoff, as the land has been continuously cultivated for longer period of time. Hence, this indicates that, the soils were deficient in nitrogen possibly due to intensive cultivation, lack of organic materials amendment and removal of crop residues after harvest and, thus, unable to support proper growth and development of crops, which confirms that the site must be fertilized with external N inputs.

In general, available P content of soil was also below the critical values for the growth of plants, and ranged from 8.21mg/kg and 9.11mg/kg, which was at low level at Semen Ambukuna and Belela sites, respectively. According to Landon (1991) has rated available (Bray II extractable) soil P level of less than 10 mg kg^{-1} as low, 11-17 mg kg^{-1}as medium and greater than 18 mg kg^{-1} as high. In agreement with the results of the present study, Mesfin (1998) has reported that the available P of *Alfisols* (*Nitisols*) is generally low, indicating that the soil of the experimental sites was low in available P content, which is not adequate for optimum growth and yield of teff. The results of the present study were also in line with the findings of Wakene and Heluf (2003) who indicated that the existence of low contents of available P is a common characteristic of most Ethiopian soils. The low level of available phosphorus in the study areas could be due to fixation in such acidic soils, indicating that, it is important to apply phosphorus fertilizer from external sources based on the recommended rates and lime to an available the inorganically bonded p in the soil. The report of FAO (2008) also shows the advantage of external application of phosphorus fertilizer sources for good crop growth and yield.

Soil pH is one of the most important properties that affect plant growth and development, as it affects cation exchange capacity and availability of essential elements. In the present study, soil pH values ranged from 5.33 and5.42 for Semen Ambukuna and Belela sites, respectively (Table three).These values indicated that the soil has moderately acidic reaction at both experimental sites, as Mesfin (2007), has rated soil pH < 4.5 is very strongly acidic, 4.5 - 5.0 strongly acidic, five point one – five point five moderately acidic, 5. 6 - 6.0 slightly acidic and 6.1 – 6.5 neutral. The moderately acidic nature of the soil at both sites may indicate that it is suitable for teff production. According to the report of FAO (2000) the preferable pH ranges for most crops and productive soils fall between 4 and 8.

Available boron in the experimental soil had values rangingfrom0.71 and 0.75mg/kg at Semen Ambukuna and Belela study area, respectively (Table 3). According to Ethio-SIS (2014), critical B value for most Ethiopian soils is 0.8 mg per kg. This indicates that soils of both experimental sites are deficient in boron and, thus, there is a need to apply boron containing fertilizers.

Soil available sulfur was found to be 13.94 and 15.22mg/kg at experimental site Semen Ambukuna and Belela, respectively (Table 3). According to the rating of Ethio-SIS (2014), soils which have < 9 mg $kg^{-1}$are regarded very low, 10 - 20 mg kg^{-1} low, 20 - 80 mg kg^{-1} medium, and > 80 mg kg^{-1}high in available sulfur. Thus, soils of both experimental sites were low in available sulfur content, which was not adequate for optimum growth and yield of teff, indicating the importance of applying sulfur fertilizer sources for good crop growth and yield (FAO, 2008). In agreement with this result, a study conducted in southern part of Ethiopia showed that S is the deficient nutrient in addition to N and P (Alemu *et al.*, 2016).

Table 3some soil chemical properties of the study sites at 0 – 20 cm depth before planting.

Soil parameter	Site one	Site two	Rating	References
	Measured values			
TN (%)	0.119	0.13	Low	Havine *et al*.(2013)
OC (%)	0.96	1.2	Low	Tekalign(1991)
OM (%)	1.66	2.02	Low	Barber (1984)
Av.P(mg/kg)	8.21	9.11	Low	Landon(1991)
Av.S(mg/kg)	13.94	15.22	Low	Ethio-SIS(2014)
Av.B(mg/kg)	0.71	0.75	Low	Ethio-SIS(2014)
pH(1:2.5suspension)	5.33	5.42	moderately acidic	Mesfin(2007)

Where; OC=Organic carbon, Av.B=Available Boron, Av.S=Available Sulfur, Av.P=Available Phosphorous, TN=Total Nitrogen, and OM=organic matter.

Cation exchange capacity (CEC) is an important chemical property of soils; as it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. In the present, study CEC values ranged from 19.8 to 23.6cmol (+)/kg for Semen Ambukuna and Belela), respectively (Table 4). According to Landon (2014), the values of CEC less than 5 cmol (+)/kg are rated as very low, 5 - 15 cmol (+)/kg as low, 15 - 25 cmol (+)/kg as medium, 25 - 40 cmol (+)/kg as high and > 40 cmol (+)/kg as very high. Hence, CEC values recorded for soils of both sites were medium, indicating that both sites are less suitable for teff production. The medium CEC values in both experimental areas may indicate the potential danger of losses of essential nutrients from soil surface due to leaching. On the other hand, such medium CEC values could be due to continuous use of inorganic fertilizers that enhanced nutrient losses due to leaching, erosion and crop harvest.

Similarly, percentage base saturation (PBS) values were medium for both experimental sites (49.7% for Semen Ambukuna and 50.6% for Belela), soils with percentage base saturation of < 20%, 20 - 60% and > 60% are considered as low, medium and high, respectively, in fertility quality (Landon, 1991). The medium values of percentage base saturation at both sites may imply losses of basic cations from the soil by leaching due to the high precipitation in the area.

Exchangeable K in these soils ranged from 0.79 and 0.81cmol (+)/kg (Table 4).According to the rating of Ethio-SIS (2014), soil exchangeable K with values< 0.2 cmol (+)/kg is rated as very low, 0.2 - 0.5cmol (+)/kg as low, 0.51 - 1.5 cmol (+)/kg as medium, 1.51 - 2.3 cmol (+)/kg as high and > 2.3cmol (+)/kg as very high. Therefore, soil K contents in the study area were in the medium range, indicating that there is no need of adding K fertilizer to the soil; as K availability would not be a limiting factor for crop production (Ethio-SIS, 2014).

Exchangeable Ca values ranged from 5.7 and 6.8cmol (+)/kg at site one (Semen Ambukuna) and site two (Belela), respectively (Table 4). According to Ethio - SIS (2014), the values of Ca less than 2 cmol (+)/kg are rated as very low, 2 - 5 cmol (+)/kg as low, 5.0 - 10 cmol (+)/kg as medium, 10 - 20 cmol (+)/kg high and > 20 cmol (+)/kg as very high. Hence, values of Exchangeable Ca recorded for soils of the study area were in the medium range. On the other hand, exchangeable Mg content (Cmol (+) kg^{-1}) of the soils was 2.9 and 2.3 Cmol (+) $kg^{-1}$for site one (Semen Ambukuna) and site two (Belela), respectively. According to the rating of Landon (2014), soils of the experimental sites qualified to be medium in exchangeable Mg, since < 0.3Cmol (+) kg^{-1}regarded as very low,0.3 - 1Cmol (+) kg^{-1} as low,1.0 - 3.0Cmol (+) kg^{-1} as medium,3.0 - 8.0 Cmol (+) kg^{-1} as high and > 8.0Cmol (+) kg^{-1} as very high. From soil fertility point of view, exchangeable Ca, Mg, and K in both study areas were in the range of medium, indicating that soils of the area are not deficient in exchangeable basic cations. Thus, application of Mg, K, and Ca containing fertilizers may not be necessary at least for the time being in the area.

Exchangeable Na values of 0.06 and 0.09 cmol (+)/kg were recorded for site one (Semen Ambukuna) and site two (Belela), respectively. Such low content of exchangeable Na may indicate that there is no soil sodicity problem at both study area (Table 4).

Table 4some basic soil fertility parameters of the study site (0-20 cm) before sowing

	Site one	Site two	Rating	References
Soil parameters	Measured values			
CEC[Cmol (+)/kg)]	19.8	23.6	medium	Landon (2014)
Ca[Cmol (+)/kg)]	5.7	6.8	medium	Ethio-SIS(2014)
Mg[Cmol (+)/kg)]	2.9	2.3	medium	Landon (2014)
K[Cmol (+)/kg)]	0.79	0.81	Medium	Ethio-SIS(2014)
Na[Cmol (+)/kg)]	0.06	0.09	very low	Landon (1991)
PBS (%)	49.7	50.6	Medium	Landon (1991)

Where: *PBS=Percentage of base saturation, K=Exchangeable potassium, Mg=Exchangeable Magnesium, Ca=Exchangeable Calcium, Na= Exchangeable sodium.CEC=cation exchangeable capacity and K= Exchangeable potassium, Site one=Semen Ambukuna and Site two=Belela*

4.2. Soil analysis for selected Soil Fertility Status after harvesting

Soil fertility is the ability of soil to supply basic important nutrients for the plant growth and development. The chemical analysis results of the soil samples collected from both experimental site sand each plots based on the treatments just after harvesting of the teff crop. Soil pH, total nitrogen, Organic carbon, Available phosphorus and CEC were measured to asses after harvesting soil fertility status. A comparison of soil chemical properties before sowing and after harvesting crop revealed that application of DAP + urea and NPSB + urea fertilizers slightly decreasing some chemical properties of soil, indicating that there is no improvement of the fertility status of soil. The Organic carbon, pH and CEC were numerically decreasing at both experimental sites due to the application of DAP + urea and NPSB + urea fertilizers after harvest, while available P slightly increased for the application of DAP plus urea and NPSB + urea fertilizer as compared to before sowing at both study area. However, the total N content of the soil analyzed from composite samples and all treated plots remained almost the same.

Soil of the present study indicated that pH values 5.34 to 5.28 and 5.43 to 5.38 at Semen Ambukuna and Belela across the whole experimental plots (Table 5), indicated that application of DAP + urea and NPSB + urea fertilizer residuals slightly influence the soil pH. These might be due a one year DAP + urea and NPSB + urea fertilizer experiment filed, which may influence soil pH but did not change the rating. These values indicated that the soil is moderately acidic reaction in both experimental sites. According to the rating by Mesfin (2007), soil pH <4.5 is regarded as very strongly acidic, 4.5 to 5.0 as strongly acidic, 5.1 to 5.5 as moderately acidic, 5.6 to 6.0 as slightly acidic and 6.1 to 6.5 as neutral.

The results of soil analysis for available soil P after harvest for all treatment plots are showed (Table 5). The application of DAP + urea and NPSB + urea fertilizer obtained highest residue on the soil after harvest crops as compared with before sowing. The highest available soil P after harvest 10.45mg/kg and 10.68mg/kg was obtained at application of 150kg DAP + 150kg urea per ha at Semen Ambukuna and Belela experimental sites, respectively (Table 5). The maximum rate of DAP + urea fertilizer increasing available soil P residue by 2.2 and 3.5% compared with maximum rate of NPSB + urea fertilizer at Semen Ambukuna and Belela study area, respectively. According to these results the content of available soil P in blended fertilizer

(NPSB) lower than that of DAP fertilizer application. According to Brhan (2012), who indicated that the plots that receive Urea and DAP under row planting were obtained next to treatments that receive blended fertilizers under broadcast planting.

The soil total N content after harvesting of application of blended (NPSB) + urea and DAP plus urea fertilizers at both experimental sites showed no any difference between the treatments (Table 5). These result indicated that application of blended (NPSB) plus urea and DAP plus urea fertilizer has no considerable effect on total N content of the soil after harvesting may be due to the mobile nature of this plant nutrient. Similarly, total N loss from the soil through various mechanisms may be due leaching, de-nitrification and volatilization soon after application of very volatile in nature, high uptake of N, mobility of N in soil, particularly due to high rainfall measured during the cropping season. The result finding was in line with Havlin *et al.* (2013), who classified soils based on their total N content was low rating. According to this results indicated that the low amount of total N content in soils which are cultivated repeatedly, due to total N leaching and total N mining. Generally, the application of blended (NPSB) + urea and DAP + urea fertilizers at both experimental sites has no nutrient increment in soil after harvest of total N.

Cation exchange capacity (CEC) is a major controlling agent of stability of soil structure, nutrient availability for plant growth, soil pH, and the soil's reaction to fertilizers and other ameliorants. The results indicated that the cation exchange capacity of the whole experimental plots ranged from 17.8 – 17.67 and 21.59 - 20.76 cmol (+) kg^{-1} at Semen Ambukuna and Belela respectively showed in (Table 5). According to Landon (2014), the values of CEC less than 5 cmol (+)/kg are rated as very low, 5 - 15 cmol (+)/kg as low, 15 - 25 cmol (+)/kg as medium, 25 - 40 cmol (+)/kg as high and > 40 cmol (+)/kg as very high. Therefore, the CEC of the whole experimental plots could be rated as moderate. However, the value of CEC was inconsistent with rate of both blended (NPSB) + Urea and DAP + Urea fertilizers.

The results indicated that the organic carbon values ranged between 0.71– 0.66 and 0.91 - 0.76% at Semen Ambukuna and Belela, respectively after harvesting. According to Tekalign *et al*. (1991) rated organic carbon ranges < 0.08 % are very low, 0.08 – 2.59% as low, 2.59 – 5.17% as medium, and > 5.17% as high. This shows that all soils had low organic carbon. The soils with low organic carbon levels have been to contain low total N and other nutrients. Soil organic matter plays a number of roles in the soil. It influences many soil biological, chemical and physical properties that influence nutrient availability (Tisdale *et al*., 1993).

Table 5. The soil fertility status after harvesting

Parameters	Semen Ambukuna					Belela				
	pH	OC %	TN%	CEC[Cmol (+)/kg)]	AV.P (mg/kg)	pH	OC %	TN%	CEC[Cmol (+)/kg)]	AV.P(mg/kg)
Control	5.34	0.71	0.11	17.8	8.45	5.43	0.91	0.123	21.59	9.58
50kg DAP + 50kg urea	5.32	0.71	0.12	17.7	9.32	5.41	0.8	0.13	21.58	9.79
75kg DAP + 75kg urea	5.31	0.69	0.12	17.7	9.84	5.41	0.79	0.13	21.52	9.93
100kg DAP + 100kg urea	5.29	0.69	0.12	17.69	10.25	5.39	0.78	0.13	20.97	10.45
125kg DAP + 125kg urea	5.29	0.68	0.12	17.68	10.29	5.39	0.78	0.13	20.96	10.53
150kg DAP +150kg urea	5.31	0.68	0.12	17.9	10.35	5.38	0.77	0.13	20.94	10.68
61kg NPSB + 44.5kg urea	5.30	0.67	0.12	17.8	8.91	5.39	0.79	0.13	21.54	9.42
91.5kg NPSB + 66.75kg urea	5.31	0.68	0.12	17.9	8.97	5.39	0.78	0.13	21.53	9.65
122kg NPSB + 89kg urea	5.28	0.67	0.12	17.85	9.4	5.38	0.77	0.13	20.99	9.91
152.5kgNPSB+111.3kg urea	5.29	0.68	0.12	17.8	9.8	5.38	0.76	0.13	20.85	10.02
183kg NPSB + 133.5kg urea	5.28	0.66	0.12	17.67	10.22	5.39	0.76	0.13	20.76	10.3

Where; OC=Organic carbon, Av.P=Available Phosphorous, TN=Total Nitrogen, CEC=cation exchangeable capacity.

4.3. Teff Phenological Parameters

4.3.1. Days to 50% heading

Days to 50% heading was highly significantly ($p<0.001$) influenced by fertilizer level and location, but the interaction between the two was not significant ($p>0.05$) (Appendix Table 4 and Table 6). Plants grown at higher DAP + Urea fertilizer rate (150kg DAP+150kg urea kg ha^{-1}) took significantly more time to heading than those grown in the control plot. This could be due to the role of DAP + urea fertilizers in enhancing vegetative growth by delaying their productive period of plants.

The longest duration to 50% panicle heading (61.5 days) was obtained from the application of 150kg DAP + 150kg urea/ha, followed by (59 days) for the application of 125kg DAP + 125kg urea/ha and (58.38 days) for 183kg NPSB + 133.5kg urea/ha, while the minimum value (45.12 days) was recorded for the control plots, which was statistically at par with application of 50kg

DAP + 50kg urea/ha and 61kg NPSB + 44.5kg urea/h. The maximum rate of DAP + urea increased days to panicle heading by 16.35 days as compared to the control plot (Table 6). Similarly, 125 kg DAP + 125kg urea and 183kg NPSB + 133.5kg urea/ha increased the number of days to panicle heading by 16.35, 13.85 and 13.24, respectively, over the control (Table 6).

This result was in agreement with the finding of Abraha (2013), who indicated that increasing the rate of nitrogen application prolonged the period to heading of teff plants. In contrast, Seifu (2018) has reported that maximum number of days to 50% panicle heading was obtained from the control plots, while the lowest was recorded for the application of138 kg N and 200kg NPSB kg per ha. Similarly, Teshome (2018) has found the highest number of days to panicle heading for the control plots, while the highest rates of 138 kg N + 200 kg NPSZnB ha^{-1} and 92 kg N + 200 kg NPSZnB ha^{-1}resulted in lower values.

Application of lower rates of NPSB + urea and DAP + urea hastened the days to 50% heading as compared to maximum rates of these fertilizers. The increase in number of days to 50% heading with application of higher rates of fertilizers could probably be due to more availability and enhanced plant uptake of nutrients, especially N, which favored more photosynthesis, rapid vegetative growth and delayed heading of teff plants. Similar to the result of the present study, Tisdal *et al*. (2002) have reported that early heading was obtained at lower rates of P fertilizer compared to the other treatments.

The result of the present study disagree with the findings of Sewnet (2005); Alemayehu (2012); Temesgen (2012): Shiferaw (2012); Assefa (2016) and Seifu (2018), who reported that, as the rate of NP, N and blended fertilizer increases, the number of days elapsed to heading decreased as compared to the values recorded for the control or lower fertilizer rates.

Mean number of days to 50% panicle heading was also significantly influenced by location with higher values recorded at location one (Semen Ambukuna) (55.36 days) as compared to location two (Belela) (50.48 days) for the same rates of NPSB + urea and DAP + urea fertilizer. Thus, significant variation among the locations for number of days to panicle heading of tef might be due to differences in soil conditions and weather variables. On the other hand, the interaction between fertilizer treatments and locations was not significant for number of days to 50% heading of teff plants.

Table 6. Days to 50% panicle heading of tef as affected by fertilizer rate and location

Treatments	Days to 50% heading
Control	45.15g
50kg DAP + 50kg urea	47.63f
75kg DAP + 75kg urea	49.38e
100kg DAP + 100kg urea	53.00d
125kg DAP + 125kg urea	59.00b
150kg DAP + 150kg urea	61.50a
61kg NPSB + 44.5kg urea	49.00ef
91.5kg NPSB + 66.75kg urea	50.38e
122kg NPSB + 89kg urea	52.00d
152.5kg NPSB + 111.3kg urea	55.50c
183kg NPSB + 133.5kg urea	58.38b
LSD0.05	1.53
Location	
Location 1(Semen Ambukuna)	55.36a
Location 2(Belela)	50.48b
Location x Treatment	Ns
LSD0.05	0.65
CV	2.9

LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation NS= non-significant. Means followed by the same letter(s) are not significantly different at 5% P level.

4.3.2. Days to 90% physiological maturity

Days to 90% physiological maturity of teff is one of the important agronomic parameters used to analyze the efficiency of applied nutrients. Accordingly, application of different rates of DAP, NPSB and urea, locations and the interaction between fertilizer treatments and locations highly significantly ($p<0.001$) affected days to 90% physiological maturity of teff.

The highest mean days required for 90% physiological maturity (110.4days) was obtained from application of 150kg DAP + 150kg urea per ha followed by 125kg DAP + 125kg urea, while the lowest mean days to 90% physiological maturity (99 days) was recorded for the un fertilizer plots. The prolonged period required by the plants to reach maturity at higher rate of DAP + urea fertilizer may be attributed to the increase in leaf area duration, rapid vegetative growth and increased light use efficiency. Hence, application of higher rates of N and P fertilizers increased the number of days to 90% physiological maturity of teff, which was hastened for the control treatment and at lower rates of NPSB + urea and DAP + urea (T2: 50kg DAP per ha + 50kg urea per ha and T7: 61kg NPSB + 44.5kg urea per ha) . This could probably be attributed to the presence of sulfur and boron in NPSB and minimum rate of P in both DAP and NPSB fertilizers, which might have helped in enhancing physiological maturity in those treatments.

Table 7. Days to 90% maturity of teff as affected by fertilizer rates and location in Tambaro District

	Days of 90% maturity											
Trt	Different rate of NPSB + urea & DAP + urea fertilizers											
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Mean
Lo1	102.^{h}	103.8^{g}	107.5^{e}	110$^{.cd}$	113.8^{b}	115.3^{a}	103.8^{g}	106.8^{ef}	109^{d}	110.5^{c}	112.8^{b}	108.^{a}
Lo2	96^{m}	97.5^{l}	98.3^{k}	100^{ij}	103.8^{g}	105.5^{f}	97.5^{l}	99.5^{jk}	99.5^{jk}	101.3^{hi}	102.5^{hg}	100^{b}
Mea	99^{h}	100.6^{g}	102.9^{f}	105de	108.8^{b}	110.4^{a}	100.6^{g}	103.1^{f}	104.3^{e}	105.9^{d}	107.6^{c}	
LSD	Trt					1.02						
	Lo					0.43						
	L X Trt					1.42						
CV						1.3						

LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation, NS= non-significant., Lo = Location. Means followed by the same letter(s) with in columns and rows are not significantly different at 5% P level.

Application of 150kg DAP + 150kg urea per ha, followed by 125kg DAP + 125kg urea and 183kg NPSB + 133.5kg urea, resulted in the highest value (115.3 days) at location one, while lowest value (96 days) was obtained from the unfertilized plots at location two. Application of maximum rate of DAP + urea fertilizer increased days to 90% physiological maturity by 19.3 days as compared to the control plot at location two (Table 7).

In general, it was observed that application of DAP + urea fertilizers at higher rates favored vegetative growth and delayed physiological maturity of teff. In agreement with the results of the present study, Temesegen (2001) has reported that application of 69 kg per ha N delayed teff maturity due to the delay in vegetative phase by seven days over the control treatment at both farmer fields and research station on Kobo *vertisols*. Similarly, Manna *et al*. (2005) have reported that combined application of NP and organic fertilizers promoted vegetative growth. In contrary, Getahun *et al.* (2018) have observed the shortest period(91days) to physiological maturity of teff with application of 69 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1} and the longest (97 days) for the control plot. Similarly, Seifu (2018) has reported the highest value for days to 90% physiological maturity (106 days) for the un-fertilized plots, while the lowest value (95 days) for the highest rate of NPSB blended fertilizer on vertisols in Hidhebu Abote Disrict.

The maximum mean number of days to 90% physiological maturity (108.6 days) was recorded at location one (Semen Ambukuna) and the minimum (100 days) was at location two (Belela). This could be due to variations between the locations for weather condition and amount and distribution of precipitation.

4.4. Growth Parameters

4.4.1 Plant height

Analysis of variance showed that the effect of fertilizer treatments was significantly different ($P < 0.05$), while location and interaction of location and fertilizer rate were not significant for plant height (Table 8).

Mean plant height significantly increased with increasing rates of NPSB + urea and DAP + urea application, where the highest value was recorded for 183kg NPSB + 133.5 kg urea per ha, which was statistically at par with application of 150 kg DAP + 150 kg urea per ha, while the lowest was for the un-fertilize plots of teff. Besides the control treatment, which showed 45.35 cm height, 50kg DAP + 50 kg urea and 61kg NPSB + 44.5 kg urea per ha also resulted in shorter plants with respective values of 67.53cm and 69.64cm. Plant height recorded for all NPSB + urea and DAP + urea fertilized plots were significantly higher than did the control plots.

In general, 183 kg per ha of NPSB + 133.5 kg per ha of urea increased plant height by about 49.2% over the control. The increase in plant height in response to increasing rate of NPSB or DAP + urea application was probably due to the vital role of N fertilizer in promoting vegetative growth of plants. In line with this, it has also been reported that height of teff plants significantly increased by application of N and P at the rates of 64 kg N and 69 kg P per ha (Lemlem *et al.*, 2002).The result of the present study was also in agreement with the finding of State (2012), who reported that plant height of teff significantly affected by application of P_2O_5 and N with blended fertilizers. Besides N and P, S and B might have also played a role in promoting vegetative growth of teff in the present study. Debnath *et al.* (2011), have also observed an increase in plant height with application of 64 kg N and 69 kg P/ha on 'dilaand dimile' Nitosols.

In general, the increase in plant height with increasing rates of DAP, or NPSB and urea application in the present study could probably be due to the role of the most essential nutrients, N and P, in promoting cell elongation and vegetative growth of plant parts. Similar results have been reported by Haftom *et al*. (2009), indicating that maximum rate of nitrogen increased plant height of teff. Dinkinesh (2018) has also indicated that increased plant height with increasing rate of blended NPSB application was probably due to the vital role of N fertilizer in promoting vegetative growth. Furthermore, Wakene *et al*. (2014) have reported that plant height of barely increased with increasing rates of N/P from 0 to 69/30 kg per ha.

Table 8.Plant height as affected by different rates of fertilizers application at Semen and Belela locations in Tambaro District.

Treatments	Plant height(cm)
Control	45.35e
50kg DAP + 50kg urea	67.53d
75kg DAP + 75kg urea	75.7bc
100kg DAP + 100kg urea	78.76bc
125kg DAP + 125kg urea	79.73cb
150kg DAP + 150kg urea	86.91a
61kg NPSB + 44.5kg urea	69.64d
91.5kg NPSB + 66.75kg urea	74.94c
122kg NPSB + 89kg urea	77.96cb
152.5kg NPSB + 111.3kg urea	79.38bc
183kg NPSB + 133.5kg urea	89.28a
LSD0.05	4.67
Location	
Location 1(Semen Ambukuna)	75.63
Location 2(Belela)	74.38
Location x Treatment	NS
LSD (5%)	1.99
CV (%)	6.23

LSD=Least Significant Difference at 5% level; CV= Coefficient of Variation NS= non-significant. Means followed by the same letters are not significantly different at 5% P level

4. 4.2.Leaf number

Analysis of variance revealed that, number of leaves per plant was not significantly affected by both fertilizer rates and location, or by their interaction (Table 9). Nevertheless, the highest mean leaf number (4.29) was resulted from application of 100kg DAP plus 100kg urea per ha and all the fertilized treatments exhibited higher values than did the control plot, probably because of the role of those essential nutrients in the fertilizers to enhance vegetative growth of plant parts, particularly the leaves.

4.4.3. Panicle length

Panicle length per plant was highly significantly ($P< 0.001$) affected by fertilizer application and location~~s~~. However, their interaction was non-significant (Table 9). Mean panicle length increased with increased rate of NPSB + urea application, where the highest value (56.6cm) was obtained from application of 183kg NPSB + 133.5kg urea per ha, which was statistically at par with application of 152.5 kg/ha NPSB + 111.3 kg/ha urea and 100kg DAP +100kg urea per ha, while the shortest panicle (40.33cm) was recorded for the control plot.

Application of maximum rate of blended fertilizer (NPSB) + urea and DAP + urea significantly increased plant panicle length as compared to lower rates of NPSB +Urea and DAP + Urea, and the unfertilized plots. On the hand, the shortest panicle recorded for the control plots might have been due to deficiency and/or an imbalance of nutrients in the soil at both locations. With respect to the locations, the maximum mean value of panicle length (52.25cm) was recorded at location one (Semen Ambukuna), while was lower (49.68cm) at location two (Belela).

Panicle length is one of the important parameters that determine both grain and biomass yields of teff, as it exhibits positive and highly significant correlation with culm length, plant height, number of internodes and grain (Legesse, 2004).The result indicated the highest rates of blended NPSB + urea and DAP + urea increasing the growth of panicle length of teff plant at both study area. The finding in line with the results of the present study, Alemayehu (2012) has reported that treatments which received blended fertilizers under row planting system responded more significantly to panicle length (133 %) than the control plots on both *Vertisols* and *Nitosols*. Okubay *et al.* (2014) have also reported that panicle length of teff increased in response to increasing rates of nitrogen application.

Table 9.Effects of different rates of fertilizers and locations on panicle length, number of productive tillers and leaves of teff at two locations in Tambaro District.

Treatment	Panicle length/plant	Number of Productive tillers/plant	Leaf number/plant
Control	40.33f	1.95h	4.05
50kg DAP + 50kg urea	47.23e	2.89g	4.20
75 kg DAP + 75 kg urea	50.29cd	4.00f	4.16
100kg DAP + 100 kg urea	55.11ab	6.29a	4.29
125 kg DAP + 125kg urea	52.76bc	5.55c	4.23
150kg DAP + 150kg urea	52.06c	5.05ed	4.30
61 kg NPSB + 44.5kg urea	48.09de	2.70g	4.25
91.5kg NPSB + 66.25kg urea	50.53cd	3.69f	4.14
122kg NPSB + 89kg urea	52.45bc	4.75e	4.28
152.5kgNPSB + 111.3kg urea	55.1ab	5.90b	4.26
183 kg NPSB + 133.5 kg urea	57.8a	5.25cd	4.23
LSD 0.05	2.76	0.316	0.27
Location			
Location 1(Semen Ambukuna)	52.25a	4.27b	4.26
Location 2(Belela)	49.79b	4.46a	4.2
Fertilizer x L	Ns	NS	NS
LSD 0.05	1.18	0.135	0.12
CV%	5.42	7.26	6.52

LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation; NS= non-significant. Means followed by the same letter(s) with in a column are not significantly different at 5% P level.

4.4.4. Number of Productive tillers

The analysis of variance indicated that number of productive tillers of teff was significantly ($P \leq 0.05$) affected by fertilizer rate and location, but the interaction of fertilize and location was not significant (Table 9). Maximum number of productive tillers per plant (6.29) was obtained from application of 100kg DAP + 100kg urea per ha, while the minimum number was recorded for the unfertilized plot. Number of productive tillers per plant significantly increased ($P \leq 0.05$) from 1.95/plants to 6.29/plants with increases in the level of DAP + urea from 0 to 100kg DAP +100kg urea per ha, but decreased with further increases in DAP + urea. The magnitude of increase in productive tiller due to application of 100kg DAP + 100 kg urea per ha was higher by 70 % than the unfertilized plots. This finding was agreed with the observation of Abraha (2013), who indicated that an increase of nitrogen rate from 0 to 46 kg N per ha increased panicle length and number of productive tillers of teff. On the other hand, Shiferaw (2012) has reported non-significant difference in productive tillers between the higher N/P_2O_5 (64/46) rate and the control. Similarly, the results of the present study disagreed with the findings of Tana and

Lemma (2015), who reported no significant difference in number of productive tillers per plant among different blended fertilizer rates in wheat.

Number of productive tillers per plant of teff was significantly affected by location. The highest mean number of total productive tillers per plant (4.46 $plant^{-1}$) was recorded at location two (Belela) and the lowest (4.27$plant^{-1}$) was at location one (Semen Ambukuna).This variation between locations could be attributed to differences in growth conditions, such as soils, temperature and precipitation. The result of the present study was in agreement with the finding of Tekele and Wassie (2018), who indicated that locations have significantly affected growth parameters of teff.

4.4.5. Total number of tillers

The main effect of NPSB or DAP and urea fertilizer and location was highly significant (P < 0.001) for total number of tillers per plant. The interaction between location and fertilizer rate was also significant (Table 10).

Application of higher rates of fertilizer increased the total number of tillers per teff plant compared to the lower rates of the treated and control plots. Accordingly, the highest tiller number (7.6/plant) was recorded for application of 150kg DAP + 150kg urea, which increased by 72% over the control, at location one and the lowest value (2.1/plant) was obtained from the unfertilized plot, followed by 150kg DAP + 150kg urea fertilizer, at location two. This shows that N and P enhanced vegetative growth and rapid initiation of new tillers. The result of the present study was in agreement with the findings of Seyfu (1993); Tekalign *et al*. (2000); Legess (2004); Haftom *et al*. (2009) and Seifu (2018), who reported significantly higher number of tillers in response to application of higher N rates in teff. Generally, increasing the rate of application of DAP + urea and NPSB plus urea fertilizer resulted in consistent increment of total tiller number in teff.

Table 10. Effects of different rates NPSB + urea and DAP + urea on total tiller number per plant of teff at Semen and Belela in Tambaro District

Total number of tillers												
Treatment	Different rate of NPSB + N & DAP + N fertilizers											
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Mean
Lo1	2.3j	3.48hi	4.43fg	6.45^{cd}	6.98^{bc}	7.6a	3.98^{hg}	4.98f	5.5e	6.58c	6.8c	5.37a
Lo2	2.1j	3.5hi	4.35g	6.6c	6.85c	7.5ab	3.25i	3.95hg	6.0ed	6.55cd	6.6c	5.205b
Mean	2.2^{g}	3.48f	4.39e	6.53c	6.9b	7.53a	3.6f	4.46e	5.79d	6.5bc	6.7bc	
LSD0.05	**Trt**					**0.37**						
	Lo					**0.16**						
	L X Trt					**0.56**						
CV						**1.3**						

LSD= Least Significant Difference at 5% P level; CV= Coefficient of Variation, LO= Location, T= Treatment. Means followed by the same letter(s) within columns and rows are not significantly different at 5% P level.

4.4.6. Leaf area

Analysis of variance showed that both main effects fertilizer rate and location, as well as their interaction, were highly significant ($p<0.001$) for total leaf area per plant (Appendix Table 4 and Table 11).

The maximum leaf area (22.9cm^2) was obtained from application of 150 kg DAP + 150 kg urea per ha at location one, which was statistically at par with application of 125 kg DAP + 125kg urea per ha and 183kg NPSB + 133.5kg urea per ha at location one and two and 150kg DAP plus 150kg urea per ha at location two, while the minimum mean value(7.9cm^2) was recorded for the unfertilized treatment with 6.9cm^2 at location one and 8.85cm^2 at location two 6.9cm^2 (Table eleven). The increase in total leaf area with increasing rates of fertilizer was highly significant and consistent. This result was in agreement with the finding of Berhane *et al.* (2015), who reported that application of high rates of N fertilizer increased total leaf area of sorghum plants.

Application of maximum rate of DAP + urea fertilizer increased leaf area by 69% as compared to the control plots. The increase in total leaf area with increasing rates of NPSB + urea and DAP plus urea could probably be due to the presence of higher amount of P in the fertilizers. In line with this, it has been reported that, when P is limiting, the most striking effects are reduction in leaf expansion and leaf surface area (Sultenfuss and Doyle, 1999).

Significantly higher mean value of total leaf area (18.76 cm^2) of teff was recorded at location two, while the mean value (16.55 cm^2) at location one was lower. Such significant variation among locations for total leaf area could probably be due to differences in soil condition, temperature, rain fall, and altitude. In line with this, Tekele and Wassie (2018) have reported that locations have significantly affected growth parameters of tef.

Table 11. Mean total leaf area per plant of teff as affected by the interaction of location and fertilizer rate in Tembaro district

	Leave area											
Treatment	Different rate of NPSB + N & DAP + N fertilizers											
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Mean
Lo1	6.9^{g}	13.8^{f}	14.3^{g}	19.7^{dce}	21.9^{abcd}	22.5^{a}	11.9^{f}	12^{f}	17.8^{e}	19.9^{bcde}	21.8^{abcd}	16.6^{b}
Lo2	8.85^{g}	17.6^{e}	18.3^{e}	19.8^{bcde}	22.2^{abc}	23.3^{ab}	17.5^{e}	18.6^{e}	18.7^{e}	19.4^{de}	21.7^{abcd}	18.8^{a}
Mean	7.9e	15.7d	16.3^{cd}	19.74b	22.06a	22.9^{a}	14.7^{d}	15.3^{d}	18.2^{cb}	19.65^{b}	21.8^{a}	
LSD	**Trt**					**1.99**						
	Lo					**0.85**						
	L X Trt					**2.77**						
CV						**11.27**						

LSD= Least Significant Difference at 5% P level; CV= Coefficient of Variation, LO= Location, T= Treatment. Lo1=Location 1, LO2= Location two. Means followed by the same letter(s) with in columns and rows are not significantly different at 5% P level.

4.5 Teff Yield

4.5.1. Teff Grain yield

The results of analysis of variance revealed that the main effect of fertilizer rate and location was highly significant ($p<0.001$), whereas their interaction was not significant for grain yield of teff (Appendix Table 5).

The maximum mean grain yield of 2426 kg/ ha was obtained from application of 183 kg NPSB plus 133.5 kg urea per ha and it was statistically at par with application of 100kg DAP plus 100kg urea per ha and 152.5kg NPSB + 111.3kg urea, while the lowest mean grain yield (470.85kg) was recorded for the unfertilized plots (Table 12). Generally, application of 183kg NPSB + 133.5kg urea per ha, 152.5kg NPSB + 111.3kg urea per ha and100kg DAP + 100kg urea per ha increased mean grain yield of teff by 80.6%, 80.5%and 80%, respectively, compared to the control plot. The lowest mean grain yield obtained from the control and lower amounts from the lower rates of fertilizer treatments may probably indicate low-level or inadequate amount of essential nutrients (available P, available S, available B, total nitrogen and organic matter) in the soils of the study area and, thus, the need for external NPSB and NP inputs to support normal growth and development of teff plants (Sallah *et al*., 1998).

This result was in agreement with the findings of Brhan (2012) and Dagne (2016), who reported that blended fertilizers significantly affected grain yield of teff and maize, respectively. The finding of the present study is also similar with that of Fikiremariam *et al.*(2014), who indicated that the highest mean grain yield of teff (2440kg/ ha) was obtained from application of 100 kg urea + 100 kg DAP per ha. In addition to that, Temesgen (2001) has reported that application of different rates of nitrogen fertilizer significantly affected the grain yield of teff.

Maximum mean grain yield (1655.28kg per ha) was obtained at location two, while the minimum value (1596.72kg per ha) was recorded at location one (Table 12). Hence, location two had 3.5% yield advantage over location one, indicating that location two has more suitable soil condition and favorable weather than does location one. This finding is in line with the report of Tekele and Wassie (2018), who indicated that locations have significantly affected teff yield in their study area.

Table 12 Effect of different fertilizer rate on grain yield, straw yield, harvest index and dry root mass of teff

Treatment	GY(kg/ha)	SY(kg/ha)	HI (%)	DRM(t/ha)
Control	470.85h	1922.5h	0.2f	0.13h
50kg DAP + 50kg urea	905.3g	3215g	0.22e	0.39g
75 kg DAP + 75 kg urea	1307.5e	3831f	0.25d	0.45f
100kg DAP + 100 kg urea	2417.2a	5037.d	0.32a	0.75a
125 kg DAP + 125kg urea	2104.88b	5491.5b	0.28c	0.69b
150kg DAP + 150kg urea	2000.9c	6223.9a	0.25d	0.67bc
61 kg NPSB + 44.5kg urea	895.95g	3037g	0.23e	0.36g
91.5kg NPSB + 66.25kg urea	1209.3f	3853.f	0.24de	0.44f
122kg NPSB + 89kg urea	1753.9d	4493.e	0.28c	0.52e
152.5kgNPSB + 111.3kg urea	2394.25a	5254.5c	0.31ab	0.61d
183 kg NPSB + 133.5 kg urea	2426a	5282.5c	0.3b	0.65c
LSD 0.05	76.683	205.89	0.0195	0.0386
Location				
Location 1(Semen Ambukuna)	1596.72b	4421.1a	0.26b	0.51
Location 2(Belela)	1655.28a	4240.9b	0.27a	0.52
Fertilizer x L	Ns	NS	NS	NS
LSD 0.05	32.698	87.793	0.008	0.017
CV%	4.72	4.76	7.42	7.47

Tables followed by same letter(s) within a column for a given variable are not significantly different at 5% P level , CV (%) = Coefficient of variation, NS= non-significant, LSD = Least Significant Difference at 5% P level, GY=Grain yields, SY = Straw yield, HI=Harvest index and DRM=Dry root mass.

4.5.2 Straw yield

Straw yield of cereal crops is an important output for farmers who use it for cattle feeding, construction of house. It is sensitive to fertility status of and nutrient supply from the soil. Results of the analysis of variance indicated that straw yield of teff was highly significantly ($p<0.001$) affected by application of blended (NPSB), DAP and urea fertilizers and location (Table 12).The highest mean straw yield (6223.9 kg/ha) was recorded for application of 150kg DAP + 150kg urea per ha, while the lowest value (1922.5 kg/ha) was for the unfertilized plot. The maximum rate of NPSB fertilizer increased average straw yield by 63.6% over the control plot.

Application of 150kg DAP + 150kg urea per ha resulted in 15% increment in straw yield over the treatment that received 183 kg NPSB + 133.5kg urea per ha. This indicates that crops supplied with adequate amount of nutrients (especially N and P) exhibit more vegetative growth and, thus, more dry matter accumulation in vegetative parts that favors an increment in straw yield. The significant increase in straw yield in response to application of the maximum rate of DAP + urea might be due to the role that the nutrients (N and P) played in enhancing growth and development of vegetative parts of the crop, as nitrogen favors vegetative growth and phosphorus plays a fundamental role in metabolism and energy producing reactions and can withstand the adverse environmental effects, thus, resulting in enhanced straw yield. The result of the present study was in agreement with the findings of Temesegen(2001); Haftom *et al*.(2009) and Berhane *et al*.(2015), who reported that application of higher rates of N may result in higher amount of biomass yields in teff and sorghum, respectively. The findings in the present study were in agreement with those of Seifu (2018) and Teshome (2018), whoreportedthat the highest straw yield was recorded for combined application of blended fertilizer and urea. Similarly, Abebaw and Hirpa (2018), an increase in straw yield of wheat with adequate supply of blended fertilizers. In contrast, Abraha (2013) has reported that application of the highest level of N resulted in less biomass yield.

The maximum mean straw yield of teff was obtained at location one (Semen Ambukuna), which was by 4% higher over that recorded at location two (Belela). This result indicates that location one has more suitable weather condition for vegetative growth of plants than does location two.

4.5.3. Harvest index

Harvest index (HI) is the ratio of harvested grain to total shoot dry matter, and this can be used as a measure of reproductive efficiency. It was significantly ($P \leq 0.05$) influenced by fertilizer rate and location (Table 12).

Harvest index increased with increasing rate of application of DAP, urea and NPSB fertilizers. Generally, increasing the levels of fertilizer from 0 to 100kg DAP + 100kg urea per ha and 0 to 152.5kg NPSB + 111.3kg urea per ha increased harvest index of teff from 20 to 32% and 20 to 31%, respectively, while further increases in the rate of these fertilizers resulted in highly significant reduction in harvest index.

The decrease in harvest index with maximum rate of application of NPSB + urea and DAP + urea encouraged more vegetative growth than the grain yield, since harvest index is the ratio of grain yield to dry biomass yield. The increase in harvest index due to application of 100kg DAP plus100kg urea per ha and 152.5kg NPSB plus 111.3kg urea per ha may be attributed to enhanced rate of photosynthesis and translocation of photosynthetic products to crop economic parts or grains.

The results of the present study were in agreement with the findings of Gebrekidan and Seyoum (2006), indicating that harvest index consistently decline with further increasing application of N up to the highest level (150 kg per ha). On other hand, it has been reported that harvest index of rice increased with application of P fertilizer at a rate of 13.2 kg/ha, while further increases beyond this level resulted in highly significant reduction.

Similarly, Gebrekidan and Seyoum (2006) have reported that harvest index increasing with application of P fertilizer. Tesfahun (2018) has also reported that higher harvest index obtained from blended fertilizers might be attributed to supply of sufficient quantity of nutrients particularly P for translocation to the sink.

This result of the present study indicated that mean harvest index recorded at location two (27%) was greater than that of location one (26%), probably indicating that location two has good soil moisture and suitable weather condition for growth and development of reproductive plant parts than does location one.

4.5.4. Dry root mass

Root dry mass of teff was significantly ($P \leq 0.05$) affected by application of different rates of NPSB + urea and DAP + urea, but the effect of location and its interaction with fertilizer rate was not Significant (Table 12). The highest dry root mass (0.75 t per ha) was obtained from application of 100kg DAP + 100kg urea per ha, while the lowest value (0.13 t/ha) was recorded for the control plot, followed by 125 kg DAP + 125 kg urea per ha (0.69 t per ha). However, root dry mass declined at application rates beyond 100kg DAP + 100kg urea per ha (Table 12). The significant increase in root dry mass due to NP fertilizer application could be attributed to sufficient supply of nutrients, particularly P, at the rate of 100kg DAP + 100kg urea per ha. Roots of some plants suffering from severe P deficiency may grow longer and thinner, resulting in lower dry weight than normal. On the other hand, in some cases, shoot growth is more affected by P deficiency than root growth, which leads to a decrease in the shoot to root dry weight ratio. Nonetheless, root growth is also reduced by P deficiency, leading to fewer roots and lower root mass to reach water and nutrients in the soil (Sultenfuss and Doyle, 1999).

4.6. Apparent Nutrient Recovery Efficiency

4.6.1 Apparent recovery efficiency of nitrogen

Apparent nitrogen recovery efficiency (ANRE) is a measure of the ability of the crop to extract N from the soil (Fageria and Baliga, 2001). In the present study, apparent nitrogen recovery efficiency of teff was highly significantly ($P \leq 0.001$) influenced by the rate of NPSB + urea and DAP + urea rates, but the effect of location and the interaction of fertilizer rates and location was non-significantly (Appendix Table 6 and Table 13).

Table 13 Effect of rate of NP and NPSB fertilizers on ANRE of teff at Semen Ambukuna and Belela experimental sites in Tembaro district

Treatments	Apparent nitrogen recover efficiency%
	ANRE%
Control	0f
50kg DAP + 50kg urea	26.48e
75 kg DAP + 75 kg urea	37.31d
100kg DAP + 100 kg	75.54a
125 kg DAP + 125kg	43.18c
150kg DAP + 150kg u	29.74e
61 kg NPSB + 44.5kg u	27.5e
91.5kg NPSB + 66.75kg	31.25e
122kg NPSB + 89kg urea	45.61c
152.5kgNPSB + 111.3kg	50.71b
183 kg NPSB + 133.5 kg	46.43c
LSD 0.05	5.82
Location	
Lo 1(Semen Ambukuna)	38.47
Lo 2(Belela)	37.84
Fertilizer x L	Ns
LSD 0.05	2.48
CV%	15.26

LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation; NS= non-significant. Lo=Location, ANRE =Agronomic nitrogen recover efficiency. Means followed by the same letters are not significantly different at 5% P level.

The highest value of apparent recovery of N (75.54%) was obtained from application of 100kg DAP +100kg urea per ha, while the smallest value (26.48%) was recorded for 50kg DAP + 50kg urea, which was statically at par with application of 61kg NPSB + 44.5kg urea, 150kg DAP plus 150kg DAP and 91.5kg NPSB + 89kg urea per ha (Table 13). This result was similar to that of Sandana (2016), who reported that the level and types of nutrient applied affects the nutrient availability in soil and at high contents of soil nutrients and their availability more nutrients might be taken up by plants.

Application of 100kg DAP + 100kg urea per ha increased recovery efficiency of N by 60% as compared with 150kg DAP + 150kg urea per ha, while application of 183 kg NPSB + 133.5 kg urea per ha decreased the apparent recover efficiency by (39%) compared with the application of 100 kg DAP + 100 kg urea per ha.

4.5.2 Apparent recovery efficiency of phosphorous

The difference in apparent recovery efficiency of P due to fertilizer rate and location, and their interaction was highly significant (P<0.001) (Appendix 6 and Table 14). The highest apparent recovery efficiency of P (11.09%) was obtained from application of 100 kg DAP plus 100 kg urea per ha, while the minimum value (3.57%) was recorded for 61kg NPSB plus 44.5 kg urea, which was statistically at par with application of150 kg DAP plus 150 kg urea and 50 kg DAP plus50kg urea per ha. Application of 150 kg DAP plus 150 kg urea and 183 kg NPSB plus 133.3 kg urea per hade creased apparent recovery efficiency of P by 67% and 61%, respectively, as compared to 100 kg DAP plus 100 kg urea per ha. Generally, application of NPSB, DAP and urea fertilizers increased apparent recovery efficiency of P, but further increases beyond 100 kg DAP plus 100 kg urea per ha decreased the value. The increase in N and P apparent recovery efficiency with 100 kg DAP plus 100 kg urea per ha might be due to balanced amount of macronutrients and, hence, increased availability of N and P. In contrast, Bakala (2018) has reported that blended fertilizer had improved N and P recovery over the recommended N and P rate, and this might be due to the contribution of macronutrient (S) and micronutrients (B and Zn) present in blend that increased the availability of macro nutrients.

Table 14. Interaction effect of location and fertilizer rate on apparent recovery efficiency of phosphorous

			AREP%									
Treatment	Different rate of NPSB + N & DAP + N fertilizers											
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Mean
Lo1	0^{k}	3.18^{ij}	4.7^{efg}	11.79^{a}	7.73^{c}	4.32^{fgh}	4.5^{fg}	6.08^{d}	6.52^{d}	7.27c	4.2^{fgh}	5.49a
Lo2	0^{k}	4.38^{fgh}	4.8^{ef}	10.39^{b}	3.95^{gh}	2.94^{ij}	2.58^{j}	3.67^{hi}	4.4^{fg}	5.33e	4.4^{fgh}	4.25b
Mean	0^{h}	3.78^{fg}	4.71^{de}	11.09a	5.84bc	3.63g	3.57g	4.87d	5.47c	6.3b	4.3ef	
LSD 0.05	**Trt**					**0.53**						
	Lo					**0.23**						
	L X Trt					**0.74**						
CV (%)						**10.89**						

LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation; NS= non-significant. Lo=Location T= Treatment, AREP =Apparent recover efficiency of phosphorous. Means followed by the same letter(s) with in columns and rows are not significantly different at 5% P level.

Application of 100 kg DAP plus 100 kg urea per ha at location one resulted in the highest mean apparent recovery efficiency of P (11.79%), followed by the same rate at location two, while the lowest mean apparent recovery efficiency of P (2.58%) was recorded for 61kg NPSB plus 44.5 kg urea per ha at location two (Table 14).

Hence, mean maximum apparent recovery efficiency of P (5.49%) was recorded at location one and the minimum value (4.25%) was at location two and, thus, apparent recovery efficiency of P increased by 23% at location one as compared to its value at location two.

4.7. Agronomic fertilizer uses Efficiency

The difference in agronomic fertilizer use efficiency due to fertilizer rates was highly significant ($P<0.001$), but location and its interaction with fertilizer rate was non-significant (Appendix Table 6 and Table 15).

Agronomic fertilizer use efficiency (AFUE) for NPSB plus urea and DAP + urea varied from 10.1 to 23.1kg/ha at harvesting stage of tef. The highest value (23.1 kg kg^{-1}) was obtained from application of 100 kg DAP + 100 kg urea per ha, while the lowest (10.1kg/kg) was obtained from the treatment that received 61 kg NPSB + 44.5 kg urea/ha, which was statistically at par with application of 50 kg DAP + 50 kg urea per ha (Table 15). This means that applications of one kg DAP + one kg urea resulted in as high as 23.1kg grain yield of teff. This is probably due to an increase in nutrient uptake of the plants with application of macronutrients (N and P) in appropriate form of fertilizer to nutrient deficient soils of the study area. Application of100kg DAP plus 100kg urea fertilizer improved agronomic fertilizer use efficiency by 56.3% and 55.4% as compared to 61 kg NPSB + 44.5 kg urea/ha and 50 kg DAP + 50 kg urea per ha, respectively, and it increased the value by 47% over the highest rate of DAP plus urea (150 kg DAP + 150kg urea per ha). On the other hand, application of 183 kg NPSB + 133.5 kg urea decreased FUE of teff by 33% as compared with 100 kg DAP + 100 kg urea per ha. This result shows that the maximum rate of NPSB, DAP and urea did not allow the uptake of enough amount of nutrients by teff plants and, thus, resulted in lower yields in the study area.

Similarly, Okubay *et al*. (2014) have reported that the maximum agronomic efficiency or N (31.27kg/kg) was obtained at application rate of 23 kg N ha^{-1} Abebe (2012) and Bereket *et al.* *(*2014) have also observed that FUE of wheat decreases with increasing N rates. Agronomic fertilizer use efficiency value for a nutrient should not be less than 5kg per kg (Mengel *et al*., 2006). Therefore, the result of the present study indicated that application of adequate amount of N and P fertilizers in the study area may result in AFUE values (23.1kg kg^{-1}) greater than the minimum standard (Mengel *et al*., 2006).In contrast, Bakala (2018) has indicated that minimum value of agronomic fertilizer use efficiency (2.5 kg per kg) was recorded for 100 kg DAP and 100 kg urea per ha.

Table 15. Effects of rate of NP and NPSB fertilizers on AFUE of teff at Semen Ambukuna (L1) and Belela (L2) experimental sites in Tembaro district

Treatments	Agronomic use efficiency
Control	-
50kg DAP + 50kg urea	10.3g
75 kg DAP + 75 kg urea	13.2d
100kg DAP + 100 kg urea	23.1a
125 kg DAP + 125kg urea	15.5c
150kg DAP + 150kg urea	12.1de
61 kg NPSB + 44.5kg urea	10.1g
91.5kg NPSB + 66.25kg urea	11.7ef
122kg NPSB + 89kg urea	15.2c
152.5kgNPSB + 111.3kg urea	18.25b
183 kg NPSB + 133.5 kg urea	15.5c
LSD 0.05	1.38
Location	
L1	13.2
L 2	13.1
Fertilizer x L	Ns
LSD 0.05	0.59
CV%	10.47

LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation; NS= non-significant. L1=Location one, L2=Location two, AFUE =Agronomic fertilizer use efficiency. Means followed by the same letters are not significantly different at 5% P level.

4.8. Economic Feasibility Analysis

Economic analysis for the influence of different rates of blended NPSB, DAP and urea fertilizers on teff production is present in (Table 16). The results of partial budget analysis (CIMMYT, 1988) revealed that net benefit of all treatments was positive and higher than that of the control plot. The highest net benefits of 77,599.1 ETB and 77,460 ETB per ha we recorded for application of 100kg DAP + 100 kg urea per ha and followed by 77,291.2 ETB and 77,122 ETB obtained from application of 152.5 kg NPSB + 111.3 kg urea/ha and 76715.9 and 76,445 ETB was obtained from application of 183kg NPSB + 133.5 kg urea, while the lowest values 15,437 ETB and 17628.4 ETB per ha, were obtained from the control plots at Semen Ambukuna and Belela study site, respectively.

The result indicated that application of DAP plus urea showed higher net benefit, followed by treatments that receive NPSB plus urea fertilizers. Contrary to this, Bakala (2018) has reported that lowest net benefit was obtained by application of 100% recommended rate of N and P.

Increased production of the crop due to application of mineral fertilizers might or might not be beneficial to farmers (CIMMYT, 1988). Nevertheless, in the present study, it was observed that application of 100 kg DAP plus 100 kg urea, followed by 152.5 kg NPSB plus 111.3kg urea and 183kg NPSB plus 133.5 kg urea. Hence, application of 100kg DAP and 100kg urea per ha was found to be, the most economically attractive practice with low cost of production and higher benefits for smallholder farmers in the study area. If the DAP fertilizers absence in the market the application of 152.5 kg NPSB + 111.3 kg urea/ha in Semen and Belela experimental sites.

Table 16. Partial budget analysis of fertilizer used to produce teff

Treatment	GR birr/ha		TVC birr/ha		NB ETB/ha		MRR%		D	
	SA	BE	SA	BE	SA	BE	SA	BE	SA	BE
Control	15894	18085.4	457	457	15437	17628	0	0		
50kg DAP + 50kg urea	31683.2	32686	2443.6	2443.6	29239.6	30242	694.8	635.0		
61kgNPSB + 44.5kg urea	31239.8	32175	2679.7	2679.7	28560.1	29495	-287.8	-316.4	D	D
75kg DAP + 75kg urea	44866	46476	2986.9	2986.9	41879.1	43489	4335.6	4555.3	ND	ND
91.5kgNPSB + 66.25kg urea	40175.2	44932	3341	3341	36834.2	41591	-1424.7	-536.0	D	D
100kg DAP +100kg urea	81453.6	83314.8	3854.5	3854.5	77599.1	79460	7938.6	7374.7	ND	ND
125kg DAP + 125kg urea	72351	74272	4073.5	4073.5	68277.5	70199	-4256.4	-4228.8	D	D
122kgNPSB + 89kg urea	59369.6	61866	4273.1	4273.1	55096.5	57593	-6603.7	-6315.6	D	D
150kg DAP + 150kg urea	69648.9	70856	4616.8	4616.8	65032.1	66239	2890.8	2515.6	ND	ND
152.5kgNPSB + 111.3kg urea	81955	81786	4663.8	4663.8	77291.2	77122	26083.2	23155.3	ND	ND
183kgNPSB +1 33.5kg urea	82041	82770	5325.1	5325.1	76715.9	76445	-87.0	-102.4	D	D

SA= Semen Ambukuna; BE= Belela; TVC = Total variable cost, MRR = Marginal rate ratio, GR = Gross return, MR = Marginal cost, NB = Net benefit and MNB = Marginal net benefit. D = dominated treatment; ND = Non- dominated treatment.

The dominance analysis indicated that the net benefits of some treatments were dominated except application of 50kg DAP plus 50kg urea per ha, 75kg DAP plus 75kg urea per ha, 100 kg DAP plus 100 kg urea per ha, 150kg DAP plus 150kg urea per ha and 152.5 kg NPSB plus 111.3kg urea per ha (Table 16). This, result showed that the net income decreased as the total variable cost increased beyond un-dominated fertilizer application. By avoiding the dominated treatment the MMR was determined. A dominated treatment is any treatment that has net income that is less than those of treatments with lower costs that vary (CIMMYT, 1988).

The marginal rate of returns of the non-dominated treatments, T4 (100 kg DAP plus100 kg urea per ha) were MRR 7938.6 % and 73747.7%, T11 (152.5kg NPSB plus 111.3kg urea/ha) were MRR 26083.2 % and 23155.3 %, T6 (150kg DAP plus 150kg urea/ha) were MRR 2890.8 % and 2515.6 %, T3 (75kg DAP plus 75 kg urea/ha) were MRR 4335.6% and 4555.3% and T2 (5 0kg DAP plus 50kg urea per ha) were MRR 694.8% and 635.0% at Semen Ambukuna and Belela experimental sites, respectively. According to CIMMYT (1988), for on farm-economic analysis of major cereals, MRR that ranged from 50% to 100% was the minimum recommended rate in most agricultural production and it is better when the MRR was > 100 %.

The results of non-dominated treatments indicated that for one birr invested in purchase or production of fertilizers it was possible to recover one birr plus an additional of 79.4 and 73.8 birr ha^{-1} as the fertilizer application changed from unfertilized plot to 100kg DAP plus 100kg urea ha^{-1}. Passing from the first treatment that had the lowest costs that vary to the end treatment which had the highest cost that vary, the marginal rate of return obtained was above the minimum acceptable marginal rate of return.

In general, the most profitable treatment was found to be application of 100 kg/ha DAP + 100 kg/ha urea at both experimental sites. Hence, the most economically attractive treatment for small scale farmers with low cost of production and higher benefits application of 100kg DAP plus 100 kg urea fertilizer at both location one and two. Therefore the DAP fertilizer out from the market the application of blended fertilizer (152.5kg NPSB plus 111.3 kg urea) at Semen Ambukuna and Belela sites.

5. CONCLUSIONS AND RECOMMENDATIONS

The analytical results of fertility status of the soil before planting indicated that was clay in texture with a pH of 5.33 to 5.42, which was moderately acidic. Both experimental sites were low in total nitrogen (0.119 and 0.13%), available S (13.94 and 15.22mg/kg), available P (8.21 and 9.11mg/kg), available B (0.71 and 0.75mg/kg), OC (0.96 and 1.2%) and OM (1.66 and 2.9%). Hence, based on these results, it can be concluded that N, P, S and B may be yield-limiting essential nutrients in the study area. Soil analysis of OM rated as low is indicative of the need for addition of organic fertilizers, such as green manure and farmyard manure. Exchangeable Ca (5.7 and 6.8cmol (+)/kg), exchangeable Mg (2.9 and 2.3cmol (+)/kg), exchangeable K (0.79 and 0.81cmol (+)/kg), PBS (49.7 and 50.6%) and CEC (19.8 and 23.6cmol (+)/kg) were at medium level at both experimental sites. However, exchangeable Na (0.06 and 0.09 cmol (+)/kg) was very low at Semen Ambukuna and Belela experimental sites.

The analytical results of fertility status of the soil after harvesting indicated that the each experimental plot based on the treatments just after harvesting teff crop. A comparison of soil chemical properties before sowing and after harvesting crop revealed that application of DAP + urea and NPSB + urea fertilizers decreased numerical some chemical properties of soil, indicating that there is no improvement of the fertility status of soil. Generally, one year mineral fertilizer application blended (NPSB) plus urea and DAP plus urea fertilizers) may slightly decreasing the soil fertility status both experimental area except available P slightly increased in both experimental plots as compared to before sowing.

In the present study, it was observed that application of different rates of NPSB + urea and DAP plus urea fertilizers and locations significantly influenced days to 50% heading, panicle length, number of productive tillers per plant, grain yield, straw yield and harvest index. But, treatment effects were highly significant for plant height, dry root mass and apparent recover efficiency of nitrogen

In general, higher application rates of NPSB, DAP and urea significantly improved teff yield and yield attributes at the both experimental sites. However, from the economic point of view, the highly performed treatment was 100 kg DAP + 100 kg urea per ha, which gave the highest economic benefit (77,599.1 ETB and 79,460 ETB per ha) with MRR% of 7938.6 and 7374.7

%, followed by 152.5kg NPSB + 111.3 kg urea highest economic benefit (77,291.2 and 77,122 ETB per ha) with MRR% of 26083.2 and 23155.3% at experimental site one (Semen Ambukuna) and site two (Belela), respectively.

Therefore, it was concluded that application of 100 kg/ha DAP plus 100 kg/ha urea per ha could be recommended for production of teff in the study area and in some other areas with similarly agro-ecological conditions but the DAP fertilizer absence in market the application of 152.5 kg NPSB + 111.3 kg urea. However, it was suggested that a similar experiment has to further be carried out on different soil types, in different years/seasons and across locations, considering comprehensive soil and plant tissue analysis, to draw sound recommendations at a wider scale. soil organic matter content is low at both Semen Ambukuna and Belela sites, addition of crop residue, compost, green manure and farmyard manure seems also very important in order to improve fertility status of soils of the area. Furthermore, as the rates of sulfur and phosphorus in the blended fertilizers are less than the requirements for cereal crops, it was suggested that fertilizer blending companies must revisit and work out the formula towards balancing the ratio of sulfur and phosphorus with other macronutrient.

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7. APPENDIX

Appendix Table 1. Appendix Table 1.Rating of organic carbon, organic matter, total nitrogen and cation exchangeable capacity.

Ratings	OC%	OM%	TN%	CEC
Very low	<0.08	<1	<0.1	<5
Low	0.08-2.59	1 -2	0.1-0.15	5-15
Medium	2.59-5.17	2-5	0.15-0.25	15-25
High	>5.17	5-10	>0.25	25-40
Very high	-	>10	-	>40

Source: organic carbon Tekalign*et al.* (1991), cation exchangeable capacity Landon (2014), total nitrogen Havlin *et al.* (2013) and Organic matter Barber (1984).

Appendix Table 2. Relationships between some soil nutrient levels and soil chemical rating.

Ratings	K(cmol(+) kg $^{-1}$	Ca(cmol(+) kg $^{-1}$	Mg(cmol(+) kg $^{-1}$	Na(cmol(+) kg $^{-1}$
Very low	<0.2	<2	<0.3	<0.1
Low	0.2-0.5	2-5	0.3-1.0	0.1-0.3
Medium	0.51-1.5	5-10	1.0-3.0	0.3-0.7
High	1.51-2.3	10-20	3-8	0.7-2
Very high	>2.3	>20	>8	>2.0

Source: Exchangeable potassium (EthioSIS, 2014), Exchangeable Calcium (EthioSIS, 2014), Exchangeable Sodium (Landon, 1991) and Exchangeable magnesium Landon (2014).

Appendix Table 3. Relationships between some soil nutrient levels and soil chemical rating.

Ratings.	A.V P(mg/kg)	A.V.S(mg/kg)	PBS%	pH H_2O	B(ppm)
Very low	-	<10	-	<4.5	0.5
Low	<10	10-20	<20	4.5-5.0	0.5-0.8
Medium	11-18	20-80	20-60	5.1-5.5	0.8-2
High	>18	80-100	>60	5.6 - 6.0	2.0-4.0
Very high	-	>100	-	6.1-6.5>4.0	

Source; Available sulfur and Boron Ethiosis (2014) and Available phosphorous Landon (1991) Bary II methods, pH Mesfie (2007).

Appendix Table 4. Analysis of Variance of Mean square values of ANOVA for days to heading, days to physiological maturity, plant height, panicle length, total number and effective tillers affected by rate of blended fertilizer and DAP for site one .

Source of variation		Mean square							
	Df	PH	PL	DF	DM	LN	TT	TE	LA
Block	3	10.92	25.109	3.28	1.31	0.21	0.56	0.215	1.47
Lo	1	34.5	133.53***	575.28***	1598.01***	0.82*	0.6*	0.82*	107.8***
Trt	10	1081.56***	177.98***	216.73***	103.35***	16.18***	24.09***	16.2***	150.39***
Lo xTrt	10	9	7.99	4.03	5.84***	0.024ns	0.31*	0.024	11.21*
Error	63	21.8	7.64	2.34	1.04	0.1	0.13	0.1	3.95
CV		6.23	5.42	2.9	1.3	7.26	6.93	7.3	11.27

Where, ***DM*** *= days to 90% maturity;* ***DF*** *= days to 50% heading;* ***LN*** *= leaf number per 20 plants;* ***PH*** *= plant height,* ***TT*** *=Total tillers,* ***ET*** *=Effective tillers,* ***LA*** *=leaf area,* ***LO*** *=location,* ***CV*** *= co- variance PL=Panicle length. NS, *, ** and *** = non-significant, significantly different at 5%, 1% and 0.1%respectively.*

Appendix Table 5. Analysis of Variance of Mean square values of ANOVA for dry root mass, leave number, grain yield, straw yield, harvest index , affected by rate of blended fertilizer and DAP at study area.

Source ofvariation		Mean square			
	DF	YD	SY	HI	DRM
Block	3	4453.95	252324.7	0.0023	0.0127
Lo	1	75441.68**	714060.6***	0.0029**	0.0011ns
Trt	10	3923415.47***	13129495.8***	0.0126***	0.296***
Lo xTrt	10	3063.11ns	39830.8ns	0.005ns	0.0126ns
Error	63	5890	42462	0.00038	0.015
CV		4.72	4.76	7.42	7.47

Where, ***DRM*** *= Dry root mass;* ***LA*** *= leave area;* ***GY*** *= Grain yield;* ***SY*** *= Straw yield,* ***HID*** *=Harvest index, NS, *, ** and* **non-significant, significantly different at 5%, 1%and0.1% respectively.*

Appendix Table 6. Analysis of Variance of Mean square values of ANOVA for apparent recovery efficiency of nitrogen and phosphorous and agronomic use efficiency in study area.

Source of variation		Mean square		
	DF	ANRE%	APRE%	AEkg/kg
Block	3	193.44	0.068	6.086
Lo	1	8.74^{ns}	33.42***	9.065^{ns}
Trt	10	2972.89***	56.51***	181.49***
Lo xTrt	10	20.89^{ns}	4.16***	0.39ns
Error	63	33.94	0.28	1.73
CV		15.26	10.89	10.47

*Where, CV= Coefficient of Variation; NS= non-significant. Lo=Location Trt= Treatment, AREN%=agronomic recovery efficiency nitrogen, AREP%=agronomic recovery efficiency phosphorus and AE=agronomic efficiency Means in columns followed by the same letters are not significantly different at 5% level of significance, *, ** and *** = non-significant, significantly different at 5%, 1% and 0.1% respectively.*

Appendix Table 7. Partial budget and dominance analysis of NPSB and NP fertilizers on yield Straw of teff production at study area.

Trt #	Grain GY kg	AJGY kg	P Birr/kg	R.Vbirr/ha (1)	Straw SY kg	AJSYkg	Price birr/kg	R.VBirr/ha (2)	GR(1+2)
		Semen Ambukuna							
T1	438	394.2	3200	12614.4	1878	1690.2	100	1690.2	14304.6
T2	887.6	798.84	3200	25562.88	3280	2952	100	2952	28514.88
T3	1278	1150.2	3200	36806.4	3970	3573	100	3573	40379.4
T4	2378.5	2140.65	3200	68500.8	5092	4582.8	100	4582.8	73083.6
T5	2084.8	1876.32	3200	60042.24	5639	5075.1	100	5075.1	65117.34
T6	1981.8	1783.62	3200	57075.84	6231.3	5608.17	100	5608.17	62684.01
T7	877.9	790.11	3200	25283.52	3147	2832.3	100	2832.3	28115.82
T8	1130.6	1017.54	3200	32561.28	3996	3596.4	100	3596.4	36157.68
T9	1709.8	1538.82	3200	49242.24	4656	4190.4	100	4190.4	53432.64
T10	2391.5	2152.35	3200	68875.2	5427	4884.3	100	4884.3	73759.5
T11	2379.5	2141.55	3200	68529.6	5321	788.9	100	4788.9	73318.5
			Belela						
T1	503.7	453.33	3200	14506.56	1967	1770.3	100	1770.3	16276.86
T2	923	830.7	3200	26582.4	3150	2835	100	2835	29417.4
T3	1337	1203.3	3200	38505.6	3692	3322.8	100	3322.8	41828.4
T4	2447.9	2203.11	3200	70499.52	4272	4483.8	100	4483.8	74983.32
T5	2125	1912.5	3200	61200	5344	4809.6	100	4809.6	66009.6
T6	2020	1818	3200	58176	6216	5594.4	100	5594.4	63770.4
T7	914	822.6	3200	26323.2	2927	2634.3	100	2634.3	28957.5
T8	1288	1159.2	3200	37094.4	3716	3344.4	100	3344.4	40438.8
T9	1798	1618.2	3200	51782.4	4330	3897	100	3897	55679.4
T10	2397	2157.3	3200	69033.6	5082	4573.8	100	4573.8	73607.4
T11	2454	2208.6	3200	70675.2	6364	4720.5	100	4720.5	75395.7

AvY= average yield and straw; AJY= average adjusted yield and straw;

Appendix Table 8. Net economic analysis of NPSB and NP fertilizers on yield Straw of teff production at study area.

Trt#	RG birr/ha	R.Sbirr/ha	G.R(a+b)	T,VC birr/ha (c)	NB (a+b)_(c)
T1	12614.4	1690.2	14304.6	457	13847.6
T2	25562.88	2952	28514.88	2443.6	26071.28
T3	36806.4	3573	40379.4	2679.7	37699.7
T4	68500.8	4582.8	73083.6	2986.9	70096.7
T5	60042.24	5075.1	65117.34	3341	61776.34
T6	57075.84	5608.17	62684.01	3854.5	58829.51
T7	25283.52	2832.3	28115.82	4073.5	24042.32
T8	32561.28	3596.4	36157.68	4273.1	31884.58
T9	49242.24	4190.4	53432.64	4616.8	48815.84
T10	68875.2	4884.3	73759.5	4663.8	69095.7
T11	68529.6	4788.9	73318.5	5325.1	67993.4
	Belela				
T1	14506.56	1770.3	16276.86	457	15819.86
T2	26582.4	2835	29417.4	2443.6	26973.8
T3	38505.6	3322.8	41828.4	2679.7	39148.7
T4	70499.52	4483.8	74983.32	2986.9	71996.42
T5	61200	4809.6	66009.6	3341	62668.6
T6	58176	5594.4	63770.4	3854.5	59915.9
T7	26323.2	2634.3	28957.5	4073.5	24884
T8	37094.4	3344.4	40438.8	4273.1	36165.7
T9	51782.4	3897	55679.4	4616.8	51062.6
T10	69033.6	4573.8	73607.4	4663.8	68943.6
T11	70675.2	4720.5	75395.7	5325.1	70070.6

Appendix Table 9. Mean minimum and maximum temperature (^{o}c) at experimental Semen Ambukuna and Belela (2014-2018).

Year	T(^{o}c)	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	AV. T(^{o}c)
Semen Ambukuna														
2014	Min	13.5	12.2	10	11.2	13.2	7.3	9.8	7.4	9.5	8.5	9.4	9.4	10.1
	Max	19.6	24	22.2	25	22.8	22.5	20.1	20	18.7	21.7	21.8	20	21.5
2015	Min	0	12.6	11.3	12.9	9.6	11.3	9.2	8.3	9.5	7.6	10.3	10.3	9.4
	Max	21.6	20.7	22.6	22.6	22.9	22.6	18.4	19	20	19.6	21	21	21.0
2016	Min	12.8	12.6	11.5	11.8	9.6	8.5	9.4	10	9.2	8.4	10.3	10.3	10.4
	Max	21.6	20.1	23.1	23.1	23.6	24.1	18.3	18	19.2	19.7	19.2	19.9	20.8
2017	Min	13.6	11	12.3	9.6	10.2	9.5	7.5	8.5	9.2	8.3	8.4	8.4	9.7
	Max	22	20.5	24	24	24.6	24.5	21.6	22	21.5	21.8	22.2	21.5	22.5
2018	Min	12.4	11.3	10.4	10.8	11.6	9.3	10.6	9.8	9.6	9.7	10.1	10.1	10.5
	Max	20	21.1	21	21	24.6	21	18.4	22	20.9	20	21	21	21.0
Belela														
2014	Min	14.2	13.5	12.3	11.9	11.3	9.8	9.4	9.5	9.5	9.9	9.6	12.1	11.1
	Max	29.1	27.6	28	26	27.8	25.4	26.2	25	26.7	28.4	26.2	27.9	24.7
2015	Min	15.1	13.2	14.1	10.4	10.3	9.7	8.5	8.5	8.6	9.6	10.3	9.2	10.6
	Max	28.8	28.4	29.5	29.5	26.5	24.4	25.3	26	24.4	25.8	26.2	26.7	24.6
2016	Min	12.6	13.1	13.1	10.7	9.9	9.5	8.5	8.5	8.5	11.3	9.6	8.2	10.3
	Max	27	27.4	27.5	27	28	26.8	26.3	28	27	26.5	23.2	27.4	24.6
2017	Min	14.6	12.4	13.4	11	12.9	8.6	9.4	9.4	9.4	9.7	10.1	9.2	10.8
	Max	27.7	26.9	28.2	28.5	28.1	28.4	24.8	26	25.4	26.2	27.3	6.42	25.3
2018	Min	13.6	12.8	11.2	10.3	11.6	9.2	9.6	9.6	9.6	9.5	10.1	8.7	10.5
	Max	29	28.1	26.5	27.3	24.7	26.3	27.2	26	25.2	28	27.7	28.1	27.0

Appendix Table 10. Mean monthly and Year total rainfall (mm) at experimental Semen Ambukuna and Belela (2014-2018).

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	AV.m Rf
2014	0	0	15.6	57.2	31.4	158	362	391	175	86	13.5	0	1290
2015	0	37.5	96	116	80.8	253	382	346	185	90	12.5	6.7	1606
2016	0	25.3	32.5	76.2	97	121	356	219	179	42	18.8	0	1166
2017	0	33	32.7	0	179	145	425	295	190	15	0	0	1315
2018	0	0	36.7	10.2	130	31.1	324	355	98	15	0	0	999.6
Belela (Site Two)													
year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
2014	0	3.5	0	45.2	90.7	184	355	302	166	9.6	1.3	0	1158
2015	0	9.7	45.8	76.1	17.5	206	316	341	165	17	3.5	0	1198
2016	0	32.8	69.3	74.4	74.2	250	395	216	115	24	11.5	0	1262
2017	0	0	35.4	45.4	38.5	255	285	265	50	11	0	0	985.6
2018	0	0	29.6	85.9	29.4	157	395	301	76	20	12	0	1106