RESPONSES OF TEF (*Eragrostis tef. L*) TO COMBINED APPLICATION OF NITROGEN AND BLENDED NPSB FERTILIZER RATES IN TEMBARO DISTRICT, SOUTHERN ETHIOPIA

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Responses of Tef (*Eragostises tef. L*) To Combined Application of Nitrogen and Blended NPSB Fertilizer Rates in Tembaro District, Southern Ethiopia

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We hereby certify that we have read and evaluated this thesis entitled **“**Response of Tef (*Eragostises tef. L*) to Combined Application of Nitrogen and Blended NPSB Fertilizer rates in Tembaro District, Southern Ethiopia Guidance by Zewde Aore. We recommend that it be submitted as fulfilling the thesis requirements.

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As members of the Board of Examiners of the M.Sc. thesis open defense examination, we certify that we have read and evaluated the thesis prepared by Zewde Aore and examined him. We recommend that the thesis be accepted as it fulfills the requirements for the Degree of Master of Science.

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DEDICATION

This thesis is dedicated to my father Aore Alito, my mother Bezunshe Worako, my Sisters and my brother for their affection and consistent care in the success of my life.

STATEMENT OF THE AUTHOR

First of all, I declare that this thesis is a result of my genuine work and all sources materials used for writing it have been duly acknowledged. I have submitted this thesis to Haramaya University in partial fulfillment of the Degree of Master of Science in Agriculture with Specialization in Agronomy. The thesis is deposited at the library of the University to be made available to borrowers under the rules and regulations of the library. I solemnly declare that I have not submitted this thesis to any other institution anywhere for the award of any academic degree, diploma, or certificate. Brief quotations from this thesis are allowed without requiring special permission provided that an accurate acknowledgement of the source is made. Requests for extended quotations from or reproduction of this manuscript in whole or part may be granted by the head of the School of Plant and Environmental Sciences or by the Dean of the School of Graduate Studies of the University when in his or her judgment, the proposed use of the material is for a scholarly interest. In all other instances, however, permission must be obtained from the author.

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BIOGRAPHICAL SKETCH

The author was born on November 3, 1989 from Mr. Aore Alito and Mrs.Bezunshe Worako at Dhabube Amebukuna Keble, Kambata Tambaro Zone, Ethiopia. He attended the Elementary School Education at Amebukuna (1-8) and completed the Junior high school at Mudulla comprehensive high school in Tambaro. After passing the EGSECE, he joined Alaga Agricultural and TVT College in Plant Science in 2004 and graduated with Diploma in Plant Science July 2006. After the graduation, he was employed Agricultural and Natural Development Office of Tambaro Woreda from September 2007up to Agust2011. After serving for 5 Year, he joined Wolita Sodo University in 2008. He graduated BSC Degree in Plant Science 2015. After the graduation, he was employed Agricultural and Natural Development Office of Tambaro Woreda, he served for 2 years. Then he joined the School of Graduate Studies of Haramya University in Sept 2019 to pursue a study leading to the Degree of Master of Science in Agronomy.

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ABBREVIATIONS AND ACRONMYS

ANOVA	Analysis of Variance
ATA	Agricultural Transformation Agency
CEC	Cation Exchange Capacity
CIMMYT	International Maize and Wheat Improvement Center
CSA	Central Statistical Agency
CV	Coefficient of Variation
DAP	Di-ammonium Phosphate
DZAR C	Debre Zeit Agricultural Research Center
Ethio SIS	Ethiopian Soil Information System
FAO	Food and Agriculture organization
LSD	Least Significant Difference
M.a.s.l	Meters above Sea Level
MoARD	Ministry of Agriculture and Rural Development
MRR	Marginal rate of return
NPSB	Nitrogen, Phosphorus, Sulfur and Boron
OC	Organic Carbon
RCB D	Randomized Complete Block Design
SNNPRS	Southern Nations, Nationalities and Peoples Regional State

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ABSTRACT

Tef is a highly valued crop in the national diet of Ethiopians and the major crops grown in Southern Ethiopia. However, its productivity is constrained by low plant-available soil nutrients due to depleting soil organic matter content and long history of intensive cultivation. Therefore, a field experiment was carried out Tambaro district during the 2019 main cropping season with the objective of:to assess the combined responses of N and blended NPSB fertilizer rates on growth, yield and yield components of tef. To determine economically optimum N and blended NPSB fertilizer, application rate for high grain yield of tef. The experiment consisted four levels of nitrogen (0,23,46 and 69 kg N ha-^{1}) and four levels of blended (0, 50, 100 and 150 kg NPSB ha-$^{1)}$ in factorial combinations using quench tef variety as a test crop. The experiment was laid out in RCBD with three replications. The result revealed that the main responses of N rates were highly Significant ($P<0.01$) in terms of total number of tillers,90% physiological maturity, 50%panicle emergence and productive tillers. Grain yield, straw yield, harvest index and aboveground dry biomass are significant($P<0.05$) on main responses of N rates. The highest values were recorded at the highest rate of 69 kg N ha-1. Similarly, the main responses of blended fertilizer were significant($P<0.01$) on plant highest, 1000 kernel weight and 90% physiological maturity. The combined application of N and blended fertilizer are not significant on plant physiological maturity, biomass, grain yield, plant highest, panicle length, total tiller and effective tillers. The highest plant height, effective tillers, panicle length and total tiller where obtained at highest application rate of (69 kg N ha-^{1}), While the lowest were obtained from-unfertilized (control) plot. On the other hand, the highest straw yield (7038.5kgha-^{1}) and biomass (7326.56kgha^{-1}) where obtained from the highest application rate of 23/150 N/NPSB and 69 N are respectively. While the lowest straw yield (5126.88kgha-^{1}) and biomass (6059.2kgha-$^{1)}$ where obtained from control plot. The maximum yield (2533.3kg ha-1) was obtained from at combined application of 46kg N and100 kg NPSB (ha-^{1}) fertilizers rate. Applying 100 kg blended NPSB (ha-^{1}) Supplemented with 46kg N (ha-^{1}) had the highest net benefit, relatively low variable cost together with highest and acceptable MRR for tef production in Tambaro district.

Keywords:Blended fertilizer, Nitrogen, Tef and yield.

1.INTRODUCTION

Tef is the only cereal crop member of the tribe Eragrostidae and genus Eragrostis which contains about 350 species Tef (Eragrostis tef /Zucc. /Trotter) belonging to the grass family poaceae, is a C4, self-pollinated annual grass, 40– 80 cm tall (Dejene & Lemlem, 2012). It is believed to have been originated in Ethiopia between 4000 and 1000 BC (Vavilov, 1951). Tef has as more food value than the major grains; like wheat, barley and maize. This is probably because it is always eaten in the whole grain form. The germ and bran are consumed along with the endosperm (Demeke and Marcantonio, 2013). In Ethiopia, Tef is a high value crop and it is primarily grown for its grain that is used for preparing injera (leavened bread), which is a staple and very popular food in the national diet of most Ethiopians.

The vitamin content seems to be about average for a cereal. The level of minerals is also good. Seyfu (1997) reported that tef is predominantly grown in Ethiopia as a cereal crop and not as a forage crop. However, when grown as a cereal, farmers highly value the straw of tef and it is stored and used as a very important source of animal feed, especially during the dry season. Farmers feed tef straw preferentially to lactating cows and working oxen. Cattle prefer tef straw over other cereal straw and for this reason, its price is higher than that of other cereals.

Tef growing area occupies about (50,204,400.47 *ha*) of the total acreage of all the major cereals grown in Ethiopia (CSA, 2017). In Ethiopia, tef is mainly produced in Amhara and Oromia, with smaller quantities in the Tigre and SNNP regions. In Southern Regional State of Ethiopia, the major tef producing zones include the Bench magi, Shako, Dawro, KambataTembaro, Wolita, Alba, Garage and sileta. Tef in Southern regional state of Ethiopia, where it currently, occupies about, 246,099.24 hacter of land annually with estimated production of 3,412,547.66 quintals (CSA, 2017). The average yield of tef in the region is 13.87 quintals per hacter; it is low compared to the national 16.6 quintals per hacter and stile low in productivity. The study area of Kambata Tambaro Zone is also one of the major tef producing Zones of SNNPR which covers an area of 11,222.8 hacter with production and yield of 159,933.17quintals and the average yield of tef in this zone is 14.25 per hacter (2016/17 cropping season (CSA, 2017).

However, tef yield in Ethiopia and the study zone are low as compared to the attainable yield, because tef production is constrained by both by biotic and a biotic factor such as diseases, insect pests, poor management practices, poor soil fertility, moisture stress, slow progress in developing tef cultivars, inappropriate sowing patterns, seed rate, rate of fertilizers, climatic condition, sowing time, weed etc. Among the several factors responsible for low yield in study area, use of unbalanced rate of fertilizers and inappropriate seed rats are important agronomic practice and research on these limiting factors will enhance yield. Balanced fertilizers containing N, P, K, S, B and Zn in blend form are recommended ameliorating site specific nutrient deficiencies and thereby increasing productivity (ATA, 2014).

Most research work so far focused on NP requirements of crops and, hence, limited information is available on various sources of fertilizers like S, Zn, B and other micronutrients. Therefore, application of other sources of nutrients beyond urea and DAP, especially those containing S, Zn, B and other micro-nutrients could increase crop productivity (CSA, 2017). Application of balanced fertilizers could be the basis to produce more crop output from existing land under cultivation through satisfying the nutrient needs of crops according to their physiological requirements and expected yields (Ryan, 2008).

Based on the Ethiopia (2014) map of blended fertilizers containing N, P, S, and B in blend were identified as deficient nutrients in Tembaro woreda of its surrounding village. However, the current blended fertilizers contain small amount of nitrogen as compared to the recommended nitrogen fertilizer rate for economical tef production. Tef responds differently to fertilizer rates and types depending on soil type and cultivars (Melesse, 2007). There are different rates of fertilizers for various soil types in Ethiopia for tef production. According to MoARD, the national blanket recommendation of N fertilizer is 64 kg N ha^{-1} for Verstisols and other soil types across the country (Kene'a et al., 2001).

Generally, the recommended rate of fertilizer for tef is 25-40 kg N ha^{-1} on light soils such as Nit sols, Luvisols and Cambisols and 50-60 kg N ha^{-1} ^{f}or heavy soils such as Vertisols (Deckers et al., 2001). Application of 46 kg N ha^{-1} (100 kg ha^{-1} urea) gave better yield and growth performance than application of 23 kg N ha^{-1} (50 kg ha^{-1} urea) on Vertisols. The average highest grain yield of 2.44 tons' ha^{-1} was obtained when 100 kg ha-1 of urea and 46 kg P2O5 ha^{-1} P fertilizer rates were used for tef (Fikiremariam et al., 2014).

The farmers in most parts of the country in general and Tembaro district in particular have limited information on the impact of different types and rates of fertilizers except blanket recommendation of nitrogen (46 kg N $ha^{-1)}$ and phosphorus (46 kg P2O5 $ha^{-1)}$ that is 100 kg urea and 100 kg DAP per ha^{-1} (MoARD, 2008). The soil fertility mapping project in Ethiopia reported the deficiency of K, S, Zn, B and Cu in addition to N and P in major Ethiopian soils and N, P, S and B particularly in the study area (Ethio SIS, 2014).

Except the blanket recommendation of nitrogen and phosphorus, the effect of other fertilizers on yield components, yield, and overall performance of tef are unknown, even though new blended fertilizers such as NPSB (18.9% N, 37.7% P2O5, 6.95% S and 0.1% B) are currently being used by the farmers in the study area. In addition to this, the amount of N in the blended NPSB is small as compared to the requirement of tef. Thus, there is a need to supplement with nitrogenous fertilizer in the form of urea. Thus, there is a need to develop site specific recommendation on the fertilizer rates to increase production and productivity of tef.

Therefore, this study was initiated with the following specific objectives:

To assess the combined responses of N and blended NPSB fertilizer rates on growth, yield and yield components of tef.

To determine economically optimum N and blended NPSB fertilizer application rate for high grain yield of tef.

2.LITERATURE REVIEW

2.1. Origin of Tef

The fact that the genetic diversity for tef exists nowhere in the world except in Ethiopia indicates that tef was originated and domesticated in Ethiopia. Vavilov (1951) identified Ethiopia as the centre of origin and diversity of tef. Tef is endemic to Ethiopia and it major diversity is found only in this country. As it is true with several other crops, the exact date and location for the domestication of tef is unknown. However, there is no doubt that it is a very ancient crop in Ethiopia, where domestication took place before Christ. According to Ingram and Doyle (2003), tef was introduced to Ethiopia well before the Semitic invasion of 1000 to 4000 BC.

It was probably cultivated in Ethiopia even before the ancient introduction of emmer wheat and barley. According to Tadesse (1975), tef seeds found by Unger (1866) in the Pyramid of Dashur (3359 BC) and from the ancient Jewish town of Ramses in Egypt were probably Eragrostis aegyptiaca or Eragrostis pilosa and thus are not good evidence for the cultivation of tef in ancient Egypt.

2.2 Morphology and Ecology of tef

Tef is a member of the tribe Eragrosteae, sub-family Eragrostoidae, of the Panacea (Gramineae) family. These species are classified based on characteristics of culms, spikelet's, lateral veins, pedicels, panicle, flowering scales and flower scale colors. The taxonomy of tef has been also clarified by numerical taxonomy techniques, cytology and biochemistry, including leaf flavanoids and seed protein electrophoretic patterns (Eshetu and Lester, 1981).

Tef is a fine stemmed tufted annual grass. The plant has the appearance of a bunch grass having large crowns and many tillers. The inflorescence is an open panicle and produces small seeds. The roots are shallow and develop a massive fibrous rooting system. Taddesse (1975) reported that plant height of tef varies depending upon cultivar type and growing environments.Tef is a warm season annual grass; its maturity varies from 93–130 days. Grain color ranges from pale white to ivory white and from very light tan to deep brown to reddish brown purple. Tef seed is very small, ranging from 1–1.7 mm long and 0.6–1mm diameter with l000 seed weight averaging 0.3–0.4 grams.

Grain and straw yield represented the maximum genetic diversity among the observed tef germplasm (Seyfu, 1997). Tef is adapted to environments ranging from drought stress to water logged soil conditions. Tef is grown under Ethiopian Vertisols to which it is ecologically well adapted due to its tolerance to water logging (Efrem, 2001). Vertisols comprise 2.5% of the world 's total land area, with major areas in India, Africa and Australia.

They occupy about 105 x106ha in Africa and about 12.6 x 106 ha in Ethiopia (Blokhuis, 1982; Debele, 1985) and around 5.9 x 106 ha is in use by farming systems in which tef is an important crop. Vertisols are damontmorillonite-rich clay soils with characteristic shrinking and swelling properties. They have high clay content (43% to at least 50 cm depth from the surface) and when dry they show cracks of at least 1 cm wide and 50 cm deep (FAO, 2000). It is reported that in Ethiopia, believed to be the center of origin of tef, maximum production occurs at altitudes between 1800 and 2100 ma.s.l with growing season rainfall of 450-550 mm and a temperature range of 10 to 27 °C (Stallknecht *et al*., 1993). Tef is day length sensitive and flowers best during 12 hours of daylight (Decker's *et al*., 2001).

2.3. Importance of Tef

Tef has as much or even more food value than the major grains such as wheat, barley, and maize. This is probably because it is always eaten in the whole grain form. The germ and bran are consumed along with the endosperm (Demeke and Di Marcantonio, 2013). In Ethiopia, tef is primarily grown for its grain that is used for preparing *injera* (leavened bread), which is a staple and very popular food in the national diet of most Ethiopians. It can also be used in many other food products, such as *kitta* (unleavened bread), *anebaberro* (double layered injera), porridge, gruel, and local alcoholic beverages, such es*tella* and katikala (Seyfu, 1997; Hailu and Seyfu, 2001).

However, tef is not suitable for bread making as it lacks the necessary amount and quality of protein complex called ―gluten‖ that can be formed into dough with the rheological properties required for the production of leavened bread in wheat. According to Patricia and Lisette Van (2008), tef is rich in energy (353-367 K cal/100 g). Its fat content averages about 2.6%. The protein content is as good as or better than that of other cereals and it ranges from 8 to 15%, with average of 11%. The protein digestibility is probably high because the main protein fraction, albumin, glutline and globulin are the most digestible types.

The vitamin content seems to be about average for a cereal. The level of minerals is also good (average ash content is 3%). Tef is reported rich in iron, calcium, potassium and phosphorus. The iron (0.011-0.033%) and calcium (0.1- 0.15%) contents are especially notable (Patricia and Lisette Van, 2008). Abay *et al.* (2011) reported that tef contains 11% protein and is an excellent source of essential amino acids, especially lysine, the amino acid that is most often deficient in other grain foods. It contains more lysine than barley, millet, wheat and slightly less than rice or oats. It is also further mentioned that tef is an excellent source of fiber, iron and has many times the amount of calcium, potassium and other essential minerals found in an equal amount of other grains. It is also noted that tef is nearly gluten-free and is gaining popularity in the whole food and health food industry in the USA as an alternative grain for persons with gluten sensitivity or allergic effect during 12 hours of daylight (Decker *set al*., 2001).

2.4. Tef Production Constraints in Ethiopia

Environmental stress is the most important factor which affects crop production. According to Classman (1999) only about 10% of world arable land may be classified into non-stress category. About 20% of the land is limited by mineral stress, 26% by drought stress and 15% by freezing stress (Blum, 1988). Modifying the environment for proper crop growth means the alleviation of environmental stresses through the current crop management practices (Arkin and Taylor, 1983). Tef is harvested very close to the ground because of the high value of the straw, leaving the soil bare for about half a year after harvest and exposing the ground further. Therefore, the loss of soil organic matter and physical erosion are major problems in some tef growing areas. Inorganic fertilizers are able to overcome some, but not all of these deficiencies.

According to Seyfu (1991) tef is mostly grown on soils that are less fertile, have moisture deficit and mostly on water logged during the main rainy season, all of which limit the growth and yield of the crop. Assefa *et al.* (2000) discussed that Lodging is the most important factor contributing to the low yield, affects productivity by interfering with water and nutrient transport as well as light interception. It also provides a favorable environment for disease and decreases grain yield of tef. On average, lodging inflicts about 11-22 % total grain yield losses of tef (Seyfu, 1993). Moreover, factors contributing to low yield of tef are low soil fertility and suboptimal use of mineral fertilizers, in addition to weeds, erratic rainfall distribution in lower altitudes, lack of high yielding cultivars, lodging, water-logging, low moisture, complete removal of field crop residues without any soil amelioration activities, low or no input of fertilizers and low soil fertility conditions (Fufa, 1998).

2.5. Rationale of the Soil Test Based Fertilizer Recommendations in Ethiopia

Soil test based application of plant nutrient helps to realize higher response ratio and benefit: cost ratio as the nutrients are applied in proportion to the magnitude of the deficiency of a particular nutrient and correction of the nutrients imbalance in soil helps to harness the synergistic effects of balanced fertilization. Location specific fertilizer recommendations are possible for soils of varying fertility, resource conditions of farmers, level of target yield conditions of similar soil classes and environment (Ahmed, 2002). A large number of soil testing laboratories have been established in Ethiopia, but not much work has been done to develop calibrations correlating soil tests to fertilizer needs. Unfortunately, in the past soil testing and related field experiments were often not complete, or they focused on only one or two nutrients, while ignoring the others (Farina, 2011).

2.6. The Need for Blended Fertilizer

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. The ingredients of a blended fertilizer can be straight materials, such as urea or potassium chloride; granulated compound fertilizer materials mixed together or a combination of the two (Oldham, 2000). The main advantages of blended fertilizers to the farmers are: nutrients are supplied in ratios to suit the needs of particular soils and crops; the cost per unit of plant nutrient is generally low; the cost of transportation and spreading is low because of the high analysis of bulk blends (Roy *et al*., 2006).

Moreover, blends have the advantage of allowing a very wide range of fertilizer grades that makes it possible to match a fertilizer exactly to a soil test recommendation (Oldham, 2000). However, the fertilizers used for mixing must be compatible both chemically and physically (Roy *et al*., 2006). Blended fertilizer allows small batches of high analysis soil and crop specific fertilizers to be mixed and transported in an economical manner contributing additional profit for farmers and improving the environment because it provides balanced fertilization (James & Beaton, 1997).

According to Fayera *et al*. (2014), the maximum tef grain yield was obtained with the highest total nitrogen, phosphorus, potassium and zinc uptake. Application of blended fertilizer gave maximum tef yield over NP fertilizer. Adera (2016) discussed that grain yield and yield components like Panicle length, total number and effective tillers were maximum under balanced fertilizer as compared to NP fertilizer. Fageria *et al.* (2011) also showed 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 (Barker et *al., 2007*). Lemlem (2012) reported that application of blended fertilizer, DAP and urea significantly increased the N, P, K, Zn, Mg and S concentrations tef grains and increased grain yield in Vertisols. Application of blended fertilizer increase tef yield from 12.4 to 39.6 % over the control plots. Tef showed significant yield response to blended fertilizer under Vertisols and Regosols (Lemlem *et al.,* 2015). According to Tamene *et al.* (2018), application of S with balanced fertilizer was higher than NP rate.

2.7. Responses of N and Blended NPSB Fertilizer rates on Yield Components and Yield of Tef

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). Soils in the highlands of Ethiopia usually have low levels of essential plant nutrients and organic matter content. Low availability of nitrogen and phosphorus has been demonstrated to be major constraint to cereal production. 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).

Tef grown in Ethiopia is represented by either landrace selections or developed varieties adapted to specific geographic regions (Taddesse, 1975; Seyfu, 1997). The improved varieties responses by far greater than the local ones to fertilizer applications. The response of tef crop to fertilizer applications depends on the types of fertilizers, rates applied, time and method of application. According to Melesse (2007) yield and yield component of tef are highly influenced by fertilizer application.

The author also reported that, it was possible to increase yield by more than two-fold using improved cultivars and their respective recommended fertilizer rates. Mineral fertilizers have been major tools to overcome soil fertility depletion and they are also responsible for the larger part of increased food production worldwide (Sanchez and Leakey, 1997). Tef responds to fertilizers especially to N highly in all its yield components. According to Behan (2012), experimental results of N and P fertilizer trial on tef showed that grain yield could be substantially improved with the application of N and P fertilizers. As expected, tef yield response varies accordingly across locations based on the soil fertility status and moisture conditions.

2.7.1. Tef Responses to N fertilizer

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; and improves the quality and quantity of dry matter protein in grain crops (Ortiz-Monasterio *et al.,*1997). An adequate supply of N is used properly in conjunction with other soil fertility inputs, can speed up the maturity of crops such as small grains (Tisdale *et al.,* 2002). The supply of N is related to carbohydrate utilization.

When N supplies are insufficient, carbohydrates will be deposited in vegetative cells, causing them to thicken, whereas under adequate N supplies and favorable conditions for growth, proteins are formed from manufactured carbohydrates resulting in more protoplasm (Tisdale *et al.,* 2002). In green plant material protein, N is by far the largest N fraction and amounts about 80 to 85% of the total nitrogen.

The nitrogen of nucleic acid and that of soluble amino N are about 10% and 5%, respectively, of the total N present in plant material. Nitrogen is also an essential constituent of various coenzymes. The protein content of vegetative plant organs as well as storage tissue may also be influenced by N supply (Mengel and Kirkby, 1996). Nitrogen is essential for plant growth as it is a constituent of all proteins and nucleic acids. It is an integral component of many essential plant compounds such as amino acids which are building blocks of all protein including enzymes, nucleic acids and chlorophyll (Bradyand Weil, 2002). Since nitrogen is present in many essential compounds, it is not surprising that growth without added nitrogen is slow in plants (Doberman and Fairhurst, 2000). An optimum supply of nitrogen to the plant stimulates root growth and development as well as uptake of other nutrients. Nitrogen also promotes activities essential for carbohydrate utilization and its most important function in plant is promotion of rapid growth through increasing height, tiller number, size of leaves and length of roots (Brady and Weil, 2002).

Nitrogen (N) is one of the most yield-limiting nutrients for crop production in the world. It is also the nutrient element applied in the largest quantity for most annual crops (Huber and Thompson, 2007). Response of crop to N fertilizer varies with rate and time of N application in relation to plant development. Every cropping system preferably includes inputs of N nutrient and should improve the efficiency of N utilization. N fertilizer use efficiency exerts a major effect on cereal production. Efficiency may decline because of N losses due to volatilization, denitrification and leaching if the N is not taken up by plants or it is not utilized efficiently (Fischer *et al*., 1993).

Tef responses to nitrogen application with remarkable changes in all its yield and yield components. Mitiku (2008) and Haftamu *et al*. (2009) noted that, application of high N fertilizer rate (90 kgN ha-1) as the best to obtain high total biomass yield, straw yield and grain yield. Similarly, Legesse (2004) found high yield components in response to application of the highest N rate (69 kg N ha-1). According to Tilahun (1994), the highest grain yield often results from high N rate. Similarly, Mulugeta (2003) found that application of high rates of N fertilizer increased the number of fertile panicles of tef.

The response of tef to different rates of N fertilizer is highly dependent on environmental factors. In dry seasons, there will be negligible or no response to fertilizers and even burning effect damages the germinating seeds or growing seedlings. This could be due to the reduced efficiency in N uptake from the soil due to moisture stress or it could be due to losses of the nutrient through gentrification (Troeh and Thompson, 1993). N fertilizer beyond the maximum nutrient requirement level of the crop resulted either in lodging or decline in yield (Seyfu, 1983). Nitrogen is highly effective when applied shortly before the period of the most rapid growth and greatest demand by the crop (Olsen and Sander, 1992). Probably, this is because the peak nutritional demand of the crop utilizes high N for rapid elongation and cell enlargement.

The numbers of productive tillers increase due to N application, which results in increment in the number of panicles per unit area and the overall grain yield. This is because panicle length is highly associated with grain yield (Seyfu, 1993). Increased N levels dramatically increased grain yield in tef due to increase in yield components (Tekalign, *et al*., 2000). The increase in yield components is the result of efficient nutrition or N uptake (Rathore *et al*., 1991; Tekalign *et al*., 2000), that may result in dry matter production and its production and its translocation to the sink as described by Dalal and Dixit (1987).

Nevertheless, increasing N supply beyond the optimum demand of crops causes reduction in grain yield (Singh and Pillai, 1994; Tekalign *et al*., 2000). Different research findings show that an increase in fertilizer rate increased the total dry matter content in tef. Another finding 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).

2.7.2. Tef Responses to P Fertilizer

Phosphorus plays a key role in cellular energy transfer, respiration, photosynthesis and is an essential component of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) (Price,1970). Phosphorus makes up 0.1 to 0.4% of the dry matter of the plant (FAO, 2000). Phosphorus (P) is classified as the second most important element for crop production (Tisdale *et al.*, 2002). A good supply of P has been associated with increased root growth and a stiff stalk to resist lodging (Miller and Donhue, 1995). Although P is essential for photosynthesis and other physic-chemical processes in the plant, it is deficient in most agricultural soils or where fixation limits its availability (FAO, 2000).

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). Phosphorous has a lower mobility than any other nutrients and it does not remain in a free state for long in which it is slowly available to plants (Parnes, 1990). In cereal crops, good P nutrition strengthens structural tissues such as those found in straw or stalks, thus helping to prevent from lodging (Brady and Weil, 2002). P in the soil comes from weathering of soil minerals and mineralization of soil organic matter by crops, accumulated to grains of cereals or seeds of legumes, and hence removed from the soil at harvest. Moreover, P from plant residues and manure is generally insufficient to meet crop production requirements. Hence, sustainable crop production is impossible without application of P fertilizer (Sanchez *et al*., 1996).

Adsorption of P in Ethiopian soils is highly associated with pH, organic matter and content of clay (Tekalign *et al.,* 2002). In phosphate fertilization, fixation is a predicament, but retention depends on types of clay, temperature, organic matter, P status of soil, and type of reaction. At pH lower than 5.5, the reaction results largely from the reaction with Fe, Al and their hydrous oxides leading into low forms of available P while at higher pH greater than 7 high concentrations of Ca, Mg, and their carbonates cause precipitation of the added P (Mengel and Kirk by, 1996). Adsorption of these soils is also highly correlated with exchangeable and extractable forms of Fe and Al in which the role of Al is more important than that of Fe under acid or neutral conditions.

Many sandy soils which are low in humus content, for instance have low available P. Soils which are prone to strong phosphate fixation and adsorption to sesquioxides and clay minerals often require extremely high phosphate fertilizer application in order to alleviate the effects of fixation. In these strongly phosphate fixing soils, pH correction is also recommended since phosphate adsorption is especially high at low pH levels (Tisdale *etal*, 2002).

Phosphorous has a lower mobility than any other nutrients and does not remain in a free state for long in which case it is slowly available to plants hence, the uptake of fertilizer P depends much on root growth and morphology of the crop being considered. Most of the P present in soils is in unavailable forms and added soluble forms of P are quickly fixed by many soils (Parnes, 1990). Plants absorb P in the form of HPO4-2 andH2PO4-. Depending on the pH of the growing medium although there is no efficient mechanism in the soil to retain H2PO4- and HPO4-2 ions in large quantities as exchangeable anions (Barker and David, 2007).

2.7.3. Tef Responses to sulfur fertilizer

Crop responses to applied sulfur have been reported in a wide range of soils in many parts of the world (Fageria, 2009). Sulfur 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, spikelet's and delayed maturity. Sulfur deficient plants have also less resistance to disease under stress condition (Doberman and Fair Hurst, 2000). The deficiency of sulfur in 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, seldom application of organic wastes, complete removal of crop residues, depletion of soil reserves due to intensive cultivation, use of high yielding cultivars that remove greater amounts of S from soil, the application of sulfur free fertilizers; declining S reserves in soil due to accelerated rate of soil erosion, the decreased use of S-containing pesticides and fungicides and depletion of S from soils by volatilization and leaching (Fageria, 2009).

Crop responses to applied sulfur have been reported in a wide range of soils in many parts of the world (Fageria, 2009). Sulfur (S) is required in similar amount as that of phosphorus and constitutes 0.2 to 0.5% dry matter accumulation in crop tissue (Ali *et al.*, 2008). It is required for the synthesis of S containing amino acids such as cystine, cysteine and methionine. Sulfur is also involved in carbohydrate metabolism of the crop plants (Balasubramaniyan and Palaniappan, 2004). Some of the most important functions of S include its role in specialized peptides, such as glutathione and thioredoxins, in red ox reactions and the role of disulfide bond (S-S) formation in the stabilization of protein Structure (Inal *et al.,* 2003). Sulfur does not affect only nitrogen utilization and grain quality, but it also plays an important part in the formation of the baking quality (Ryant and Hrivna, 2004). It is absorbed by plants as SO42- ion. Sulfur can be limiting for plant growth in intensive farming system, after a rainy winter, mainly on sandy soils (Mat hot *et al.*, 2008).

Sulfur deficiency is characterized by stunted growth, reduced plant height, tillers and spikelet's, delayed maturity, and general yellowing of plants. Sulfur deficient plants have also less resistance under stress condition (Doberman and Fairhurst, 2000). Yellowed plants are also characteristic of nitrogen deficiency. However, unlike nitrogen deficiency which begins in the older leaves and progresses up on the plant, sulfur deficiency symptoms begin in the young, upper leaves first. Sulfur deficiencies are often misdiagnosed as nitrogen problems, leaving growers to wonder why their nitrogen applications are ineffective. In many crops, an acute sulfur deficiency causes the entire plant to turn yellow. In crops like maize and small grains, however, yellow stripes that run parallel to the leaf blade are common. Sulfur deficiency is most frequently observed on very sandy soils with low organic matter content during seasons of excessive rainfall.

Generally, the deficiency of S has pronounced retarding effect on plant growth and is characterized by uniformly chlorotic plants which are stunted, thin stemmed and spindly (Brady and Weil, 2002). Without adequate sulphur, crops cannot reach their full potential in terms of yield (Jarvan *et al*., 2012); the most important role in such an increase of grain yield was performed by the number of grains per ear as one of the yield components. Addition of S to a calcareous soil may result in a decline in soil pH and consequently may increase availability of micronutrients like B (Nadian *et al*., 2010).

According to Habtegebrial and Singh (2006) found that combined N and S fertilization increased the dry matter and grain yields of tef on average by 1.7 and 0.3 kg ha^{-1}, compared with the control and S fertilization increased the nitrogen use efficiency of the tef crop by 36%. Reproductive growth of wheat appears to be more sensitive to Sulphur deficiency, the vegetative growth, with decreased grain size under sulfur-limiting conditions. Similarly, Jarvan *et al.* (2012) reported that when sulfur is added at the rate of10 kg ha-1 to nitrogen, the cysteine and methionine contents increased by 8.1 and 15.1%, respectively. Similarly, addition of 100 kg N ha-1 with 10 kg S ha-1 to winter wheat gave yield of 5.88 t ha-1 while it gave 5.73 t ha-1 when 100 kg N ha-1 with 6 kg S ha-1 (Jarvan *et al.*, 2012).

2.7.4. Tef Response to Boron Fertilizer

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. Boron is also involved in the transport of sugars across cell membranes and in synthesis of cell wall material. It influences transportation through the control of sugar and starch formation (Singh *et al*., 2015). Boron deficiency is one of the major constraints to crop production (Sillanpaa, 1982) and has been reported in more than 80 countries and for 132 crops over the last 60 years (Shorrocks, 1997). Boron deficiency has been realized as the second most important micronutrient constraint in crops after that of zinc on global scale. Boron-deficiency symptoms first become evident on the younger leaves, which change color and become hardened, malformed, and necrotic (Dursun *et al*., 2010).

Deficiency of boron can also cause reduction in crop yield and inferior crop quality (Singh *et al*., 2015). Its deficiency results in low grain set, poor seed quality and interferes rapidly with cell division, cell membrane permeability and often results in phenolic compounds accumulating in plant tissue (Shorrocks, 1997). Even the cereals (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). Boron is involved in N and P metabolism, in plants poorly supplied with B, NO3–, N accumulated in the roots, leaves and stems, showing that NO3– 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).

Boron uptake by plants is controlled by the B level in the soil solution rather than the total B content in the soil (Fageria and Barbosa Filho, 2006). Plants absorb boron in the form of H3BO3 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 boron is not efficiently remobilized in many plant species and that is why B deficiency occurs in young parts of the plant and toxicity in mature parts of plants (Fageriaand Barbosa Filho, 2006).

The decrease in B uptake at harvest was associated with translocation of this element to grain. In B-deficient soils, use of appropriate source is fundamental to improve crop yields and B use efficiency. Principal B carriers are boric acid, borax, or sodium tetra-borate that are commonly used fertilizers for correcting B deficiency in crop plants. Boron fertilizers can be applied as broadcast, band, or folar (Fageria, 2009). The behavior of boron in soil and plant is uniquely different to other trace elements and naturally high soil reserves or over-application of boron fertilizer can rapidly lead to toxicity in cereals and other sensitive crops (James, 1997).

When plants are exposed to boron toxicity, it will cause reduction of leaf area, formation of chlorotic and necrotic patches in older leaves, delay of development and inhibition of plant growth (Nable *et al*., 1997). According to Debnath *et al*. (2014), wheat cultivar "Shatabdi" was grown successfully for obtaining maximum yield with 120 kg N ha^{-1} and 2 kg B ha^{-1} individually or in combination along with recommended rates of TSP and gypsum fertilizers. Muhmood *et al.* (2014) reported that application of 2 kg B ha^{-1} along with recommended doses of chemical fertilizer gave 11% more grain yield of wheat than with the sole application of N, P and K fertilizers.

3. MATERIALS and METHODS

3.1. Description of the Experimental Site

The study was conducted on at Bella Farmers Training Center (FTC) ‘in Tembaro District, in Kambata Tembaro zone in Southern Nations, Nationalist and Peoples Regional State (SNNPRS). Tembaro District is located at 302 km in the south of Addis Ababa and 185Km Northwest from Hawassa, the capital city of SNNPR State and situated at 57 km to the West from the Zonal capital town Durame. Geographically the experimental sites are located between at latitude of 34^{o}10’00’’ -34^{o}30’00” and 33^{o}70$^{’’}$00’’- 34^{0}80’0’’North and longitude 08^{0}00’00” - 08^{o}40’00’’ and 07^{0}30’00”- 07^{o}99’00’’East. The total area of Tembaro district and Bella Keble are bout 27,917ha, and 1257ha, respectively (WARDO, 2018).

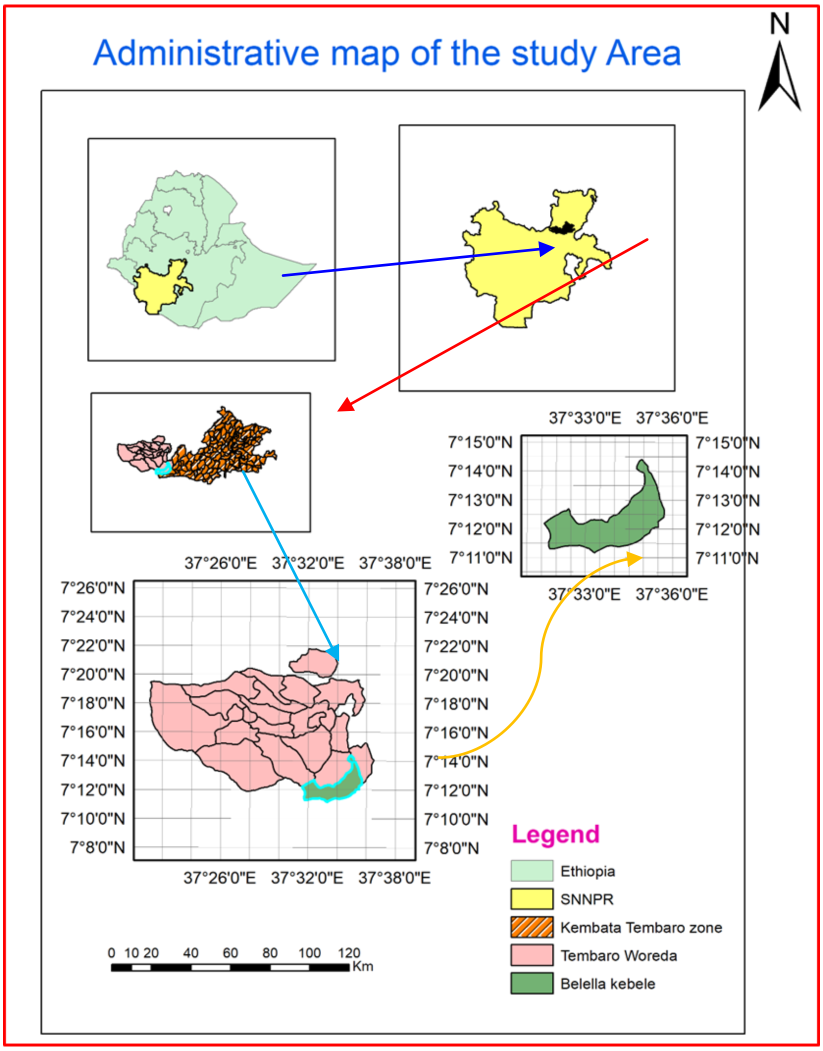

FIGURE 1.STUDY AREA MAP

3.1.1. Climate

The study area consists of three distinct agro-climatic zones, *"Kola*" (60%), *"Wayne-Degas"* (30%) and10%Dega. The average annual temperatures of Belle Keble 25.24oC with mean annual precipitation of 1141.92mm,). The areas have bimodal rainfall distribution such as *Belg*"and"*Meher*". "*Belg*"is the short rainy season that lasts between March and May. The "*Me her* 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 / Bella Keble (FTC) is about 1750 a.m. s.l (WARDO, 2018).

*TABLE 1.**MEAN MONTHLY AND ANNUAL MINIMUM AND MAXIMUM TEMPERATURE (OC) AT EXPERIMENTAL (2015-2019).***

Belela Site														
Year	T(^{o}c)	Months												AV. T(0c)
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
2015	Mean	14.2	13.5	12.3	11.9	11.3	9.8	9.4	9.5	9.5	9.9	9.6	12.1	11.08
	Max	29.1	27.6	28	26	27.8	25.4	26.2	25	26.7	28.4	26.2	27.9	24.68
2016	Mean	15.1	13.2	14.1	10.4	10.3	9.7	8.5	8.5	8.6	9.6	10.3	9.2	10.63
	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
2017	Mean	12.6	13.1	13.1	10.7	9.9	9.5	8.5	8.5	8.5	11.3	9.6	8.2	10.29
	Max	27	27.4	27.5	27	28	26.8	26.3	28	27	26.5	23.2	27.4	24.59
2018	Mean	14.6	12.4	13.4	11	12.9	8.6	9.4	9.4	9.4	9.7	10.1	9.2	10.84
	Max	27.7	26.9	28.2	28.5	28.1	28.4	24.8	26	25.4	26.2	27.3	6.42	25.31
2019	Mean	13.6	12.8	11.2	10.3	11.6	9.2	9.6	9.6	9.6	9.5	10.1	8.7	10.48
	Max	29	28.1	26.5	27.3	24.7	26.3	27.2	26	25.2	28	27.7	28.1	27.02

*TABLE 2.**MEAN MONTHLY AND YEAR TOTAL RAINFALL (MM) AT EXPERIMENTAL (2015-2019).***

Belela (Site)													Av.Rf(mm)
Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
2015	0	3.5	0	45.2	90.7	184	355	302	166	9.6	1.3	0	1158
2016	0	9.7	45.8	76.1	17.5	206	316	341	165	17	3.5	0	1198
2017	0	32.8	69.3	74.4	74.2	250	395	216	115	24	11.5	0	1262
2018	0	0	35.4	45.4	38.5	255	285	265	50	11	0	0	985.6
2019	0	0	29.6	85.9	29.4	157	395	301	76	20	12	0	1106

3.1.2. Population

The total population of the study district is 190,350, from these female108302; male 89272 and total population of Bella Keble 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.), teff [*Eragrotis tef (Zucc.) Trotter*], sorghum (*Sorghum bicolor* L.), chickpea (*Cicerarietinum* L.), root and tubers, including enset (*Ensete ventricosum*) and sweet potato. Fruits such as avocado (*Persea americana*), mango (*Mangifera indica*), banana (*Musa paradisiaca*), 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 speciesand other various native vegetations (WARDO, 2007).

3.1.5. Soil

The common soil in the district is Nitsol (SNNPR BoFED, 2004). It is also the predominated soil type in the study area with a traditional name of (Bsha bunch) 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 alleviation horizon of high structural stability. Nit sols 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). Nit soils (alfisoils) develop on a wide range of parent materials, volcanic, metamorphic, granite, sandstones and limestone (Mesfin, 1998; Brady and Weil, 2002).

3.2. Experimental Design and Treatments

The treatments of the field experiment consisted four blended fertilizer (NPSB) level's (0,50, 100 and 150 kg(ha^{-1}) and four N levels (0, 23, 46 and 69 kg(ha^{-1}). The experiment was laid out in a factorial randomized complete block design with three replicate plots. The total treatments were 4 x4=16 per replication. Each plot had an area of 1.6m x 1.6m (2.56m^2) with eight rows. Spacing between blocks, plots and rows were 1m, 0.5m, and 20cm, respectively.

3.3. Experimental Materials

3.3.1. Planting material

The tef variety named 'Quencho' (DZ-Cr-387 RIL355) which was developed and released by Debre Ziti Agricultural Research Centre (DZARC) in 2006 was used for the experiment. Quencho is a high yielding white-seeded cultivar adapted to a wide range of altitudes (MoARD, 2008) and it is now planting/sowing in the study area.

3.3.2. Fertilizer materials

Blended fertilizer NPSB (18.9% N, 37.7% P2O5, 6.95% S and 0.1% B) and Urea (46%) were used as a source of nutrient elements from Woreda agricultural and natural resource development office.

Table.3. Fertilizer compositions of experimental treatments

NO-	Treatment		Total composition of fertilizer in the treatments			
	Blended NPSB	N $Kgha^{-1}$	N	P_2O_5	S	B
1	0	0	0	0	0	0
2	0	23	23	0	0	0
3	0	46	46	0	0	0
4	0	69	69	0	0	0
5	50	0	9.45	18.85	3.48	0.05
6	50	23	32.45	18.85	3.48	0.05
7	50	46	55.45	18.85	3.48	0.05
8	50	69	78.45	18.85	3.48	0.05
9	100	0	18.9	37.7	6.95	0.1
10	100	23	41.9	37.7	6.95	0.1
11	100	46	64.9	37.7	6.95	0.1
12	100	69	87.9	37.7	6.95	0.1
13	150	0	28.35	56.55	10.43	0.15
14	150	23	51.35	56.55	10.43	0.15
15	150	46	74.5	56.55	10.43	0.15
16	150	69	97.35	56.55	10.43	0.15

Table 4. Treatment combinations and treatment codes

No.	N (kg ha-1)	NPSB(kgha-1)	Code
1	0	0	T1
2	0	50	T2
3	0	100	T3
4	0	150	T4
5	23	0	T5
6	23	50	T6
7	23	100	T7
8	23	150	T8
9	46	0	T9
10	46	50	T10
11	46	100	T11
12	46	150	T12
13	69	0	T13
14	69	50	T14
15	69	100	T15
16	69	150	T16

3.4. Experimental Procedure

The experimental field was prepared according to the local practice. Thus, the land was Plough three times using oxen before planting and the third plugging was done before Sowing to make it ready for compaction and to bury early emerging weeds. In accordance with the specifications of the design, a field layout was prepared the size of each experimental plot was 2.0 m x 2.0 m (4.0 m2). The blocks were separated by 1.0 m wide open spaces; whereas, the plots within a block were 0.5 m apart from each other. After the layout, the plots were leveled manually and each treatment was assigned randomly to the experimental plots within a block.

The tef variety ‘Quencho’ (DZ-Cr-387 RIL355) was drilled uniformly at the rate of 5.0 kg ha-1 in rows of 20 cm apart on 16th of August 2019. Thus, there were 10 rows in each plot. The entire blended NPSB fertilizer was applied as per the treatments at a full dose at Sowing time, whereas, N was applied in two splits (½ at till ring/25days after sowing and ½ at mid till ring / 35 days after sowing) through application of urea. The outer most two rows from each side of a plot and 0.1 m on both ends of each row were considered as border and were not included for recording the data. Thus, the net plot size was 1.6x1.6 (2.56 m2).

Harvesting was done on the 21th of November 2019. When the senescence of the leaves took place as well as the grains came out free from the glumes when pressed between the forefinger and thumb. The harvested total biomass yield was sun dried for three days to insure uniform drying of the whole stock. The total dry matter was weighed by using field balance. Threshing and winnowing were done manually by hand on a mat. After threshing, the grain yield was weighed using sensitive balance. All other cultural practices were applied to each of the plots as per the recommendations.

3.5. Soil Sampling and Analysis

Surface soil samples (0-20 cm) were collected randomly by Auger sampler in a zigzag Pattern before sowing the crop from the entire experimental field and composited into one sample. From this mixture, a sample weighing 1.0 kg was taken. Air dried soil sample was ground with a wooden pestle and mortar under shading. Before analysis, the sample was sieved through a 2-mm sieve mesh. The soil analysis was done for soil textural class, soil pH, organic carbon, total N, available P, CEC and available S and B.

The soil analyze were made at the Sodo Soil and Water Analysis Laboratory. Soil textural Class was determined by Bouyoucos Hydrometer Method (Bouyoucos, 1962). Soil pH was determined in 1:2.5 soils: water ratio using a glass electrode attached to a digital meter (Weakley and Black, 1934). Organic carbon was estimated by the wet digestion method (Walker and Black, 1934) after air-dried soil was ground to pass a 0.2 mm sieve. To determine the cat ion exchange capacity (coml. kg-1 soil), the soil sample first was leached using 1 M ammonium acetate, washed with ethanol and the adsorbed ammonium was replaced by sodium (Na). Then, the CEC was determined titrimetrically by distillation

3.6. Data Collected

3.6.1. Phenological data

Days to 50% panicle emergence: was determined as the number of days from sowing to the time when 50% of the plants started to emerge the tip of panicles through visual observation. **Days to 90% physiological maturity**: was determined as the number of days from sowing to the time when 90% of the plants reached physiological maturity based on visual observation. It was indicated by senescence (turning to light yellow) of the leaves and vegetative parts as well as free threshing of grain from the glumes when pressed between the forefinger and thumb.

3.6.2 Growth parameters

Plant height: was measured at physiological maturity from the ground level to the tip of Panicle by hand meter from ten randomly pre-tagged plants in each net plot.

Panicle length: is the length of the panicle from the node where the first panicle branches emerge to the tip of the panicle by hand meter which was determined from an average of ten pre-tagged plants per net plot.

3.6.3 Yield components and yield

Total tillers: The numbers of tillers (both effective and non-effective tillers) were determined at maturity by counting all the tillers in 0.5 m length from two rows of net plot area at physiological maturity and then converted to m^2.

Number of productive tillers: The numbers of tillers bearing panicle were determined by counting the tillers from an area of 0.5 m length from two rows of net plot at maturity and then converted to m^2.

Biomass yield: At harvest maturity, the total aboveground dry biomass was weighted after Sun drying for three days the harvested crops from the net plot area and then expressed in kg ha^{-1}**.**

Grain yield: was weighted after harvesting and threshing the crop from the net plot area and the yield was expressed in kg ha-1 then the weight was adjusted to 12.5% moisture content.

Thousand kernels weight: The weight of 1000 kernels from the bulk of threshed yield was determined by carefully counting the small grains by hand and weighing them using a sensitive balance.

Straw yield: After threshing and measuring the grain yield, the straw yield was measured by subtracting the grain yield from the total aboveground biomass yield.

Harvest index: Harvest index was calculated by dividing grain yield by the total above ground dry biomass yield and multiplied by 100.

Lodging index (%): The degree of lodging was assessed just before the time of harvest by visual observation based on the scales of 1-5 where 1 (0-15^o) indicates no lodging, 2 (15-30^o) indicate 25% lodging, 3 (30-45^o) 50% indicate lodging, 4 (45-60^o) indicate 75%lodging and 5 (60-90^o) indicate 100% lodging (Donald, 2004). The scales were determined by the angle of inclination of the main stem from the vertical line to the base of the stem by visual observation. Each plot was divided based on the displacement of the aerial stem into all scales by visual observation. Each scale was multiplied by the corresponding percent given for each scale and average of the scales represents the lodging percentage of that plot. Data recorded on lodging percentage were transformed by arcsine transformation method to normalize the error mean squared as described by Gomez and Gomez 1984).

3.7. Statistical Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using Gens tat release 15thed Software (Gens tat, 2012). Means of significant treatment effects were separated using the Fishers' protected Least Significant Difference (LSD) test at 5% level of significance.

3.8. Partial Economic Analysis

An economic analysis was done using partial budget procedure described by CIMMYT (1988). Labor costs involved for application of blended NPSB and N fertilizer rates were recorded and used for analysis. The current (November to October 2019/2020) price of grain and straw yield of tef were valued at an average open market price at Mudulla town which were 32 ETB kg^{-1} and 0.5 ETB kg^{-1}, respectively. The net returns (benefits) and other economic analysis were based on the formula developed by CIMMYT (1988) and given as follows:

Unadjusted grain and straw yield (UGY and USY) (kg ha^{-1}): are the average grain and Straw yield of each treatment.

Adjusted grain and straw yield (AGY and ASY) (kg ha^{-1}): are the average grain and Straw yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers.

Gross field benefit (GFB) (ETB ha^{-1}): was computed by multiplying field/farm gate price that farmers receive for the crop when they sell it as adjusted yield. GFB = AGY (ASY) ×field/farm gate price for the crop.

Total variable cost (TVC) (ETB ha^{-1}): was calculated by summing up the costs that vary, including the cost of blended NPSB fertilizer (15.00 ETB kg^{-1}) and urea as N source fertilizer (14.00 ETB kg^{-1}) at the time of planting (August 16, 2019) and labor cost for application of fertilizers (12 person's ha^{-1}, each 50 ETB day^{-1}). The costs of other inputs and Production practices such as labor cost for land preparation, planting, weeding, harvesting and threshing were considered the same for all treatments or plots.

Net benefit (NB) (ETB ha-1): was calculated by subtracting the total variable costs (TVC) from gross field benefits (GFB) for each treatment as NB = GFB – TVC.

Marginal rate of return (MRR) (%): was calculated by dividing change in net benefit (ΔNB) by change in total variable cost (ΔTVC) as

$$MRR = \frac{\Delta NB X 100\%}{\Delta TVC}$$

The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using the technique were referred to as dominated and non-dominated treatments, respectively. Identification of a candidate recommendation was from among the non-dominated treatments. That is the treatment which gives the highest net return and a marginal rate of return greater than the minimum acceptable to farmers (100%) was considered for the recommendation.

4. RESULTS AND DISCUSSION

4.1. Physico-Chemical Properties of the Experimental Soil before Planting

The results of the pre-sowing composite soil sample laboratory analyses indicated that the soil of experimental site was 17% clay, 15% silt and 68% sand (Table.4). Thus; the texture of the soil was sandy loam according to Bouyoucos (1962) classification. The texture properties of the soil influence water holding capacity, water intake rates, aeration, root penetration and soil fertility which is suitable for tef production as it is well adapted to wide range of soil types and ability to perform well in black soil (ATA, 2013b). The pH of the soil was 5.2 (Table. 4) which was almost acidic (Tekalign, 1991). In this pH range the soil is less conducive for tef production as compare to optimum soil pH for tef production is from 6-7.5 (Seyfu, 1993).

The CEC of the site was 7.4 meq/100g soil (Table. 4). According to Landon (1991), top soil's having CEC greater than 40 coml. (+)/kg are rated as very high. Thus, the soil of the study area has law CEC, which is an indication less fertile soil. Usually, soil cation exchange capacity describes the potential fertility of soils and indicates the soil texture, organic matter content and the dominant types of clay minerals present. In general, soils high in CEC contents are considered as agriculturally fertile (Tegbaru, 2014). The organic carbon content (OC) of the experimental field was 1.587. This indicates less amount of the soil to supply nitrogen to plants through mineralization of organic carbon. The less amount of soil organic carbon might be due same removal of crop residues and less aeration due to soil compaction of sub-soils.

The total nitrogen was 0.1368% (Table .4.) which was low according to the classification of Tekalign (1991). According to Olsen *et al.* (1954), classified soil P availability of <3 ppm very low, 4-7 ppm low, 8-11 ppm medium, 12-20 ppm high >20 ppm very high. Therefore, the experimental soil has very low P content of 2.498007 ppm. The available sulfur and boron in the experimental soil had value of 1.29 ppm of available sulfur which is rated under low and 0.01 ppm of available B which is rating as very low according to Ethio-SIS (2001.

Table.5. physical and chemical properties of the experimental soil before planting

Soil properties	Value	Ratings	Reference
A. Physical properties			
Clay (%)	17		
Silt (%)	15		
Sand (%)	68		
Textural class	sandy loam		Bouyoucos (1962)
B. Chemical Properties			
Soil PH	5.2	acidic	Tekalign (1991
Organic carbon (%)	1.587	Low	Tekalign(1 991)

Total nitrogen (%)	0.1368	Low	Tekalign (1991)
Available P (ppm)	2.498007	very low	Olsen *et al.* (1954),
CEC (meq/100 g soil)	7.4	Very low	Landon *et al.* (1991)
Available sulfur (ppm)	1.29	Low	Ethio-SIS (2014)
Available boron ppm))	0.01	Very low	Ethio-SIS (2014)

4.2. Phenological Traits

4.2.1. Days to panicle emergence

Days to panicle emergence was highly significantly ($p<0.01$) different due to the main response of nitrogen and blended NPSB fertilizers, but the combined application of nitrogen and blended NPSB fertilizers are not significant on days to panicle emergence of tef. The maximum (69.33) days for panicle emergence was observed under the control (unfertilized) plots. The highest combined rates of 69 kg N + 150 kg NPSB ha^{-1} and 69 kg N + 100kg NPSB ha^{-1}, minimized the days to panicle emergence date of heading by 17 days, as compared to the control plots. Application of N and blended fertilizer (NPSB) hastened the days to Panicle emergence, because the tef plants were able to take up sufficient nutrients from the soil which encouraged early establishment, rapid growth and development of crop. Assefa (2016) also indicated that as the rate of NP increased, the number of days elapsed to heading was shortened. Hence, the longest days (69) to Panicle emergence was recorded in the control plots.

Similar result was reported by Seifu (2018), the highest days to 50% panicle emergence (73 days) was recorded from the control plot, while the lowest days (51) was recorded from the combined application of 69 kg N and 150 kg, 69kg N and100kgblended NPSB (kg ha-1) fertilizers**.** In contrast to these results, increasing the rate of nitrogen application Prolonged the days to panicle emergence of the tef plants (Abraham, 2013). This may be due to longer time required to establish, grow and complete the vegetative growth. In line with the current finding, application of N fertilizer reduced days to heading compared to unfertilized treatment in tef (Temesegen, 2012; Shiferaw, 2012).

Table. 6.mean of days to 50% panicle emergence of tef as affected by the main response of N and blended NPSB fertilizer rates.

Treatment	days to 50% panicle emergence (%)
N (kgha-1) fertilizer rates	
0	69.33a
23	58.66 b
46	56c
69	55.66d
LSD (0.05)	0.4535
Blended NPSB(kgha-1)fertilizer rates	
0	68a
50	55b
100	54c
150	53.33d
LSD (0.05	0.4535
CV	2.6

Where, LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation. Means in columns followed by the same letters are not significantly different at 5% level of significance.

4.2.2. Days to physiological maturity

The days to attain physiological maturity highly significantly ($P<0.01$) differ due to the main response of N and NPSB fertilizer application, but the interaction responses of N and blended NPSB fertilizers were not significant on days to maturity of tef (Appendix Table. 2) In general, results showed that nitrogen and blended fertilizer application had no significant response on crop maturity (Table.6). Similar to that of the days to 50% panicle emergence, the highest value for days to 90% Physiological maturity (103.33 days) was recorded from the control (unfertilized) plots, while the lowest physiological maturity (91 days) was recorded from the highest application rate of 150/69NPSB and N (kg ha^{-1}), respectively. The enhanced maturity with the application of blended fertilizer could be due to the presence of balanced fertilizer in the blended fertilizer.

Normally, crops treated with nitrogen show better vegetative growth and that treated with P fertilizer exhibit good root development to reach physiological maturity in time. Brady and Weil (2002) described that Phosphorus application could possibly shorten maturity date since it promotes rapid cell division. Onasanya *et al*. (2009) showed that phosphorus plays an important role in many physiological processes that occur within a developing and maturing plants. It is involved in enzymatic reactions in the plant and hastens the maturity of plants. However, the delay of physiological maturity in unfertilized plots may be due to insufficient amount of essential elements. In line with the result, Tilahun *et al*. (2013) reported that increasing of P2O5 from 50 kg ha-1to 100 kg ha-1 with increasing compost rate from 0 to 7.5 t ha-1 showed reduction in days to maturity and increased grain yield of rice.

Similarly, Getahun *et al.* (2018) reported that the shortest days (91) to physiological maturity of tef were obtained from the application of 69kg N ha-1 and 30 kg P2O5 ha-1 and the longest days (97) from the control. The result of present study is contrary with the result of Temesgen (2001) who reported that application of 69 kg N ha-1 delayed days to maturity of tef by seven days over the control at farmer's fields on *Vertisols*. Similarly, Abraha (2013) reported that as the rate of N increased from 0 to 69 kg N ha-1, days to maturity of tef was significantly delayed.

Table 4.Mean days to maturity of tef influenced by the main response of N and blended NPSB fertilizer rate application.

Treatment **N rates (kgha^{-1})**	**Day to Physiological maturity (90%)**
0	103.33a
23	99.33b
46	98.66b
69	97c
LSD (0.05)	0.5961
Blended(NPSB) fertilizer (kg ha^{-1})	
0	102a
50	97b
100	96.66b
150	95.33c
LSD (0.05)	0.5961
CV	1.51

Where, LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation. Means in columns followed by the same letters are not significantly different at 5% level of significance.

4.3. Growth Parameters

4.3.1. Plant height

The main response of N fertilizer rates and blended NPSB was significant ($P<0.05$) on plant height of tef. The analysis of variance showed that the interaction responses of the two factors was not significant on plant height of tef (Appendix Table.2). Generally, as the rate of N fertilizer increased to the highest rate from 0 to 69 kg ha-1, a significant increase in plant height.

The highest plant height (122.26cm) was recorded at the highest rate of nitrogen (69 kg ha-1) application, while the shortest plant height (95.35cm) was recorded from the control (unfertilized) plot (Table.7). This increment in plant height may be due to nitrogen Plays vital role in cell division, elongation and vegetative growth of plants (Marschner, 1995). This result was in agreement with the research findings of Legless (2004) who reported that high N application (69 kg N ha-1) resulted in tef plants with significantly taller plants (94 cm) as compared to control (82 cm) due to direct effect of nitrogen on vegetative growth of Plants.

Similar result was reported by Okubay *et al.* (2014) where the maximum plant height (112.33 cm) was obtained from the application of the highest rate (69 kg N ha-^{1}), whereas the lowest plant height was obtained from the control plot of the tef crop. This result is also in line with the report of Wakene *et al*. (2014) who stated that plant height of barley was increased with increasing rates of N from 0 to 69 kg ha-1. Similarly, Melesse (2007) reported that as the nitrogen fertilizer rate increased from 0 to 69 kg ha-1, the plant height of bread wheat was increased from 82.63 cm to 94.18 cm.

In contrast, increasing the rate of NPSB application from 0 to 150 kg ha-1 did not significantly responses the height of tef plants. The non-responsiveness of the plant height to blended NPSB fertilizer might be due to the low amount of nitrogen in the blended NPSB fertilizer. This could also be attributed due to the lower mobility of P than any other nutrients and does not remain in a free state for long in which it is slowly available to plants. Hence, the uptake of fertilizer P depends much on root growth and morphology of the crop being considered (Parnes, 1990).

4.3.2. Panicle length

The analysis of variance showed that the main response of N fertilizer rates was highly significant ($P<0.01$) on panicle length of the tef, but the interaction of the two factors and the main response of blended NPSB showed not significant on panicle length of the tef plant (AppendixTable.2). Similar to plant height, panicle length also increased with increasing N fertilizer rate. The highest panicle length (42.36 cm) was recorded at the highest rate of 69 kg N ha-1 application, while the shortest mean panicle length (34.26cm) was recorded from the unfertilized (control) plot (Table.7). This highest panicle length is due to high nitrogen plays critical role in the structure of chlorophyll and usually favors vegetative growth of tef which results in taller tef plants having relatively greater panicle length.

In many studies, the response of high nitrogen application on tef yield was attributed to the major role played by panicle length on grain yield. Longer panicles bear more number of Spikelet's that contain higher number of grains, higher total biomass and straw yield. This result is consistent with the findings of Mulugeta (2003); Legesse (2004); Mitiku (2008) and Haftamu *et al*. (2009) who reported that panicle length exhibited positive and highly Significant correlation with plant height and grain yield.

In line with this result, Abraha (2013) reported that the application of nitrogen rate from 0 to 69 kg N ha-1 markedly increased the panicle length of the plants by about 15%. Similarly, Getahun *et al.* (2018) reported that the longest panicle length (39.9 cm) was from the application of 69 kg N(ha-1), while the shortest (31.6 cm) was recorded from the control. Thus, increasing nitrogen from 0 to 69 kg N ha-1 increased panicle length by about 26.3%, compared to the control.

Table 5.Mean plant height and panicle length of tef as influenced by the main response of blended NPSB and N fertilizer rates.

Treatment	Plant height (cm)	Panicle length (cm)
N rates (kgha^{-1})		
0	95.53d	34.26d
23	113.33c	35.97c
46	118.09b	39.76b
69	122.26a	42.31a
LSD (0.05)	0.4059	0.4768
Blended(NPSB) fertilizer (kg ha^{-1})		
0	95d	34d
50	109.13 c	37.26c
100	112.38b	38.88b
150	113.57a	39.15a
LSD (0.05	0.4059	0.4768
CV	2.10	1.94

Where, LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation. Means in columns followed by the same letters are not significantly different at 5% level of significance.

4.4. Yield Components and Yield

4.4.1. Number of total tillers

The analysis of variance showed that total number of tiller per plant was highly significantly (P<0.01) affected by the main response of N rate, but the interaction responses of two factors and the main response of NPSB fertilizers where not significant on the total number of tillers. The highest total number of tillers (1289.66m^2) was recorded at the rate of 69 kg N ha-1 and the lowest (769.66m^2) was obtained from the control (Table.8.). Increasing N levels from 0 to 69 kg N ha-1 resulted in linear and consistent increment of tiller number. However, total numbers of tillers at different rates of applied N were statistically at par except from the control plot.

The possible reason for increment in number of tiller might be due to the more availability of N which played a positive role in cytokines synthesis and cell division. Consistent with this result, Seifu (2018) and Haftamu *et al*. (2009) reported significantly higher number of total tillers in response to the application of N rate on tef.The highest number of total tillers (1315.33 m^2) was obtained with the application of 100kgNPSB and 69kgN(ha-1), while the lowest number of total tillers (812 m^2) was obtained from the unfertilized (control) plots (Table.8).

The highest number of tillers at the highest rates of NPSB might be due to the rapid conversion of synthesized carbohydrates into protein and consequently the increase in number and size of growing cells, ultimately resulting in increased number of tillers. The improvement in total number of tillers with NPSB application might be due to the role of P found in NPSB in developing radical and seminal roots during seedling establishment and nitrogen play positive role on vegetative growth and cell division (Cook and Veseth, 1991).

This result is in agreement with that of Behan (2012) who reported that application of blended fertilizer (69 kg N ha-1 + 46 kg P2O5 + 22 kg S ha-1 + 0.3 kg Zn ha-1) brought significant increase in total tillers (15 tillers per plant) of tef as compared to 5 tillers per plant of unfertilized plot. This result is in contrary to the finding of Shiferaw (2012) who reported no significant difference on total tiller number of tef as the rate of P2O5 was increased from zero to 46 kgha-1. In barley, Wakene *et al.* (2014) also reported no significant differences between application of 46 and 69 P2O5 kg ha-1 in total tillers of barley. Similarly, result was also obtained by Essays (2015) who reported no significant differences in the numbers of total tillers per plant among different blended fertilizers (NPSZnB) in durum wheat.

4. 4 .2. Numbers of Productive tillers

Number of productive tiller was highly significantly ($P < 0.01$) influenced by the main response of N rate application, but the combined application of two factors fertilizer rate and the main response of blended NPSB are not significant on productive tiller of tef AppendixTable.2). The highest number of fertile/ **p**roductiv**e** tillers (1194.66m^2) of tef plant was recorded at the rate of 69kg N (ha-^{1}) application. While, the lowest (699.33m^2) plant was obtained from the control plot. Productive tillers from plots treated with 46and 69 kg N ha-1 were in statistical parity and only significantly differed from the control plot (Table.8.).

Consistent with this result, Haftamu *et al.* (2009) and Tekalign *et al.* (2000) reported significantly higher number of tillers in response to the application of N rate on tef. Mossedaq and Smith (1994) also revealed that tillering is enhanced by increased light and N availability during the vegetative growing period of the crop.

The highest number of productive tillers plant (1268.33m^2) was recorded at the combined application of 69 kg N and 100 kg blended NPSB(ha-1), while the lowest was obtained from the control plot. This may be due to the promotion of vigorous vegetative growth by application of N and blended fertilizer. In agreement with the result of this study, Fayera *et al.* (, 2014) found that the highest productive tillers of tef under the application of 200 kg ha- (NPKSZnB) blended (14 N, 21 P_2O5, 15 K_2O, 6.5 S, 1.3 Zn and 0.5 B) + 23 kg N ha-1 fertilizer.

Table 6.Number of total tillers and productive tillers as influenced by the main effect of N and blended NPSB fertilizer rates on tef.

Treatment N rates (kgha^{-1})	Number of total tillers(m^2)	productive tillers(m^2)
0	769.66d	699.33d
23	1026.66c	944.33c
46	1143b	1048.33b
69	1289.33a	1194.66a
LSD (0.05)	23.688	19.511
Blended(NPSB)fertilizer (kg ha^{-1})		
0	768.88c	696.4d

50	1093b	1018.33c
100	1181.66a	1105ba
150	1216.66a	1140.66a
LSD (0.05	23.688	19.511
CV	9.57	10.93

Where, LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation. Means in columns followed by the same letters are not significantly different at 5% level of significance.

4.4.3 Above ground biomass

The analysis of variance showed that the main response of N fertilizer rates are significantly($p<0.05$) difference in aboveground dry biomass yields, but the main response of blended NPSB fertilizer and interactions response of N and NPSB fertilizer rates are not significant on aboveground dry biomass yields of tef (Appendix 3).The highest biomass yield (7326.56kgha$^{-1)}$ was obtained from the highest rate of N 69 kg (ha-^{1}) application, while the lowest dry biomass yield (6059.2 kg ha-^{1}) was obtained from the control (unfertilized) plot (Table.9).

Higher above ground dry biomass yield obtained from larger amounts of nitrogen may be due to the increased investment of assimilates to leaves and stems that finally increase dry matter yield. A similar result was reported by Cass man etal. (2003) and Gupta (2004) in which the average maize Stover yield increased for the N and green manure treatments ranged with yield increments of 25 to 75% and 6 to 68%over the control treatments, respectively, due to increased N application.

The highest (8399.91kg ha-1) above ground dry biomass yield was obtained at 150 kg (ha-^{1}) blended NPSB fertilizer application. The result was in conformity with the findings of Adera (2016) and Bereket *et al.* (2014) which showed that above ground dry biomass yield was significantly affected by application of blended fertilizer. Others authors also reported that application of 120 kg ha-1 NPS fertilizer produced the maximum biomass yield of tef (eg. Wakjira, 2000).

4.4.4. Grain yield

Grain yield of tef was significantly($p<0.05$) influenced by the main response of N fertilizer rate, but analysis of variance showed that the combined application of two factors and the main response of blended NPSB are not significant on grain yield of tef (AppendixTable.3). The highest grain yield (1264.4 kg ha-^{1}) was obtained at the highest rate of 69 kg N (ha -^{1}), while the smallest (932.32 kg ha-1) was obtained from the control (unfertilized) plot (Table.9). Moreover, increased application of Nitrogen to 69kg ha-^{1} significantly increased grain yield but, further increasing N fertilizer rates linearly decreased grain. This may be attributed to the asynchrony in the time of availability of sufficient amounts of the nutrient in the soil proportionate with the demand of the plant for uptake.

Studies on response of tef to N application by Abraham (2013) found that N application significantly increased grain yield. Increased grain yield due to increased N application was also reported for different cereal crops. Application of 150 kg NPSB (ha_$^{1)}$ produced the maximum grain yield (1505 kg ha-^{1}) of tef, while the lowest grain yield (926.24 kg ha-^{1}) was obtained under the control treatment.

The highest grain yield (2533.3 kg ha-^{1}) was recorded at the combined application of 46 kg N and 100 kg(ha-^{1}) blended NPSB fertilizer, which was statically at par with the combined rate of 69 kg N and100kg blended NPSB fertilizer and 69N kg and 150 kg NPSB (2501.43kgha_^{1}) and (2130.2kgha-$^{1)}$ respectively. However, the other treatment combinations of N and blended fertilizers resulted in statistically similar performance each other. Whereas, the lowest (932.33kg ha-^{1}) was obtained from the control (unfertilized) plot (Table.9).

The grain yield increment from plot treated with N and blended fertilizer might be due to the contribution of balance nutrient (macro and micro nutrient) present in fertilizers which increased yield attributes through more uptakes of all the nutrients and increased translocation of photosynthetic materials from source to sink. On the other hand, the lower grain yield of tef in this study at the highest combined rate of 69kg N and 150 kg NPSB ha-^{1,} this may possibly be attributed to excess supply of the nutrient that favors more vegetative growth of plant parts leading to lodging before the translocation of dry matter to grain.

In conformity with this finding, Tagesse *et al.* (2018) and Seifu (2018) reported the highest grain yield was obtained at 200 kg blended NPS ha-1 supplemented with 92 kg Nha-1. Similarly, Jarvan *et al*. (2012) reported that the addition of 100 kg N ha-1 with 10kg S ha-1 to winter wheat gave yield of 5.88 t ha-1 while it gave7 .3 t (ha-1) when 100 kg N (ha-1) with 6 kg S(ha-1).

4.4.5 Straw yield

The analysis of variance showed that the main responses of N fertilizer rates were significant ($p<0.05$) on straw yield of tef, but the interactions response of N ,NPSB and the main responses of blended NPSB are not significant on straw yield of tef (Appendix Table.3).The highest straw yield (7038.5kgha-^{1}) was recorded with combination of 23 kg N and 150kgNPSB fertilizer rates application, though, statistically at par with the application of 150/46 and 150/69 100/46 kg(ha-^{1}) of NPSB and N fertilizer rates are respectively ,while the lowest straw yield (5126.88kg ha-^{1}) was recorded from the control (unfertilized) plot (Table.9).

The significant increase in straw yield in response to the highest rate of combined application of NPSB and N might be attributed to the synergic roles of the nutrients in enhancing growth and development of the crop. The high N application produced higher numbers of tillers, increased plant height, and panicle length that might have resulted in increased straw production.

Similar results were found by Temesgen (2001); Largesse (2004); Mitiku (2008); and Okubay *et al.* (2014) who indicated that the highest straw yield (3136-9652 kg ha-^{1}) of tef was obtained in response to the application of higher rates of N application (46-69 kg N ha-^{1}) and this attributed to the production of significantly higher number of tillers, longer panicles and taller plants that enhanced greater biomass yield. Straw yield of tef has to be considered while evaluation of any agronomic practice as its importance has become as equal as its grain yield as it is preferred as animal feed during dry period and also sold at reasonable price.

Table 7.Mean aboveground biomass yield, grain yield and straw yield of tef as influenced by the main responses of blended NPSB and N fertilizer

Treatment Blended NPSB rate (kgha-1)	Aboveground dry mass (kgha-1)	Grain yield (kgha-1)	Straw yield (kgha-1)
0	6059.2 c	932.33c	5126.88b
50	6627.93b	1160.9b	5467.02b
100	7670.12a	1464.55a	6205.57 a
150	8399.93a	1505 .64a	6894.27a
LSD (5%)	390.03	237.15	290.38
N rate (kg ha-1)			
0	6048.14d	913.64d	5103.13d
23	6384.76c	1038.41c	5346.35cb
46	6499.47b	1101.11b	5398.36b
69	7326.56a	1264.4a	6062.16 a
LSD (5%)	371.08	227.15	272.18
CV	5.94	18.39	5.50

Where, LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation. Means in columns followed by the same letters are not significantly different at 5% level of significance.

4.4.6. Lodging index

Lodging index was highly significant ($P<0.01$) on the main responses of blended NPSB and N fertilizer and the interaction response of two factors (Appendix Table.3). The highest lodging (67%) was recorded from the highest blended NPSB 150 kg (ha-1) and 69 kg N (ha-^{1}) fertilizer rate, while the lowest lodging index (16.06%) was recorded from the control (Table.10). The highest lodging might be due to increasing rate of total nitrogen in the combination of the highest rate of blended NPSB and N fertilization that enhanced fast vegetative growth, plant height and succulent stem elongation of tef and the wind prevailed in the study area during the second week of November month of growing season.

Though, the lodging percent is high, as it occurred mostly after the maturity of the crop, the yield reduction was not significant. This result was in line with the findings of Shiferaw (2012) who reported highest lodging of tef (74%) at N/P2O5 rate of 64/46 kg ha-1. Likewise, Fayera *et al.* (2014) reported the highest lodging percentage (79.74%) of tef withthe highest rate of NPK (138 kg N ha-1 combined with 55 kg P ha-1 and 0 kg K2O ha-1) application. It has been reported that lodging is the serious problem of tef production causing high yield reduction, because of the use of high amount and unbalanced rates of fertilizers practiced in the country. On average, lodging inflicts about 11-22% total grain yield losses of tef (Seyfu, 1993).

Table .8.Mean lodging index (%) of tef as affected by the combined application of blended NPSB and N fertilizer rates.

Blended NPSB (kg ha-^{1}) fertilizer rates	N (kgha-^{1}) fertilizer rates			
	0	23	46	69
0	16.06l	23.33k	32.19f	25.65j
50	26.55i	7.15n	38.75d	40.25c
100	23.85k	28.06g	15.45m	43.2b
150	23.35k	27.65h	37.05e	67a
LSD (0.05	7.04			
CV	11.04			

Where, LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation. Means in columns and rows followed by the same letters are not significantly different at 5% level of significance.

4.4.7 Thousand kernel weight

The analysis of variance indicated that the main response of blended NPSB fertilizer rate application is significant($p<0.05$) on **t**housand kernel weight of tef, but N fertilizer rates and the combined application of the two factors are not significant on thousand kernels weight of tef (Appendix Table.3).

4.4.8 Harvest Index

Harvest index oftef was significantly ($P < 0.05$) influenced by the main responses of N fertilizer rates. The interaction responses of N, blended NPSB fertilizer rates and the main responses of NPSB are not significant on harvest index oftef (Appendix Table 3).The highest harvest index (28.4) was recorded at the combined rates of 100 kg NPSB and 46 kg N (ha-^{1}) fertilizers, while the lowest harvest index (15.41) was recorded from the control plot(Table.11).

This implies that harvest index is the balance between the productive parts of the plant and the reserves which form the economic yield, greater improvement in grain yield compared to the corresponding increase in straw yield contributed to the N rate (kg ha-^{1}) increase in harvest index across the increasing levels of N and blended fertilizer.

Table 9.Mean thousand kernels weight and harvest index of tef as influenced by the main response of blended NPSB and N fertilizer rates.

Treatment	Thousand kernels Wight (g)	Harvest index (%)
Blended NPSB rate (kg ha-^{1})		
0	0.3d	15.41c
50	0.31c	17.51b
100	0.33b	19.09a
150	0.34a	17.93b
LSD (5%)	0.09498	2.4380
N rate (kg ha-^{1})		
0	0.3c	14.75c
23	0.3c	16.33b
46	0.31b	16.94b
69	0.33a	17.25a
LSD (5%)	0.09498	2.346
CV (%)	2.20	15.21

Where, LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation. Means in columns followed by the same letters are not significantly different at 5% level of significance.

4.5. Partial Budget Analysis

Attainment of maximum profitability lies not only in reducing use of N and blended fertilizers per unit area, but also in lowering costs per unit crop production through higher yields. Farmers are profit-oriented, and therefore, they are interested in net returns than the gross returns. To assess the cost and benefit associated with different treatments, the partial budget analysis technique of CIMMYT (1988) was applied. From the final yield and straw data, the gross yields of sixteen treatments were obtained.

Then the recommended level of 10% was reduced from all treatments to obtain net grain yield and the recommended level of 10% was reduced from all treatments to obtain net straw yield. Net yield was multiplied by market price to obtain gross field benefit**.** All variable costs were calculated based on the current price of the fertilizers as per the information obtained from local markets and unions.

The cost of Urea and blended fertilizers were 14 and 15 Birr (kg-1), respectively. The selling price of tef at the local market around mudulla area was taken as Birr 32 (kg-1) for grain yield and birr 0.5 (kg-1) for straw yield. Variable costs were summed up and subtracted from gross benefits, which were taken as net benefit. The highest net benefit of 69243.48 Birr (ha-$^{1)}$ was obtained from the combined application of 46 kg N (ha-^{1}) and 100 kg blended NPSB(ha-^{1}), while the lowest net benefit 29153.7Birr (ha-^{1}) was obtained from the control plots (Table .12).

Although the calculation of net benefits accounts for the costs that vary, it is necessary to compare the extra (or marginal) costs with the extra (or marginal) net benefits. The process of calculating the marginal rates of return (MRR) of alternative treatments, proceeding in steps from the least costly treatment to the most costly and deciding if they are acceptable to farmers, is called marginal analysis (CIMMYT, 1998).

According to the dominance analysis on mean value over control, same treatments were dominated by other treatments, hence, eliminated from further economic analysis. The highest MRR% (8488.21) was attained from treatment combination of 46 kg N (ha-1) and 100 kg blended NPSB (ha-^{1}) fertilizers, followed by 150 kg NPSB and46 N kg (ha-1) (3396.5) as compared to other to get more profit as described in (Table. 12). This implies that for everyone birr invested in Urea and blended fertilizer application, farmers can expect to recover.

Table 10.Summary of partial budget analysis of the responses of blended NPSB and N fertilizer rates application on tef.

Treatments		Adjusted grain yield (Kgha-$^{1)}$	Adjusted Straw yield k/g (ha -^{1})	Total Revenue ETB (ha -^{1})	TVC ETB (ha -^{1})	Net benefit ETB	Marginal rate (%)
NPSB (Kgha-^{1})	N (Kgha-^{1})						
0	0	839.09	4605.192	29153.7	0	29153.7	00
0	23	934.59	4811.71	32312.47	4767.83	27544.64	467.76
0	46	990.99	4858.52	34140.44	5089.79	29050.65	1452.83
0	69	1137.96	5455.94	39142.69	5411.93	33730.8	1403.3
50	0	1044.81	4920.318	35894.08	5195.83	30698.25	2863.61
50	23	1326.67	5954.48	45414.68	5517.08	39897.6	D
50	46	1286.13	6059.99	44186.15	5839.84	38346.31	D
50	69	1248.2	6239.08	43061.94	6161.69	36900.25	985.34
100	0	1318.09	5585.01	44971.54	5946	39025.54	901.98
100	23	1408.92	6221.57	48196.22	6267.83	41928.39	324.43
100	46	2279.97	5748.15	75833.11	6589.63	69243.48	8488.21
100	69	2251.28	6137.64	75109.78	6911.92	68197.86	D
150	0	1355.07	6204.84	46464.66	6695.83	39768.83	1130.18
150	23	1476.8	6334.65	50424.92	7017.8.	43407.12	1681.54
150	46	1657.6	6236.26	56161.33	7339.79.	48821.54	3396.5
150	69	1917.18	6075.22	67424.98	7661.93	59763.05	D

Where, D = dominated treatments. ETB ha-1 = Ethiopian Birr per hectare; price of tef = 32 ETB kg-1; Market price of straw= 0.5 ETB kg-1; Cost of blended NPSB fertilizer =15 ETB kg-1; Cost of Urea (N-source) fertilizer = 14 ETB kg-1, Labor cost for fertilizer application=6 person's ha-1, each at 50 ETB day-1.

SUMMARY AND CONCLUSION

Tef is one of the major small cereal crops in Ethiopia in terms of both production and consumption. Although it is such an important cereal crop in Ethiopia, its productivity is low yield due to many production constraints such as minimum use of improved varieties, lack of appropriate management practices, low soil fertility and lack of location specific fertilizer recommendation in Ethiopia and in the study area.

Application of balanced fertilizers could be the basis to produce more crop output from existing land under cultivation and nutrient needs of crops according to their physiological requirements and expected yields.

Therefore, the study was designed with the objectives of assessing:

To assess the combined responses of N and blended NPSB fertilizer rates on growth, yield and yield components of tef. To determine economically optimum N and blended NPSB fertilizer application rate for high grain yield of tef, on yield components and identifying the economically feasible rates of N and blended fertilizers for high yield of tef on soils of, Tembaro district.

The treatments of the field experiment consisted four N levels (0, 23 46 and 69 kg (ha^{-1}) and four blended NPSB fertilizer levels (0, 50, 100 and 150 kg (ha^{-1}). The experiment was laid out in a factorial randomized complete block design with three replicate plots. The tef variety used in the experiment was quencho (DZCR-387) which is widely adopted in the study area (Kebebew *et al*, 2017).

The analytical results of physic-chemical properties of the soil before planting indicated that the experimental soil was sandy loam in texture, acidic in reaction (pH 5.2,) very low in OC (1.587 %), low in total N (0.1368%), low in available S (1.29 mg kg-1), low in available CEC (7.4mg kg-1), very low in available B (0.01 mg kg-1) and very low in available P (2.498007 mg kg-1).

Analysis of the results revealed that number of total tillers, number of productive tillers, 90%p. maturity ,50%DH, Plant height and panicle length were highly significantly ($P<0.01$) affected by the main response of N fertilizer rates, but the combined application of N and blended NPSB fertilizer rates are not significant. The highest number of total tillers (1216.66

plant m-2), productive tillers (1140.66plant m-2), aboveground biomass yield (8399.91 kg ha-1) and grain yield (1505.64 kg ha-1) was recorded at highest rate of application of 150 kg NPSB (ha-^{1}) rate. The highest number of total tillers (1289.33 plant m-$^{2)}$, number of productive tillers (1194.66 plant m-^{2}), aboveground biomass yield (7326.56kg ha-^{1}), grain yield (1264.4 kg ha-$^{1)}$, plant height (122.26 cm) and panicle length (42.36 cm) were obtained from at the highest rate of N application (69 kg N ha-^{1}), while the lowest were obtained from control plots.

Generally, as the rates of NPSB and N fertilizers increased the number of total tillers, productive tillers, aboveground biomass yield and grain yield were increased. The highest days to panicle emergence (69.33 days) and days to 90% physiological maturity (103.33) days were obtained from unfertilized (control) plot. While, the lowest (51) days for panicle emergence and 90% physiological maturity (91) days were recorded from combination application of 150kg NPSB and 69kgN (ha-^{1}) plot.

The economic analysis showed that combined application of 100 kg blended NPSB fertilizer (ha-1) supplemented with 46 kg N (ha-$^{1)}$ provided relatively high net benefit (69243.48 ETB(ha-^{1}) and hence these could be the best rate to apply. Marginal rate of analysis from un dominated treatments also indicated that for each one birr invested in purchase or production of fertilizers it was possible to recover one birr plus an extra of birr (ha-1) as the fertilizer application changed from unfertilized plot to 46 kg N (ha-^{1}) combined with 100 kg(ha-^{1}) blended fertilizer.

Therefore, we recommend the treatment (46kg N +100 kg NPSB kg (ha-^{1}) with high marginal rate of return (8488.21), high net benefit and relatively small total cost of production for tef production in the study area. Furthermore, emphasis and consideration required to the issue in the future research: Since the experiment was conducted only for one season and one site, repeating the trial at different sites as well as in the same trial site would be important in order to draw sound recommendation. Since, the soil is dominantly Vertisols, N is the limiting nutrient in the study area, therefore, more attention must be given in additional to blended fertilizer.

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7. APPENDICES

Appendix Table 1.Partial budget analysis for N and blended NPSB fertilizer rates on tef.

Treatments		Un-adjusted grain yield (Kgha-1)	Un - adjusted Straw yield k/g (ha $^{-1}$)	Input cost ETB (ha $^{-1}$)		Application cost ETB (ha $^{-1}$)	
NPSB (Kgha-^{1})	N (Kgha-^{1})			NPSB	Urea	NPSB	Urea
0	0	932.33	5126.88	0	0	0	0
0	23	1038.41	5346.35	0	322	0	300
0	46	1101.11	5398.36	0	644	0	300
0	69	1264.4	6062.16	0	966	0	300
50	0	1160.9	5467.02	750	0	300	0
50	23	1474.08	6616.09	750	322	300	300
50	46	1429.04	6733.33	750	644	300	300
50	69	1386.89	6932.32	750	966	300	300
100	0	1464.55	6205.57	1500	0	300	0
100	23	1565.47	6912.86	1500	322	300	300
100	46	2533.3	6386.84	1500	644	300	300
100	69	2501.43	6819.61	1500	966	300	300
150	0	1505.64	6894.27	2250	0	300	0
150	23	1640.88	7038.5	2250	322	300	300
150	46	1841.77	6929.18	2250	644	300	300
150	69	2130.2	6750.25	2250	966	300	300

.

ETB ha-1 = Ethiopian Birr per hectare; Cost of blended NPSB fertilizer =15 ETB kg-1; Cost of Urea (N-source) fertilizer = 14 ETB kg-1; Labor cost for fertilizer application= (6 persons’ ha-1, each at 50 ETB day-1)

Appendix Table 2.Mean squares of ANOVA for pheological growth parameters, yield and Yield components

Source of variation	Mean square					
	DF	DH	DM	PH	PL	NTT	NPT
Replication	2	o.896	6.396	0.405	0.4999	18150	12659
NPSB rate	3	147.056**	110.722**	107.218**	29.0717ns	156076ns	184696**
N rate	3	60.833**	54.500**	516.312**	69.9102*	64540*	55711**
NPSB*N rate	9	24.037ns	2.296ns	39.201ns	2.4976ns	38825ns	40121ns
Error	30	2.029	2.085	1.638	0.6097	13787	15606
CV		2.6	1.51	2.10	1.94	9.57	10.93

Where, **=highly significant; * = significant; ns = non-significant at 5% probability level; DF = degrees of freedom and CV =coefficient of variation.

DH=day of heading; DM=day of maturity; PH=plant height; PL=panicle length; NTT=number of total tiller; NPT=number of productive tiller.

Appendix Table 3.Mean squares of ANOVA for yield components and yield of tef as response by N and blended fertilizers rates.

Source of variation	Mean square						
	DF	AGBM	G.Y	S.Y	H.I	1000K.W	L.I (%)
Replication	2	101668	230230	27620	26.529	0.00008	44.78
NPSB rate	3	3.96107ns	2304176ns	5152633ns	123.992ns	0.00297*	710.35*
N rate	3	2912572*	6981468*	979633*	39.255*	0.00058ns	1511.34*
NPSB*N rate	9	2770383ns	202194ns	314311ns	21.44ns	0.00008ns	291.14ns
Error	30	218832	80904	121301	8.551	0.00005	14.56
CV		5.94	18.39	5.50	15.21	2.20	11.04

Where, **=highly significant; * = significant; ns = non-significant at 5% probability level; DF = degrees of freedom and CV =coefficient of variation.

Where, DF= Degree of freedom, AGB= Above ground biomass; GY = Grain yield; SY = Straw yield; LI= Lodging index; HI = Harvest index and1000KW =kernel weight

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