EFFECT OF SEED AND BLENDED FERTILIZER (NPSB) RATES ON YIELD AND YIELD COMPONENTS OF TEF (*Eragrostis tef /Zucc./*Trotter) AT DUNA DISTRICT, SOUTHERN ETHIOPIA

MSc THESIS

ADANE LAMBORE

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Effect of Seed and Blended Fertilizer (NPSB) Rates on Yield and Yield Components of Tef (*Eragrostis tef /Zucc.*/Trotter) in Duna District, Southern Ethiopia

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I hereby certify that I have read and evaluated this thesis entitled **"Effect of Seed and Blended Fertilizer (NPSB) Rates on Yield and Yield Components of Tef (*Eragrostis tef* /*Zucc*./Trotter) in Duna District, Southern Ethiopia"** prepared under our guidance by Adane Lambore**.** I recommend that it be submitted as fulfilling the thesis requirement.

Dr. Yibekal Alemayehu (PhD)	_________________	_________________
Major Advisor	Signature	Date
Dr. Jemal Abdulahi (PhD)	_________________	_________________
Co-advisor	Signature	Date

As members of the Board of Examiners of the MSc Thesis Open Defense Examination, I certify that I have read and evaluated the Thesis prepared by Adane Lambore and examined the candidate. I recommend that the Thesis be accepted as it fulfils the Thesis requirement for the Degree of Master of Science in Agriculture (Agronomy).

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DEDICATION

This thesis was dedicated to the memory of my father Mr. Lambore Kabule who was willing to see my success but passed away, to my be loved mother Edame Masebo, brothers Solomon and Gizachew lambore for all-rounded and unconditional support to me for betterment of my life.

STATEMENT OF THE AUTHOR

By my signature below, I declare that this Thesis is a result of my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this Thesis. Any scholarly matter that is included in the Thesis has been given recognition through citation.

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Name: Adane Lambore

Signature: ___________________

Date of submission: ___________

School: School of Plant Sciences

BIOGRAPHICAL SKETCH

Mr. Adane Lambore was born on the 12th of August 1991 at a village called Semen Wagebeta Kebele in Duna District, Hadiya Zone of Southern Nation, Nationalities and Peoples' Regional State (SNNPRS), Ethiopia, to his father Lambore Kabule and his mother Edame Masebo. He attended his elementary education at Kenkicho Primary School from 1998 to 2005 and Senior Secondary and Preparatory High School from 2006 to 2009 at Wachemo Senior Secondary and Preparatory High School. After passing the Ethiopian Higher Education Entrance Certificate Examination (EHEECE) in 2010, he joined Wolaita Sodo University College of Agriculture and Rural development and graduated with Bachelor of Science (BSc) degree in Plant Science in July 2014.

After graduation, he was employed as a Rural job creation in Hadiya Zone, Duna District Youth and Sport Office in January 2015 and worked until he joined Haramaya University, Post Graduate Program Directorate in October 2018 to pursue study leading to Master of Science Degree in the field of Agronomy.

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LIST OF ACRONYMS AND ABBREVIATIONS

AARC	Areka Agriculture Research Center
ANOVA	Analysis of Variance
CEC	Cation Exchange Capacity
CSA	Central Statistical Agency
DWARDO	Duna Woreda Agriculture and Rural Development Office
DZARC	Debre Zeit Agricultural Research Center
ETB	Ethiopian Birr
FAO	Food and Agriculture organization
FTC	Farmers' Training Center
IAEA	International Atomic Energy Agency
LSD	Least Significant Difference
MoA	Ministry of Agriculture
MoARD	Ministry of Agriculture and Rural Development
MRR	Marginal Rate of Return
NPSB	Nitrogen, Phosphorus, Sulfur and Boron
P_2O_5	Diphosphate Pentaoxide
RCBD	Randomized Complete Block Design
SNNPRS	Southern Nations, Nationality and Peoples' Regional State

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ABSTRACT

Low soil fertility and poor crop management practices including use inappropriate seeds rates are among the major constraints limiting the productivity of tef in Ethiopia in general and in the study area in particular. Thus, field experiment was conducted to assess the effect of rates of seed and blended fertilizer (NPSB) on growth, yield components and yield of tef and to identify economically feasible rates of seed and blended NPSB in the study area. Factorial combination of three level of tef seeding rates (3, 5 and 7 kg ha^{-1}) and five levels of NPSB (0, 50,100, 150, 200 kg ha^{-1}) fertilizer and 100 kg of urea (46 kg N ha^{-1}) were used. The treatments were laid out in a Randomized Complete Block Design (RCBD) with three replications. The results revealed that the dry biomass yield were significantly ($P < 0.01$) affected by the main effects of NPSB fertilizer rates and panicle length affected by the effects of seed rates while, days of heading, days to 90% physiological maturity, plant height and culm length were affected by main effects of blended NPSB fertilizer and seed rate. The highest total dry biomass yield (7885 kg ha^{-1}), panicle length (42.29 cm) were recorded at NPSB rate of 200 kg ha^{-1} . The maximum days of heading (63.56), days to 90% physiological maturity (103.56 days) were recorded at 0 NPSB, plant height (102.01 cm) and culm length (68.91 cm) were recorded at 200 NPSB and 150 NPSB kg ha^{-1}, respectively. With regards to the effect of seed rate, highest total dry biomass yield (7773 kg ha^{-1}), panicle length (42.73 cm was recorded at seed rate of 3 kg ha^{-1}. Maximum days of heading (63.53 days), days to 90% physiological maturity (102.73 days), plant height (103.26 cm) and culm length (67.49 cm) were recorded at 3, 3, 7, and 3 kg ha^{-1}, respectively. The interaction of the two seed and blended fertilizer (NPSB) rates also significantly affected grain yield, total tillers, productive tillers, straw yield and lodging percent. The highest grain yield (2975 kg ha^{-1}), total tillers (21.13 m^{-2}), productive tillers (20.13 m^{-2}), straw yield (6192 kg ha^{-1}) and lodging percent (74.33%) were recorded at combination of the highest rates of 200 kg NPSB fertilizer with 7 kg seed rate ha^{-1} while, highest grain yield were recorded at combination of 200 kg ha^{-1} NPSB fertilizer with 5 kg ha^{-1}. The partial budget analysis revealed that combined applications of 200 kg blended NPSB fertilizer with seed rate of 5 kg ha^{-1} gave higher net benefit of 58882.85 Birr ha^{-1} with MRR of 1449.01%, which is above the acceptable minimum range of MRR 100%. Based on the result of this study, it can be tentatively concluded that tef at seed rate of 5 kg ha^{-1} and NPSB rate of 200 kg ha^{-1} to be appropriate for tef production in study area. However, since the experiment was conducted for one season at one location, it is suggested that the experiment has to be repeated over seasons and locations using this and other improved tef varieties in order to give a comprehensive recommendation.

Keywords: Blended fertilizer, Grain yield, Lodging percent, Physiological maturity, Quncho variety, Yield attributes

1. INTRODUCTION

Tef (*Eragrostis tef /Zucc./*Trotter) is a small cereal grain indigenous to Ethiopia. It has been recognized that Ethiopia is the center of origin and diversity of tef (Vavilov, 1951). It belongs to the family *Poaceae*, sub family *Eragrostidae* and genus *Eragrostis* (Seyfu, 1993). Tef is a warm season, annual C-4 plant (Kebede *et al*., 1989), which is grown in Australia, India, and South Africa as a forage (Costanza *et al.*, 1979). Tef is most widely important cereal grain of Ethiopia, which is most probably domesticated thousands of years ago before the birth of Christ (Seyfu, 1997). Ethiopia ranks first in the world tef crops production and daily staple food for about 57.20 million people of Ethiopia for more than 64% of the total population of the country (ATA, 2013b).

Tef was staple and very popular food in Ethiopia, that make it the most important crop to the farm household compared to other crop enterprises. It is the most preferred crop because of its best *injera* quality, long seed-storability, drought resistance and ability to render more satisfaction from a unit volume or weight, locally known as *Bereket*; hence, it is a high valued crop. It has high protein; fiber and complex carbohydrates content, a relatively low calorie content, and is gluten free (ATA, 2013a and Berhane *et al*., 2011). It is also a source of cash income to the farm household and straw used to reinforce mud used for plastering the wall.

In Ethiopia, tef was cultivated on an area about 3.01 million hectares and with productivity 1.7 t ha^{-1}. More than six million households' lives depend on the production of tef covering the largest agricultural area of the country than any other types of grain (Tareke *et al*., 2011). The production of tef was covered with area (23.85%), maize (16.79%), sorghum (14.79%) and wheat (13.38%), respectively, of the total cereal grain production (CSA, 2018). Moreover, the ability of it to tolerate and grow on *Vertisols* with drainage problems makes it a preferred cereal by farmers (Workneh, 2009). As to production, the cereals contribute 87.30% of the grain production. Cereals in which 19.9% is contributed by tef during the main season (CSA, 2015) mainly contribute about 17 million tons (87%) of the gross grain production in the country.

The main production areas are Amhara and Oromia regions and, to a lesser extent, in Tigray and the Southern Nations, Nationalities and Peoples (SNNPR) regions. The SNNPRS total production area covered about 248,124.17 and with productivity 1.5 t ha^{-1} (CSA, 2018). Tef is resistant to extreme water conditions, as it is able to grow under both drought and waterlogged conditions (Minten *et al*., 2013, Teklu and Tefera, 2005). Tef covers the largest agricultural area of the country than any other types of grain, but its productivity is low (Lee, 2018 and Tareke *et al*., 2011). The low tef crop productivity due to a complex interaction among the environments, lack of appropriate management practices, biotic and abiotic stresses. Of these, soil fertility problem is the major causes of temporal and spatial yield variability (Brhan, 2012).

The study area (Hadiya Zone) is also one of tef producing Zones with production area 38,850.27 hectare of SNNPR (CSA, 2017). In this zone, tef production system used by the majority of farmers is backward, traditional and on average farmers use row spacing by drilling with hands or with different local material without knowing the optimum amount of seeding and fertilizer rates of 7 kg ha^{-1} and use blanket recommendation of nitrogen (64 kg N ha^{-1}), phosphorus (46 kg P_2O_5 ha^{-1}), and 100 kg ha^{-1} Urea respectively (DWARDO, 2019). However, tef yield in Ethiopia in general and the study zone in particular are low as compared to the attainable yield of 1.4 t ha^{-1} (CSA, 2017) because tef production is constrained by both biotic and abiotic factors such as diseases and pests, poor management practices, poor soil fertility and moisture stress.

One of the major problems affecting food production in Africa, including Ethiopia is rapid depletion of nutrients in smallholder farms (Achieng *et al*., 2010), nitrogen is deficient in almost all soils and phosphorus (P) is deficient in about 70% of the soils in Ethiopia. Recently acquired soil inventory data from EthioSIS (2014), also revealed that in addition to nitrogen and phosphorus, sulfur, born and zinc deficiencies are widespread in Ethiopian soils. Balanced fertilizers containing N, P, K, S, B and Zn in blended form are recommended in ameliorating site-specific nutrient deficiencies and thereby increasing productivity (ATA, 2013b). Today, in view of multiple nutrient deficiencies and increasing costs of crop production, fertilization with N or NPK without ensuring adequate supplies of all other limiting nutrients (S, and B, etc.) makes little sense and in fact, becomes counterproductive by reducing the efficiency of the nutrients that are applied (FAO, 2000). Application of balanced fertilizers could be the basis to produce more crop output from existing land under cultivation and nutrient need of crop according physiological requirement and expected yield (Ryan, 2008).

Seeding rate is the important factors to reduce or increase agricultural yields and productivities. Higher tef grain yield with better quality requires appropriate seeding rate for different cultivars. Increase in seed rate above optimum level may only enhance production cost without any increase in grain yield (Rafique *et al*., 2010). These cause for lower productivity by lodging due to lack of knowledge about proper seed rate. Because of this, reduction in 22% grain and straw yield resulted (Assefa *et al.*, 2016). Seed rate broadcasted at a rate 25-30 kg ha^{-1} and covered lightly with soil by handheld twigs (Decker *et al*., 2001). The yield of the broadcasting plot was 500-1200 kg ha^{-1} whereas the transplanted and drilled one gave 3,400-5,100 kg ha^{-1} with three to fourfold increase in grain yield. According to ATA (2013a), the recommended amount of seeding rate of tef is 2.5-3 kg ha^{-1} by row spacing. According to Amare and Adane (2015) the recommended seeding rate is 2-5 kg ha^{-1} through row spacing or drilling. Seeding rates for row planting varies with 5-8 kg ha^{-1} generally recommended (Stallknech, 1993).

Tef yield varies considerably from farmers to farmers and is highly dependent on rates of seed and NPSB fertilizers. As a result, the effects of seeding and fertilizer rates on tef yield and yield components have received greater attention in this study. Using of proper seed rate enables to improve production and productivity of tef through minimizing of lodging percent (ATA, 2012). This study is also intended to conduct the site-specific research with reduced amount of seeding rate by row spacing and optimum fertilizer application rate on sandy loam soil of Duna district particularly on Semen Wagebeta Kebele of experimental site.

However, the optimum seed rate, fertilizer type and rate at one site may not be applied at other locations because of variation in weather, soil type, soil moisture, varieties etc that further trials are needed at each site to validate general recommendations (Azam-Ali and Squire, 2002). Similarly, farmers in the study area use variable seed rates. Moreover, there is no location specific recommendation of the seed rate and fertilizer rate and the interaction of the fertilizer and seed rates is not known.

This study, therefore, was initiated with the following objectives:

- to assess the effect of different seed and blended fertilizer (NPSB) rates on growth, yield and yield components of tef; and
- to identify economically feasible rates of seed and blended NPSB in the study area.

2. LITRATURE REVIEW

2.1. Origin and Botany of Tef

According to volvilov (1951) who observed a tef genetic diversity unseen nowhere in world concluded Ethiopia at center of tef origin. Tef is endemic to Ethiopia and its major diversity is found only in this country. Seyfu (1993) stated that the word 'Tef' was originated from the Amharic word *'teffa'* that means lost because of its small grain size, which is difficult to find once it is dropped. Tef is an alloteraploid (2n=4x=20) species (Tareke, 1981; Tavassoli, 1986); however, the two diploid parents that contributed to its genome have not been identified. Based on morphological traits and biochemical markers, several wild species of *Eragrostis* were identified to be close relatives or progenitors of the present day tef. Jones *et al*. (1978) identified nine species that are closely related to tef. These included *Ergrostis aethiopica, E. barrelieri, E. cilianensis, E. mexicana, E. minor, E. pilosa, E. bicolor, E. heteromera, and E. papposa*. These are *E. cilianensis, E. minor, E. pilosa, and E. macilenta.*

Based on biochemical markers, Endashaw and Lester (1978) suggested that *E. aethiopica, E. barrelieri* and possibly *E. curvuala* and *E. cilianensis* might have been involved in the evolution of tef. From cytological evidence, *E. aethiopica, E. mexicana, E. barrelieri, E. mimor and E. cilianensis* were suggested to be the closest to tef (Tavassoli, 1986). Botanically tef plant varies height from 25–135 cm depending on cultivar type and growing environments. The panicle length, ranges from 11–63 cm and the spikelet numbers per panicle varies from 190-1410. Panicle types also vary from loose, lax, compact, multiple branching, multi-lateral and unilateral loose to compact forms (Hesselbach and Westphal, 1976). In its native habitat, maximum production occurs with a growing season rainfall of 43 to 56 centimeters and a temperature range of 10 to 30 (Hurder, 2011).

2.2. 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 as *tella* and *katikala* (Hailu and Seyfu, 2001).

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, glut line, 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, and wheat and slightly less than rice or oats. It is also further mentioned that tef is an excellent source of fiber and 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.

Tef may also have benefits for persons with celiac disease. It contains 11% total carbohydrates, 24% dietary fiber, 10% thiamine, 2% riboflavin, 4% niacin, 8% calcium and 20% iron and is free from saturated fat, sugar and cholesterol (Abay *et al.*, 2011). Tef straw, besides being the most appreciated feed for cattle, is also used to reinforce mud used for plastering the walls of house and local grain storage facility called *gotera*. Tef grain, owing to its high mineral content, has been used in mixtures with soybean, chickpea and other grains in the baby food industry (Seyfu, 1997).

Farmers feed tef straw preferentially to lactating cows and working oxen. Cattle prefer tef straw over other cereals' straw, and for this reason, its price is higher than that of the other cereals. Seyfu (1991), described the reason as why Ethiopian farmers prefer to grow tef as: it can be grown in areas experiencing moisture stress; can be grown in waterlogged areas and withstands anaerobic conditions better than many other cereals, including maize, wheat and sorghum. It is suitable for use in multiple cropping systems such as double, relay and intercropping; its straw is a valuable feed during the dry season when there is an acute shortage.

2.3. Agro-Ecology and Production Areas of Tef

Tef is adapted to a wide range of environments and presently it is cultivated under diverse agro-climatic conditions (Minale *et al.,* 2005). Tef has a short growing season with rainfall needs of 450–550 mm, and temperature range of 10–27ºC (Roseberg *et al.,* 2005). Tef is day length sensitive and flowers best during 12 hours of daylight (Stallknecht, 1997). Tef can grow at under broad range of altitudes where many other crops cannot, and it can be grown from sea level to as high as 3000 meters above sea level (m.a.s.l) with maximum production occurring between 1800-2100 meters above sea level (Seyfu, 1997; Stallknecht, 1997). Dry land areas with shortage of rainfall are well secured through the production of tef. Tef is a reliable cereal during unreliable rainfall, especially during the occurrence of unpredictable dry spells. This makes tef an important grain for drought-prone and food insecure areas. Its production is currently expanding to include many drought-prone areas of the country (ATA, 2013b).

Tef is well adapted to a wide range of soil types. It has the ability to perform well in black soils and, in some cases, in low soil acidities. Tef is normally grown on soils of neutral pH, but it has been observed that it tolerates soil acidity below pH 5. Differences exist between cultivars for response to saline conditions. In addition, tef has the capacity to withstand waterlogged, rainy conditions, often better than other cereal grains except rice (ATA, 2013b). In Ethiopia, tef is mainly produced in vast areas of Tigray and Amhara, the total area covered by tef in (CSA, 2018) cropping season in these regions cover area were 167,748.22 hectare with yield 25.37 ha^{-1} and 1,138,030.51 hectare with yield 1.7 t ha^{-1} respectively (CSA, 2018). With smaller quantities in the Oromia cover area 1443,847.96 hectare with yield 17.88 ha^{-1}, SNNPS 246,099 hectare (8.15%) and Benishangul-gumuz 24,432 hectare (0.81%) regions produced.

According to CSA (2017), Hadiya Zone is among the potential tef producing Zones with production area coverage of 38,840.49 hectare. Yield with productivity of 1.4 t ha^{-1}, which is a little increase over the country average. Thus, it is crucial to conduct location specific research on the response of the popular varieties with farmers to the newly introduced blended fertilizers (NPSB) that will help to increase the yield of tef.

2.4. Tef Production Constraints in Ethiopia

Environmental stress is the most important factor, which affects crop production. According to (Sidibe *et al.,* 2018) 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

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 (Singha *et al*., 2014), 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.* (2016) 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 (Assefa *et al*., 2016).

2.5. Effect of Seed Rate on Yield and Yield Components Tef

Seeding rates are the most important factor for crop production at any agricultural activities. Seeding rate can affect tillering, grain yield and protein quality (Zecevic *et al*., 2014). Hence, achieving higher agronomic performance and better end-use quality requires optimizing and periodically reviewing management practices such as seeding rates (yadi *et al.,* 2016). However, in cultivars that produce fewer tillers, higher seeding rates compensated for reduced tiller and promoted more main stem spikes (Arduin *et al*., 2018).

On the other hand, it was stated that protein concentration declined as seeding rates and yields increased (Geleta *et al.*, 2002 and Mekonnen, 2017). The decrease in plant height in response to lowering the seeding rate to 100 kg ha^{-1} may reflect formation of more secondary tillers in less populated stands, which tend to be shorter in stature. At the highest seeding density, the increased intra-plant competition may have also contributed to the reduction in plant height. Arif *et al.* (2003) reported that increased tillers with increase in seed rate. Increase in seed rate above optimum level may only enhance production cost without any increase in grain yield (Rafique *et al*., 2010). Optimum seed rate is one of the most important agronomic practices for maximum yield of crop. If more seed rate is used, plant population will be more and there will be competition among plants for water, nutrients and sunlight resulting in low quality and low yield. If less seed rate is, used yield will be less due to lesser number of plants per unit area (Hamid *et al*., 2002).

Ethiopian farmers mainly use broadcasting method for sowing tef. Typically, the farmers apply seeds between 25 to 50 kg ha^{-1}. In order to enhance germination, tef needs moderate soil compaction to make the seedbed firm and flat so as to prevent the soil surface drying quickly which causes seed desiccation. In most parts of the country, soil compaction of tef field is done using cattle, sheep, goats and/or donkeys and sometimes humans (Fufa *et al.*, 2001). In addition, trampling of the seedbed is also practiced to free the seedbed from weeds by turning them under (Assefa *et al*., 2011). Depending on the method of planting used, farmers use seed rate from 15-50 kg ha^{-1} to 3-5 kg ha^{-1} for row planting, and to as low as 0.5 kg ha^{-1} for transplanting (ATA, 2013a). According to (Assefa *et al.*, 2011), about 15-55 kg ha^{-1} of tef is sown per hectare under different conditions.

Planting seedlings on a flat bed and transplanting them into the field showed a promising result. For example, it reduces the seed rate from the broadcasting method and in the new method 3 - 5 kg ha^{-1} would be enough for a hectare. The yield of transplanted tef has a fourfold increase. This provides ample space for seedlings and enables easier weeding. Furthermore, Tareke (2008), reported that more dramatic yield obtained when spacing is combined with three types of fertilizers such as DAP + Urea, DAP coated with Zinc and Copper micronutrients and a rice fertilizer known as Sucube commonly used in Mali which contains NPK, Zn, S, and Mg. Farmers use 25-55 kg ha^{-1} of seeding rate under different conditions. If a manually or motor driven broadcaster or drill is available, a lower seeding rate is recommended. Planting seedlings on a flat bed and transplanting them into the field showed a promising result. Therefore reducing seed rate is important to get optimum growth and development. The yield of transplanted and drilled has increased three to fourfold. The yield of the broadcasting plot was 500-1200 kg ha^{-1} whereas the transplanted and drilled one gave 3,400-5,100 kg ha^{-1} with three to fourfold increase in grain yield. In addition, the straw yield also increased from those grains (Tareke, 2008).

2.6. Effect of Fertilizers on Yield and Yield Components of Tef

Plants like all other living things need food for their growth and development. Plants require 16 essential elements. Carbon, hydrogen, and oxygen are derived from the atmosphere, soil and water. The remaining 13 essential elements (nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, zinc, manganese, copper, boron, molybdenum, and chlorine) are supplied either from soil minerals and soil organic matter or by organic or inorganic fertilizers. Macronutrients includes nitrogen (N), phosphorus (P), potassium (K), sulfur (S), magnesium (Mg) and calcium (Ca), which are needed in large amounts, and large quantities have to be applied if the soil is deficient in one or more of them (FAO, 2000).

2.6.1. Effect of nitrogen fertilizer on yield and yield components of tef

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 (Belete *et al.*, 2018). Among the macronutrients, N is ranked first in limiting sustainable crop production (Tisdale *et al.*, 2002). 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).

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 (Parchlic and Tegeder, 2018). 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 (Brady and Weil, 2002).

Since nitrogen is present in many essential compounds, it is not surprising that growth without added nitrogen is slow in plants ((Liu *et al*., 2014)). 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 (Singh *et al.,* 2016). Excessive nitrogen supply causes higher photosynthetic activity, vigorous growth, weak stem resulting in crop lodging, dark green color, reduced productive tillers, reduced product quality, delayed in maturity, increase in susceptibility to insect pest and diseases and build-up of nitrate which is harmful to animals (Singh *et al*., 2016).

Nitrogen deficiency causes stunted plant growth, development of thin spindly stem, low protein and high sugar content (thickening of cells) and chlorosis as deficiency symptoms on older leaves, which could progress to necrosis under severe conditions. Nitrogen deficient plants respond quickly to the addition of N fertilizers if applied in a timely manner and properly. However, adverse effects on annual plants caused by early-stage lack of N cannot usually be corrected by late application of N (IAEA, 2000). Tef responds to application with remarkable changes in all its yield and yield components. Studies on the response of tef to N fertilizer, by different authors showed that increased application resulted in increased production. Different studies in various environments and times reported that tef responds highly to higher N fertilizer rates. Mitiku (2008) and Haftamu *et al.* (2009) noted that application of high N fertilizer rate (69 kg N ha^{-1}) was the best to obtain high total biomass yield, straw yield and grain yield. Similarly, Legesse (2004) found that, high yield components were recorded in response to application of high N rate of 69 kg N ha^{-1}. As applied N rates increased, the grain uptake also increased which was also reflected in the plant height, yield and yield components like panicle length, panicle weight, grain yield, straw yield and biomass yield (Legesse, 2004). Similarly, Mulugeta (2003) found that application of high rates of N fertilizer 90 kg ha^{-1} N increased the number of fertile panicles of tef.

2.6.2. Effect of phosphorus fertilizer on yield and yield components of tef.

Phosphorus plays a key role in cellular energy transfer, respiration, and photosynthesis and is an essential component of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) (Raven and Ralph, 2015). 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) cereal crops, good P nutrition strengthens structural tissues such as straw or stalks, thus, helping to prevent lodging (Brady and Weil, 2002). Thus, sustainable crop production is impossible without application of P fertilizers (Sanchez *et al*., 1996). Contrary to this, the application of P had shown no significant effects on crop phenology, growth, lodging, and yield and yield components of tef on *Vertisols* (Legesse, 2004). 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.

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 (Menegezens *et al*., 2018). Plants absorb P in the form of HPO_4^{-2} and $H_2PO_4^{-1}$ depending on the pH of the growing medium although there is no efficient mechanism in the soil to retain $H_2PO_4^-$ and HPO_4^{-2} ions in large quantities as exchangeable anions (Barker and David, 2007).

Therefore, in order to get optimum yield, 46 kg P_2O_5 ha^{-1} amount of P application was needed to satisfy the fixing ability of the soil and increased yield (Legesse, 2004). Phosphorus application did not significantly affect panicle and grain weight, panicle length, plant height, harvest index, biomass, grain and straw yield of tef (Legesse, 2004). Grain P content also showed inconsistent trend with the increase in the application rate of P while the straw P remained almost the same (Legesse, 2004). Phosphorus fertilizer trial on tef according to the finding of (Alemayehu *et al*., 2006) indicated that the highest grain yield was obtained with the highest P fertilizer rate (80 kg P_2O_5 ha^{-1}) in most localities of *Vertisols* and the highest grain yield in most localities of *Nitosols* were obtained at 60 kg P_2O_5 ha^{-1} with interaction of 100 and 60 kg N ha^{-1} respectively.

Similarly, phosphate fertilizer effect on most of the agronomic parameters of tef was discussed. Mehreteab (2008) reported that days to heading and maturity were significantly reduced as the level of phosphate fertilizer increased. However, panicle length, plant height, number of nodes, number of effective tillers, lodging index, biomass yield, grain yield and harvest index increased with an increased level of phosphate fertilizer and the optimum grain yield was obtained by applying phosphate fertilizer rate of 46 kg P_2O_5 ha^{-1}. According to the finding of Alemayehu (2014), grain yield and yield related parameters of tef increased with increasing P rate except for days to flowering and maturity, and grain filling period. Grain yield increased from 84 to 218 g m^{-2}, total biomass 586 to 1016 gm^{-2}, harvest index 0.14 to 0.22%, panicle weight 0.49 to 0.73 gm^{-2} and seed weight 0.25 to 0.38 gm^{-2} when P rate was increased from 0 to 9 gm^{-2} P_2O_5. In addition, increasing P rate from 0 to 9 g m^{-2} P_2O_5 reduced days to flowering and maturity by 14 and 13 days, respectively.

2.6.3. Effect of sulfur fertilizer on yield and yield components of tef

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 redox 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 (Hrivna and Ryant, 2004). It is absorbed by plants as SO_4^{-2} ion. Sulfur can be limiting for plant growth in intensive farming system, after a rainy winter, mainly on sandy soils (Mathot *et al*., 2008). Sulfur deficiency has been reported in almost all cereal crops in various countries. 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.

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 appears to be more sensitive to Sulphur deficiency than vegetative growth, with decreased grain size under sulfur-limiting conditions. Similarly, Jarvan *et al.* (2012) reported that when sulfur is added at the rate of 10 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 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).

2.6.4. Effect of boron fertilizer on yield and yield components of tef.

Boron is an essential element for better utilization of macronutrients by plants and there by greater translocation of photo-assimilates from source to sink during growth period (Ali *et al.*, 2013). Boron is also involved in the transport of sugars across cell membranes and in synthesis of cell wall material. It influences transportation through the control of sugar and starch formation (Singh *et al*., 2015). Boron-deficiency symptoms first become evident on the younger leaves, which change color and become hardened, malformed, and necrotic (Dursun *et al.*, 2010). Deficiency of boron can also cause reduction in crop yield and inferior crop quality (Singh *et al*., 2015).

Boron is involved in N and P metabolism, and in plants poorly supplied with B, NO_3^-, N accumulated in the roots, leaves and stems, showing that NO_3^- reduction and amino acid synthesis were inhibited. Boron is mainly associated with cell wall pectin and physical characteristics of the growing cell wall were altered under B deficiency The B level in the soil solution rather than the total B content in the soil (Fageria and Barbosa Filho, 2006) control boron uptake by plants.

Plants absorb boron in the form of H_3BO_3, and it moves to plant root mainly by mass flow and diffusion. Uptake of B in crop plants is mainly determined by yield level. Variation in B uptake was about 99% in rice and 97% in dry bean with increasing plant age. This variation in 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 (Fageria and 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 foliar (Fageria, 2009). Boron is unevenly distributed within plants and highest levels are found in reproductive structures such as anthers, stigma and ovaries. Boron requirements vary with plant type: in monocotyledons species, leaf content ranges from one to 6 mg/kg; in most dicotyledons from 20 to 70 mg/kg and in dicotyledons with latex systems from 80 to 100 mg/kg. Crops such as sugar beet, celery, apple, pear and grape have higher B requirement (Benton, 2003).

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.

2.7. The Interaction Effect of Seed and Blended NPSB Fertilizer Rates on Yield and yield Components of Tef

The grain yield responded significantly to the application of different rates and sources of N fertilizer. The highest mean grain yield of tef (3443.67 kg ha^{-1}) was obtained from 69 kg ha^{-1} with 1332.34 kg ha^{-1} yield advantage over the control plot. The next highest mean grain yield (3379.67 kg ha^{-1}) was obtained from 46 kg ha^{-1} of nitrogen. Generally, grain yield exhibited a linear increase with increasing rate of application of N fertilizer in both wheat and tef crops. Moreover, grain yield of tef was highly and positively correlated with most of the growth parameters and yield components such as straw yield, total biomass yield, thousand grains weight, plant height, fertile tillers and panicle length (Okubay *et al*., 2014).

According Shiferaw, (2012) the application of different rates and sources of N fertilizer affected tef plant heights. In Ethiopia, the local people commonly use broadcasting system rather than using row planting for tef. The recommended seed rate for broadcasting tef is 25 - 30 kg ha^{-1}, but farmers often use 25–50 kg B ha^{-1} because it is difficult to distribute the seed evenly, the viability of farmers' sown seed is reduced (i.e. uncertainty of the germination percentage) and to suppress weeds at early stages (Tareke *et al.*, 2013). Since tef transplanting and row planting technology is a new breakthrough in the country, the agronomic components (row spacing, spacing between hills, seedling age, fertilizer rate, etc.) should be optimized for each specific agro ecology, soil type and tef variety (Fikiremariam *et al*., 2015). According to Amare and Adane (2015), the grain yield varies with seed rate levels, variety and soil types for tef broadcast planting system. Therefore, the selection of appropriate seeding rates and varieties of tef for different soil types is one of the issues to be considered. Farmers broadcast the seed using a rate of 25–50 kg ha^{-1} (ATA, 2013a).

Reducing the seed rate to between 2.5 and 3 kg ha^{-1} allows for reduced competition between seedlings and optimal tillering of the tef plants. Row planting or transplanting the seeds, land management and especially weeding can also be done more readily and the incidence of lodging is reduced (Tareke *et al.*, 2011). While row planting is considered as one of the potential techniques to increase yield. The adoption of row planting is likely to be slowed by its technical challenges given the small size of the tef seed. Row planting is most effectively carried out with a planting machine, which controls the seed rate (ATA, 2013b)

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted at Semen Wagebeta Farmers' Training Centre (FTC), in Duna District, Hadiya Zone during *meher* rain seasons of 2019. Duna District is located in the Southern, Nations, Nationalities, and Peoples Region State (SNNPRS). It is located at 7º 20`07''N latitude and 37° 39' 09''E longitude (Figure 1). The District is bordered by Kembata Tembaro Zone to the East and South and Soro District (Hadiya Zone) to the West and North. Duna District capital town Ansho is located at 270 km in the South of Addis Ababa through Butajira road, about 170 km from Hawassa, the capital city of SNNPR State, and situated at 42 km North-West from the Zonal capital city of Hossana.

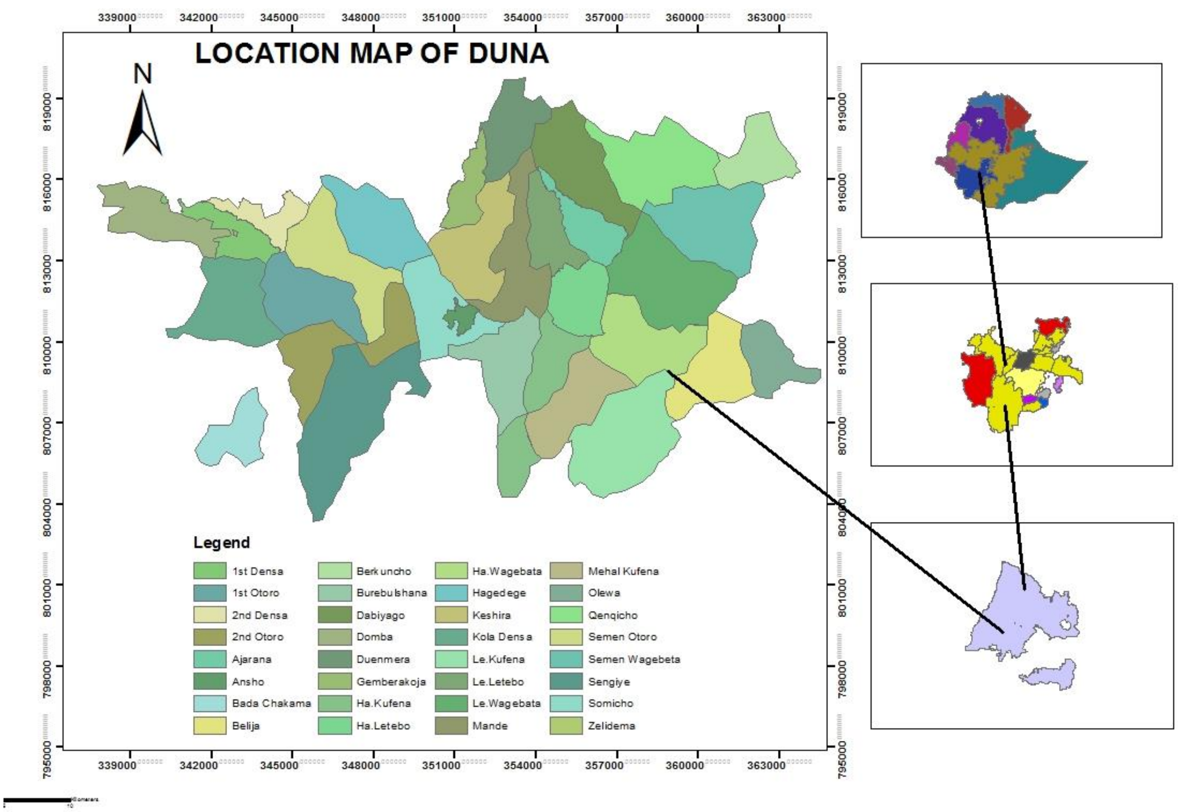

Figure 1. Map of the study area

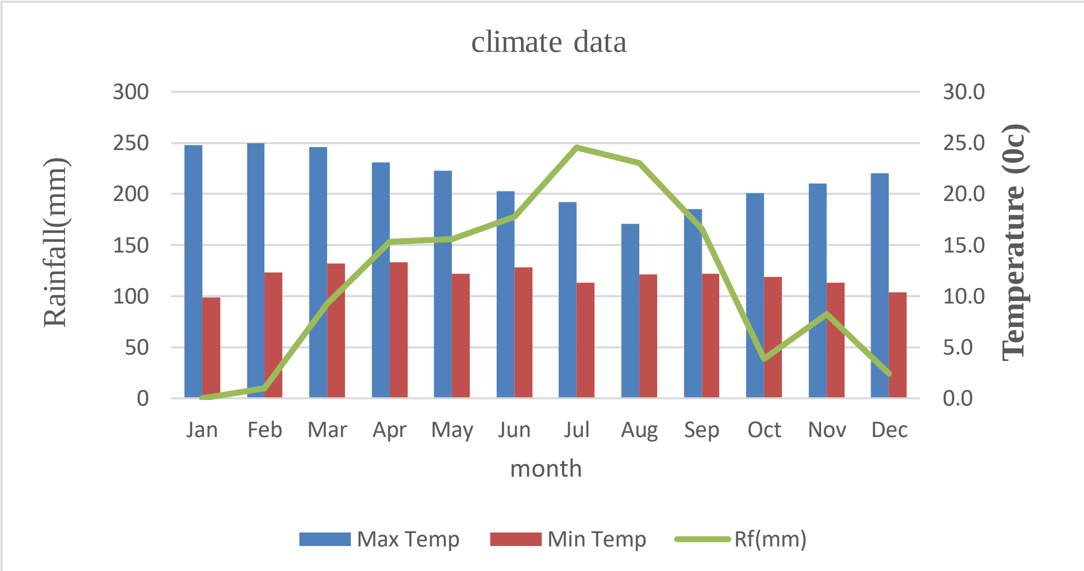

Figure 2. Climatic description

The long term annual rainfall and temperature ranges from 1000-1400 mm and 11.9-21.5ºC, respectively (Figure 2). The Woreda has two Agro-ecological Zones; 21% Weina Dega and 79% Dega climatic type. The elevation of study area was maximum at sengye mountain peak 2957 and 2245 meters above sea level at awonda plane in sana river outlet from woreda The District constitutes wide ranges of soil types, but the experimental site is known by sandy loam (DWARDO, 2019 unpublished). The study area was characterized by a bimodal rainfall pattern with the main wet season (*kiremt*) extending from mid-June to September and the small wet season (*Belg*) extending from March to May. The area is characterized by heavy and erratic rainfall distribution. The area has crop-dominated mixed crop-livestock farming system. The dominant crops growing around the experimental site are wheat (*Triticum aestivum* L.), tef (*Eragrostis tef*), sorghum (*Sorghum bicolor* L.) and some species of legume crops. The district is known for its tef production.

3.2. Experimental Materials

3.2.1. Planting material

The tef variety named 'Quncho' (DZ-Cr-387 RIL355) which was developed and released by Debre Zeit Agricultural Research Centre (DZARC) in 2006 was used for the experiment (table

1). Quncho is a high yielding white-seeded cultivar adapted to a wide range of altitudes (MoARD, 2008), and it is now popular in the study area.

Table 1. Description of tef variety ‘Quncho’ (DZ-Cr-387 RIL355) used for the study

№	Description	Agronomic characteristic
1	Altitude (masl)	1700-2400
2	Rain fall (mm)	500-1200
3	Year of release	2006
4	Seed rate (kg ha^{-1})	5
5	Grain yield on station (t ha^{-1})	2.0-3.2
6	Grain yield on farm (t ha^{-1})	1.8-2.6

Source: MoA (2010).

3.2.2. Fertilizer materials

Blended NPSB (18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B) were used as a source of nutrient elements from Woreda agricultural and rural development office.

3.3. Treatments and Experimental Design

The treatments consisted of factorial combinations of three levels of seed rates (3, 5, and 7 kg ha^{-1}) and five levels of blended NPSB (0, 50, 100, 150 and 200 kg ha^{-1}) fertilizer rates and 100 kg of urea ha^{-1} (Table 2). The experiment was laid out in a randomized complete block design (RCBD) with three replications in factorial arrangement of 3 x 5 = 15 treatment combinations. The gross size of each plot was 2 m × 2 m (4 m^2) consisting of eight rows and the distance between adjacent plots and blocks were separated by 0.5 m and 1 m apart, respectively. The net plot was 1.6 m × 1.8 m (2.88 m^2) consisted of eight rows of 1.8 m length. The outermost one row on both sides of each plot and 20 cm of two ends was considered as border plants, and was not be used for data collection to avoid border effects.

Table 2. Blended fertilizer treatments for the experiment and their respective plant nutrient composition

Fertilizer Treatment ha^{-1}	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	S (kg ha^{-1})	B (kg ha^{-1})
T1=0 kg NPSB+0 kg urea ha^{-1}	-	-	-	-
T2=50 kg NPSB+100 kg urea ha^{-1}	55.5	19	3.5	0.05
T3=100 kg NPSB+100 kg urea ha^{-1}	65	38	7	0.10
T4=150 kg NPSB+100 kg urea ha^{-1}	74.5	57	10.5	0.15
T5=200 kg NPSB+100 kg urea ha^{-1}	84	76	14	0.20

3.4. 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. Then, the composite sample was air-dried at room temperature under shade and the samples were mixed thoroughly to produce 1.0 kg of a representative composite sample. The composite sample was submitted to Sodo soil testing laboratory. Then in the laboratory, it was ground to pass through a 2 mm sieve whereas for organic carbon (OC) and nitrogen (N) determination, the soil was ground to pass through a 0.2 mm sieve. The soil sample was analyzed for selected physico-chemical properties mainly for soil texture, soil pH, cation exchange capacity (CEC), total N, and available P following standard laboratory procedures at Sodo soil testing laboratory where available S and B was analyzed at Areka Agricultural Research Center (AARC).

Then, the CEC was determined titrimetrically by distillation of ammonia that was displaced by Na (Sahlemedhin and Taye, 2000). Total nitrogen was analyzed by Kjeldhal method (Dewis and Freitas, 1970). The pH of the soil was determined at 1:2.5 soil to water dilution ratio using a glass electrode attached to digital pH meter (Page, 1982). Cation exchange capacity was measured after saturating the soil with 1N ammonium acetate (NH_4OAC) and displacing it with 1N NaOAC (Chapman, 1965) whereas available phosphorus was determined using the Bray method (Bray and Kurtz, 1945). Available S was determined using turbid metric method (Chesnin and Yien, 1951), and available boron was determined using hot water method (Havlin *et al.*, 1999).

3.5. Experimental Procedure

The experimental field was prepared according to the local practice. Thus, the land was ploughed two times using oxen before planting and the third ploughing 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 m^2). The blocks were separated by 1.0 m wide open spaces, where as the plots within a block were 0.5 m apart from each other.

The field layout was prepared as per the experimental design, and the plots were leveled manually, and each treatment was assigned randomly to the experimental plots within a block. After seedbeds were well prepared, seeds were manually drilled at the rate of (3, 5 and 7 kg ha^{-1}) with the depth of 2 cm. The seeds were manually drilled in 0.12, 0.2 and 0.28 g for 3, 5 and 7 kg ha^{-1} respectively. The first weeding was accomplished at two weeks from sowing and the second weeding was at a month. Weeding was manually done by hands for four times. Weeds are a major constraint in tef production (Kene'a *et al*., 2001). The entire blended NPSB fertilizer was applied as per the treatments at a full dose at sowing, whereas urea was applied in two splits (½ at sowing and ½ at tillering) about 34 days after sowing. Harvesting was done on the 25th of November 2019.

The harvested total biomass yield was sun dried for three days to insure uniform drying of the whole stock. The total dry matter was weighted by using field balance. Threshing and winnowing were done manually by hand on a mat. After threshing, the grain yield was weighed using sensitive digital balance. All other cultural practices were uniformly applied to each of the plots as per the recommendations for the test location.

3.6. Data Collection

Before taking phenological, yield and yield components data, ten plants were tagged randomly from the central six rows of net plots.

3.6.1. Phenological data

Days to heading: Days from seeding emergence until emergence of the panicle tips of 50% of the plants in each plot.

Days to maturity: the number of days elapsed from the date of sowing to the date when 90% of the crop stand - stems, leaves, and floral bracts - in a plot changed to light yellow color was recorded.

Grain filling period: it is the deference in days, between the dates of heading and date of physiological maturity.

3.6.2. Crop growth parameters

Plant height (cm): Height from the base of the main tiller to the tip of the panicle was recorded on ten randomly per-tagged plants in each plot.

Culm length (cm): It was obtained by subtracting the panicle from the total plant height.

Panicle length (cm): The length from the node where the first primary panicle branch starts to the tip of the panicle was recorded at maturity on the main tillers of ten randomly per-tagged plants in each experimental unit.

Panicle weight (g): Panicle weight of the main tiller panicles of ten pre-tagged plants was measured.

Grain Yield/ panicle (g): The average grain weight was obtained from the primary panicles of ten pre-tagged plants.

Number of total tillers: The number of total tillers was counted on the ten tagged plants from the central net area of each plot.

Number of productive tillers: The number of productive panicle bearing tillers was counted on the ten pre-tagged plants.

Number of non-productive tillers: This was taken as the difference between the first total tillers and fertile tillers.

Above ground dry biomass yield (kg): The total above ground dry biomass yield was determined by weighing the straw and grain yields for each net plot after sun drying for a week.

3.6.3. Yield, yield components, lodging and harvest indices

Grain yield (kg ha^{-1}): Grain yield was taken by harvesting and threshing the grain from net plot area and converted to kg per hectare. The grain yield was adjusted to 12.5% moisture content as: Grain yield (kg ha-1) = Yield obtained (kg ha-1) x $\frac{(100-\%\ \text{Actual Moisture Content})}{100-12.5}$

Thousand grain weight (g): The weight of thousand seeds was determined by measuring the weight of 1000 grains counted by hand from the total grains harvested from each experimental plot. The seed was adjusted at 12.5% moisture content by using Dicky John hand moisture tester instrument and then weighed.

Straw yield (kg): After threshing and measuring the grain yield, the straw yield was obtained by subtracting the grain yield from the total above ground dry biomass yield.

Lodging index: It was recorded using the method of Caldicott and Nuttall (1979), who defined lodging index as the product sum of each degree of lodging (0-5 scale) and the respective percentage divided by five. By definition the calculated values for lodging index between 0 (no lodging or erect) and 100 (complete lodging).

Harvest index: The ratio of grain yield per plot to biological yield per plot expressed in percent.

3.7. Data Analyses

For data recorded on individual plant basis, the averages of the ten plants per plot were used for statistical analysis. The yield, yield components and phenological crop data were subjected to analysis of variance (ANOVA) appropriate for randomized complete block design using Genstat 18th edition software program. The analytic results of soil sample were interpreted using descriptive statistics. Comparisons among treatment means with significant difference for measured characters were done by using Fisher’s 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 seed and blended NPSB fertilizer rates were recorded and used for analysis. The current (November to December, 2019) price of grain and straw of tef were valued at an average open market price at Duna town (*Ansho*) which were 27.30 ETB

kg^{-1} and 0.75 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 the seed (32 kg ETB kg^{-1}) blended NPSB fertilizer (14 ETB $kg^{-\mathbf{1}}$) at the of time planting (July 20, 2019), and labor cost for application of fertilizers (5 persons ha^{-1}, each 55 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= $\frac{Change\ in\ NB\ (NBb - NBa)}{Change\ in\ TCV\ (TCVb - TCVa)} \times 100$. 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. Soil Physico-chemical Properties of the Experimental Site

The results of the pre-sowing composite soil sample laboratory analyses indicated that the soil textural class of experimental site was 15% clay, 19% silt and 66% sand (Table 3). According to Hailu (1991), soil types used for wheat production vary from well-drained fertile soils to waterlogged heavy *Vertisols*. Thus, the soil of experimental site is texturally classified as sandy loam suitable for the production of tef. The soil pH was 5.4 which is medium acidic. According to Landon (1984); this value is considered to be low pH value. However, Miller and Donahue (1997) indicated that most plants grow well between pH 5.5 and pH 8.5. FAO (2000) also reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Thus, the pH of the experimental soil was within the range for productive soils. Even if the optimum pH range of tef production is around 6.5-7, tef tolerates lower pH even lower than 3 pH of the soil (Rosenberg, 1996).

Cation exchange capacity (CEC) is an important parameter of soil, because it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. According to Landon (1991), top soils having CEC greater than 40 cmol (+) kg^{-1} are rated as very high and 25-40 cmol (+) kg^{-1} as high, and 15-25, 5-15 and < 5 cmol (+) kg^{-1} of soil are classified as medium, low and very low, respectively, in CEC. According to this classification, the soil of the experimental site had medium CEC (15.72 cmol (+) kg^{-1} soil), indicating its high capacity to retain cations (Table 3)

The organic carbon content (OC) of the experimental field was 1.89% which is medium according to the rating of Tekalign (1991). This indicates the medium potential of the soil to supply nitrogen to plants through mineralization of organic carbon. Tekalign (1991) has classified soil total N content of < 0.05% as very low, 0.05-0.12% as poor, 0.12-0.25% as moderate and > 0.25% as high. According to this classification, the soil samples were found to have moderate level of total N (0.23%) (Table 3), indicating that the nutrient to be a limiting factor for tef production in the study area.

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 medium P content of 8.95 ppm. The analysis for available sulfur and boron indicated that the experimental soil had value of 28.31 ppm of available sulfur which is rated under optimum and 0.91 ppm of available B which is rating as very low according to Ethio-SIS (2014).

Table 3. Selected physico-chemical properties of the soil of the experimental site

Soil properties	Values	Ratings	References
Soil Texture			
Clay (%)	15		
Silt (%)	19		
Sand (%)	66		
Textural Class	Sandy loam		
pH (1 : 2.5 H_2O)	5.4	Medium acidic	Tekalign (1991)
Total N (%)	0.23	Moderate	Tekalign (1991)
Organic Carbon (%)	1.89	Low	Tekalign (1991)
CEC[Cmol (+) kg^{-1} soil]	15.72	High	Landon (1991)
Available Phosphorus (ppm)	8.95	Medium	Cottenie (1980)
Available Sulfur (ppm)	28.31	Very low	Ethiosis (2014)
Available boron (ppm)	0.91	Very low	Ethio-SIS (2014)

4.2. Phenological and Growth Parameters

4.2.1. Days to heading

The number of days to heading were highly significantly ($P < 0.01$) affected by the main effects of blended NPSB fertilizer and seed rate but, interaction of the two factors had non- significant effect on days to 50% heading (Appendix Table 2). Even though, days to 50% heading was statistically significant, the highest prolonged duration to reach 50% heading (63.56 days) was observed in without application of the fertilizers or control kg ha^{-1} NPSB. However, the minimum duration to 50% heading (52.22 days) was observed in the 200 kg ha^{-1} blended NPSB fertilizer (Table 4). This result was also in agreement with that of Sate (2012) found that N and P_2O_5 at the rates of 64/46 kg ha^{-1} significantly reduced days to heading of tef over the control. This result is line with Sewnet (2005) reported that early flowering with an increase in the rate of N application in rice.

The present result is in line with the result of Bekelu and Arega (2016) indicated that sufficient N at right time resulted in rapid growth and heading. Temesgen (2012) also reported that increasing N levels on tef hasten days to heading and maturity. Similarly, Getahun *et al*. (2018) reported that the heading of tef plants was accelerated as NP rate increased from zero to 69 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1} fertilizer applications.

Seeding rate was also affects heading of tef, the highest prolonged duration to reach 50% heading (63.53 days) was observed in with 3 kg ha^{-1} and minimum duration to 50% heading (55.00 days) was observed in the 7 kg ha^{-1}. The present result is in line with the report of Abreham (2014) and Bekelu and Arega (2016) reported increased seeding rate hastened heading and maturity of tef.

4.2.2. Days to 90% physiological maturity and grain filling period

The main effect of blended NPSB fertilizer and Seed rats were highly significantly ($P < 0.01$) on days to 90% physiological maturity whereas, grain filling was significant ($P < 0.05$) while, in both parameters the interactions (NPSB x seed rate) effect did not significantly affected days to 90% physiological maturity and grain filling time (Appendix Table 2). The longest days to physiological maturity (103.56 days) was recorded at the control (unfertilized) rate of NPSB kg ha^{-1} whereas, the shortest (92.89 days) was obtained from 200 kg NPSB ha^{-1}. The longest days to grain filling was (40.00 days) was recorded at control NPSB kg ha^{-1} whereas, the shortest (36.22 days) was obtained from the highest rate of 200 kg NPSB ha^{-1} (Table 4).

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 N 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.

Nitrogen is involved in all major processes of plant development and yield formation. Besides, a good supply of nitrogen to the plant stimulates root growth and development as well as uptake of other nutrients (FAO, 2000; Brady and Weil, 2002). An adequate supply of N is associated with high photosynthetic activity, vigorous vegetative growth, and dark green color as result it delayed the crop maturity. On the other hand, sulfur is an essential element best known for its role in the synthesis of proteins, oils, vitamins and flavored compounds and it is essential not only for plant growth and quality produce, but also enhances other nutrients use efficiency. Sulfur plays an important part in many physiological processes that occur within a developing and maturing plant and it also hastens the ripening of fruits thus counteracting the effect of excess nitrogen application to the soil. Also, Boron was an essential element for better utilization of macro-nutrients by plants and there by greater translocation of photo-assimilates from source to sink during growth period (Ali *et al.,* 2013). Boron is also involved in the transport of sugars across cell membranes and in synthesis of cell wall material. The result in line with the study was similarly, Manna *et al.* (2005) reported that combined application of NP and organic fertilizers promoted vegetative growth, leading to prolonged days to maturity.

In agreement with the current result, Tilahun *et al*. (2013) reported that increasing of P_2O_5 from 50 kg ha^{-1} to 100 kg ha^{-1} with increasing compost rate from control 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 69 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1} and the longest days (97) from the control.

Table 4. Main effect of blended NPSB fertilizers and seed rate on days to 50% heading, days to 90% physiological maturity and grain filling period of tef

Treatments	Days to heading	Days to maturity	Grain filling period
NPSB rates (kg ha^{-1})			
0	63.56^{a}	103.56^{a}	40.00^{a}
50	59.22^{b}	98.78^{b}	39.56^{a}
100	57.89^{bc}	97.00^{b}	38.44^{ab}
150	56.44^{bc}	94.33^{c}	38.11^{ab}
200	52.22^{c}	92.89^{c}	36.22^{b}
LSD	2.49	3.49	3.18
Seed rates (kg ha^{-1})			
3	63.53^{a}	102.73^{a}	39.47^{a}
5	59.27^{b}	97.33^{b}	39.07^{a}
7	55.00^{c}	91.87^{c}	36.87^{b}
LSD	1.94	2.71	3.72
CV (%)	1.3	0.6	2.1

Means followed with the same letter (s) in the column for a factor are not significantly different at 5% level; CV (%) = Coefficient of variation; LSD $_{(0.05)}$ = Least Significant Difference at 5% level.

4.3. Growth Parameters

4.3.1. Plant height (cm)

The plant height was highly significantly ($P < 0.01$) affected by the main effects of blended NPSB fertilizer and seed rate but, the interaction of the two factors had no significant effect on plant height (Appendix Table 3). The tallest plant (103.26 cm) was recorded at seed rate of 7 kg ha^{-1} while the shortest plant (92.71 cm) was obtained at the seed rate of 3 kg ha^{-1} (Table 5). The result indicated that height of tef plants increased as seed rate increase. The tallest plant height at the highest seed rate might be due to aerial intra-specific competition among tef plants for light and space and promoted elongation of stem or tillers of tef. These are due larger seed rate resulting in higher competition for nutrients while, in small seed rate less plant competition for nutrients (Shiferaw Tolosa, 2012).

The current result is in line with the study by Ali *et al*. (2004) reported that increasing plant density significantly increased plant height. Similarly, Hasan Kilic and Songul Gursoy (2010) reported that the highest plants was observed with seed rates were high while the shortest plant height (96.7 cm) was recorded when the seed rate was low. Likewise, Soomro *et al*. (2009)

showed that wheat sowing at higher seed rate that is 175 kg ha^{-1} produced highest plant height (101.25 cm).

The plant height was also response for application of blended NPSB fertilizer. The tallest plant (102.01 cm) was recorded at 200 NPSB kg ha^{-1} while, the shortest plant (85.56 cm) was obtained at the controlled NPSB kg ha^{-1} (Table 5). This in agreement with present result, Okubay *et al*. (2014) also reported a positive and linear response of plant height of tef due to increasing N fertilizer application. Hence, the uptake of fertilizer P depends much on root growth and morphology of the crop being considered (Parnes, 1990). Also Boron is involved in N and P metabolism, and 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. Several authors, Dewal and Pareek (2004), Arif *et al*. (2006), Gupta *et al*. (2004), Bereket *et al*. (2014) report that macro and micro nutrients (Nitrogen, Phousporous with Sulfur and Born) fertilizers application can increase plant height, spike length, number of tillers and number of kernel with increasing doses and combination.

4.3.2. Panicle and culm length (cm)

The analysis of variance revealed that highly significantly difference ($P < 0.01$) among treatment levels as to the main effects of blended NPSB fertilizer and seed rates on Culm length and the analysis of variance showed that panicle length highly significantly difference ($P < 0.01$) effects of seed rates while, blended NPSB fertilizer significant difference ($P < 0.05$) on panicle length. However, the interaction of blended NPSB fertilizer and seed rates did not significant those panicle and culm length (Appendix Table 3). Significantly, shortest Culms (50.72 cm) and panicles (35.79 cm) were scored from controlled NPSB kg ha^{-1} fertilizer and high culm (68.91) and panicle (42.29) was recorded from 150 and 200 NPSB kg ha^{-1} fertilizer application respectively (Table 5).

Culm and panicle length decreased as seeding rates increased. This could be because of high competition among tef plants for common resources such as nutrient, light, moisture and space at the highest density and this could hinder the development of plant height and panicle length

(Abreham, 2014). Longer panicles bear more number of spikletes 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) reported that panicle length exhibited positive and highly significant correlation with plant height and grain yield. The present finding is in line with Tareke *et al*. (2013) and Abreham (2014) reported that panicle length of tef was increased with decreased seeding rates.

Table 5. Main effect of blended NPSB fertilizers and seed rate on plant height, culm length and panicle length of tef

Treatments	Plant height (cm)	Culm length (cm)	Panicle length (cm)
NPSB rates (kg ha^{-1})			
0	85.56^{d}	50.72^{c}	35.79^{c}
50	95.14^{c}	60.46^{b}	38.59^{b}
100	100.42^{ab}	58.87^{b}	39.67^{b}
150	101.00^{ab}	68.91^{a}	39.92^{b}
200	102.01^{a}	59.72^{b}	42.29^{a}
LSD (0.05)	6.26	7.49	3.11
Seed rates (kg ha^{-1})			
3	92.71^{c}	67.49^{c}	42.73^{a}
5	97.15^{b}	56.56^{b}	41.59^{a}
7	103.26^{a}	50.55^{a}	39.23^{b}
LSD (0.05)	6.4	5.35	2.19
CV (%)	0.5	1.4	1.5

Means followed with the same letter (s) in the column for factor are not significantly different at 5% level; CV (%) = Coefficient of variation; LSD $_{(0.05)}$ = Least Significant Difference at 5% level.

4.4. Yield Components and Yield

4.4.1. Number of total tillers

The analysis of variance indicated that number of total tiller produced per meter square was highly significantly ($P < 0.01$) affected by the main effects of blended NPSB fertilizer, seed rate and the interactions effect of NPSB and seed rate of tef (Appendix Table 4). The maximum number of total tillers (21.13 m^{-2}) was produced with application of the highest rates 200 NPSB ha^{-1} and 7 kg ha^{-1} of seed rates while, followed by 200 kg NPSB with 5 kg seed rate ha^{-1} whereas the minimum number of tillers (7.17 m^{-2}) was recorded from the combination of control kg NPSB and 3 kg seed rate ha^{-1}. The total number of tillers was increased significantly across the increased rates of the two factors (Table 6).

The highest number of tillers at the highest rates of NPSB and seed rate 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. These of result might be like due to the fact that plants such as wheat can increase root proliferation in high-P regions to enhance P uptake, especially during early growth stage (Cook and Veseth, 1991). Likewise, Haftamu *et al*. (2009) and Bekelu and Arega (2016), reported that numbers of tillers of tef increased with increased rates of N fertilizer. According to Kumela and Thomas (2016) N stimulates tillering probably due to its effect on cytokinin synthesis.

The current result is in agreement with that of Okubay *et al*. (2014) reported that the number of total tillers increased significantly with increasing levels of N from control to 69 kg ha^{-1} in tef. Similarly, Melesse (2007) reported that as the N fertilizer rate increased from control to 69 kg ha^{-1}, the total number of tillers of bread wheat was increased from 4 to 7 per plant, respectively. The present result also agree with the study of Javaid *et al*. (2012) reported that higher number of tillers was observed a high seeding rate while, less number of tillers was recorded at lower seeding rate. The highest number of total tillers at the highest seed rates could also be due to the highest number of plants per unit area with the highest seed rate.

Generally, number of total tillers recorded by the treated plots was significantly higher than the unfertilized plot/control. In conformity with this result, Ahmad *et al*. (2000); Khan *et al*. (2000); Hussain *et al*. (2001); Naeem (2001); and Otteson *et al*. (2008) reported increased number of tillers per unit area with increasing seeding rate. Similarly, Kumar *et al.* (1991); and Ahmad *et al.* (1999) reported that higher sowing rates increased the number of tillers m^{-2} due to more number of seeds sown and numbers of plants emerged, but tillers per seedling decreased with increased in seed rate.

Table 6. Interaction effect of NPSB fertilizers and seed rate on mean number of total tillers of tef

Blended NPSB (kg ha^{-1})	Seed rate (kg ha^{-1})		
	3	5	7
0	7.17^{i}	9.47^{k}	11.13^{ijk}
50	9.60^{jk}	12.27^{hi}	13.97^{fgh}
100	11.37^{ij}	15.20^{ef}	16.73^{de}
150	12.77^{ghi}	17.50^{cd}	18.83^{bc}
200	14.20^{fg}	19.90^{ab}	21.13^{a}
LSD	1.93		
CV (%)	4.6		

Means in columns and rows followed by the same letters for a factor are not significantly different at 5% level of significance; LSD $_{(0.05)}$ = Least Significant Difference at 5% level; CV = Coefficient of variation.

4.4.2. Number of productive tillers

The analysis of variance indicated that number of productive tillers from per meter square was highly significantly ($P < 0.01$) affected by the main effect of blended NPSB fertilizer and seed rate as well as by the interaction effect of NPSB and seed rate (Appendix Table 4). The maximum number of productive tillers (20.13 m^{-2}) was recorded from the application of the highest rates of NPSB and seed rate (200 kg NPSB ha^{-1} + 7 kg seed rate ha^{-1}) followed by 200 kg NPSB + 5 kg seed rate ha^{-1} whereas the minimum number of productive tillers (6.07 m^{-2}) was recorded from the combination of controlled plots and lower seed rates (zero kg NPSB + 3 kg seed rate ha^{-1}) (Table 7).

The highest number of productive tillers at the highest seed and NPSB rates might be that increasing seed rates and NPSB fertilizer resulted in increased plants emerged and favored tillering or contributed to tiller maintenance when the rate increased due to that the more number of fertile tillers. The current result is in line with the result of Kraft and Spiss (1988) reported that increasing seed rate increased the fertile tillers and total tillers significantly mainly because of more number of plants per unit area. Similarly, Islam *et al*. (2002) reported that percentage of effective tillers increased with highest sowing rate due to which grain yield also increased. Number of tillers m^{-2} and effective tillers m^{-2} of tef increased as seeding rate (Shiferaw, 2012).

In current agreement with the results of this study Fayera *et al.* (2014) found that the highest productive tillers of tef (26 tillers per plant) under the application of 200 kg ha^{-1} NPKSZnB blended (14 N, 21 P_2O_5, 15 K_2O, 6.5 S, 1.3 Zn and 0.5 B) + 23 kg N ha^{-1} fertilizer. Similarly, Haftamu *et al.* (2009) reported higher number of productive tillers of tef three per plant with application of 69 kg N ha^{-1}. Similarly, Okubay *et al*. (2014) reported that highest fertile tillers (23 per plant) of tef was obtained from the application of the highest rate (69 kg N ha^{-1}) whereas the lowest number of fertile tillers per plant was obtained from the control plot.

Table 7. Interaction effect of NPSB fertilizer and seed rates on number of productive tillers of tef

Blended NPSB (kg ha^{-1})	Seed rate (kg ha^{-1})		
	3	5	7
0	6.07^{j}	9.47^{hi}	10.33^{ghi}
50	8.60^{i}	11.53^{fg}	12.97^{ef}
100	10.37^{ghi}	14.67^{de}	15.73^{cd}
150	11.37^{fgh}	17.30^{bc}	17.83^{b}
200	13.20^{ef}	19.90^{a}	20.13^{a}
LSD	2.05		
CV (%)	4.8		

Means in columns and rows followed by the same letters for a factor are not significantly different at 5% level of significance; LSD $_{(0.05)}$ = Least Significant Difference at 5% level; CV = Coefficient of variation.

4.4.3. Number of non-productive tillers

The analysis of variance indicated that number of non-productive tillers from per meter square was not significantly affected by the main effect of blended NPSB fertilizer and seed rate as well as by the interaction effect of NPSB and seed rate (Appendix Table 4). The highest number of non-productive tillers (1.944 plant m^{-2}) was obtained with the application of blended fertilizer 150 kg NPSB ha^{-1}, while the lowest number of non-productive tillers (1.456 plant m^{-2}) was obtained from the 50 NPSB kg ha^{-1} fertilizer applied plots (Table 8). Similarly, the highest number of non-productive tillers should be obtained 7 kg ha^{-1} seed rates and lowest number of non-productive tillers should be obtained 3 kg ha^{-1} seed rates. This is due to lower access of plants to nutrients, water and light at higher seeding rate than lower seeding rates. Resulting from completion, as the number plant population increased competition for common resource is also increased (Bekelu and Arega, 2016).

4.4.4. Panicle weight and grain yield per panicle weight (g)

The analysis revealed on panicle weight was highly significantly ($P < 0.01$) influenced by seed rates but, blended NPSB fertilizer at panicle weight was significant ($P < 0.05$) the interaction of blended NPSB fertilizer and seed rates did not significant at this parameters of tef. However, grain yield per panicle weight by the main effects of blended NPSB fertilizer, seed rates and the interactions was non-significant (Appendix Table 5). The highest panicle weight 5.20 g was recorded at the rate of 100 kg NPSB ha^{-1} while the lowest panicle weight 4.17 g was recorded from the unfertilized plot and highest grain yield per panicle weight 1.638 g was recorded at the rate of 150 kg NPSB ha^{-1} while, the lowest grain per panicle weight 1.437 g was recorded from the unfertilized plot (Table 8).

In many studies, the effect of high NPSB application on tef yield was attributed to the major role played by panicle weight and on grain yield per panicle. Longer panicles bear more number of spikletes 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) reported that panicle exhibited positive and highly significant correlation with plant height and grain yield. Getahun *et al.* (2018) reported that the longest panicle length (39.9 cm) was obtained from the application of 69 kg N ha^{-1} while the shortest (31.6 cm) was recorded from the control. Thus, increasing N from zero to 69 kg N ha^{-1} increased panicle by about 26.3%, compared to the control.

Table 8. Main effect of blended NPSB fertilizer and seed rates on panicle weight, grain per panicle and non-productive tiller of tef

Treatments	Panicle weight (g).	Grain yield per panicle (g).	Non- productive Tiller
NPSB rates (kg ha^{-1})			
0	4.17^{c}	1.437	1.544
50	4.80^{b}	1.615	1.456
100	5.20^{a}	1.609	1.656
150	4.75^{b}	1.638	1.944
200	4.90^{b}	1.597	1.667
LSD (0.05)	0.45	NS	NS
Seed rates (kg ha^{-1})			
3	5.520^{a}	1.601	1.640
5	5.535^{a}	1.592	1.713
7	3.409^{b}	1.545	1.847
LSD (0.05)	0.732	NS	NS
CV (%)	11.3	4.6	10.9

Means in columns and rows followed by the same letters for a factor are not significantly different at 5% level of significance; LSD $_{(0.05)}$ = Least Significant Difference at 5% level; NS= non-significant; CV = Coefficient of variation.

4.4.5. Thousand grains weight (g)

Thousand grains weight is an important yield determining component of crop. Analysis of variance revealed that main effects of blended NPSB fertilizer, seed rate, as well as interaction effects had not significantly affected thousand grains weight of tef (Appendix Table 5). It is evident from the data that maximum thousand seed weight (0.2860 g) was recorded when plots were from low seed rates with 3 kg ha^{-1}, while minimum thousand seed weight (0.27510 g) were recorded 7 kg ha^{-1} seed rate was used (Table 9), but statistically there is no significant different between different seed rate. These results are in conformity with Marwat *et al.* (1989) reported that 1000 grain weight decreased with increasing in seeding densities.

4.4.6. Above ground dry biomass (kg ha^{-1})

The analysis of variance showed that the main effect of blended NPSB fertilizer was highly significant ($P < 0.01$) and seed rate had significant ($P < 0.05$) effect on above ground dry biomass yield of tef while, the interaction effect was not significant (Appendix Table 6). The highest above ground dry biomass yield (7885 kg ha^{-1}) was recorded from 200 kg ha^{-1} NPSB fertilizer applied while, the lowest above ground dry biomass yield (6200 kg ha^{-1}) was recorded from unfertilized plot (cotrolled NPSB kg ha^{-1}) (Table 9).

In general, as the seeding rate increases from 3 kg ha^{-1} to 7 kg ha^{-1} the above ground dry biomass yield was increased which might be due to higher seed rates might result in more plant populations per unit area which enhanced yield components and yield of crop. The highest above ground dry biomass yield (7773 kg ha^{-1}) was recorded from the seed rate of 7 kg ha^{-1} while the lowest above ground dry biomass yield (6641 kg ha^{-1}) was recorded from seed rates of 3 kg ha^{-1} plot (Table 9). Biological yield is sum total of all dry matter produced through physiological and biochemical processes occurring in the plant system. Biological yield is an important factor because farmers are also interested in straw mainly as animal feed and source of income in addition to grain.

This result agrees with the finding of Woubshet *et al.* (2017) found that application of 150 kg ha^{-1} NPSB blended fertilizer with compost increased the biomass by 11.5 t ha^{-1}. This due to Sulfur enhanced the formation of chlorophyll and encouraged vegetative growth and B helps in N absorption. In agreement with this result many studied have showed that higher planting density within limit might produce more total dry matter per unit area which agrees with the results of this study. In conformity with this result, Ali (2013) reported a linear increase in biological yield as the seed rate was increased.

The current studies result was in conformity with the findings of Adera (2016) and Bereket *et al.* (2014) showed that above ground dry biomass yield was significantly affected by application of blended fertilizer. Similarly, Workineh *et al.* (2015) reported that the highest biomass yield (11890 kg ha^{-1}) of wheat was observed with 138/115 kg N/P_2O_5 ha^{-1} while the lowest (9780 kg ha^{-1}) was recorded with 46/46 kg N/P_2O_5 ha^{-1}. Likewise, Melesse Harfe (2017) reported that increasing the N/P fertilizer rate from 46/20 kg N/P_2O_5 ha^{-1} to 69/30 kg N/P_2O_5 ha^{-1} for wheat biomass yield was increased from 10417 kg ha^{-1} to 11233 kg ha^{-1}. Similarly, Yasir *et al*. (2015) reported that maximum above ground dry biomass of wheat (14734.5 kg ha^{-1}) at 140 kg N ha^{-1} applied at sowing and 20 kg S ha^{-1} applied at anthesis.

Table 9. Main effect of blended NPSB fertilizers and seed rate on plant thousand grain yield (TGY), above ground dry biomass (AGDB) and harvest index (HI) of tef

Treatments	TGY (g)	AGDB (kg ha^{-1})	HI (%)
Blended NPSB (kg ha^{-1})			
0	0.2740	6200^{c}	31.37^{b}
50	0.2772	6522^{b}	31.84^{b}
100	0.2780	7637^{a}	34..02^{a}
150	0.2820	7743^{a}	32.72^{ab}
200	0.2890	7885^{a}	35.54^{a}
LSD	NS	1312.4	4.23
Seed rates (kg ha^{-1})			
3	0.2860	6641^{b}	31.39^{b}
5	0.2832	7538^{a}	34.88^{a}
7	0.2751	7773^{a}	33.51^{ab}
LSD	NS	1016.6	3.14
CV (%)	10.9	1.7	5.2

Means in columns and rows followed by the same letters for a factor are not significantly different at 5% level of significance; LSD $_{(0.05)}$ = Least Significant Difference at 5% level; NS= non-significant; CV = Coefficient of variation.

4.4.7. Grain yield (kg ha^{-1})

The analysis of variance showed that the main effects of blended NPSB fertilizer and seed rate and their interactions highly significantly ($P < 0.01$) affected the grain yield of tef (Appendix Table 6). The highest grain yield (2975 kg ha^{-1}) was obtained at combined rates of 200 kg NPSB ha^{-1} with 5 kg seed rate ha^{-1} and it was statistically at par with 150 kg NPSB ha^{-1} with 7 kg seed rate ha^{-1} with grain yield of 2818 kg ha^{-1} whereas the lowest grain yield (1875 kg ha^{-1}) was recorded at control level of blended NPSB fertilizer with 3 kg seed rate ha^{-1} (Table 10).

The highest grain yield at the highest NPSB and seed rates might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to synergetic effect of the four nutrients and the highest seed rate produced greater plant population which enhanced yield components and yield. Higher grain yields obtained with optimum rates of seed and NPSB could mainly be attributed to significant improvements in growth and yield components such as plant height, panicle length, grain yield per panicle and thousand grains weights. In general, the mean grain yield obtained from the all fertilized plots statistical exceeded the grain yield from the unfertilized or control plots. Instead of using blanket recommendation of 100 kg ha^{-1} NPSB and 100 kg ha^{-1} urea, in study area using 200 kg blended

NPSB fertilizer with 100 kg ha^{-1} urea had increases more yield (Table 10). This clearly indicates that the synergic effect of the four nutrients in increasing yield of tef.

This result agrees with the previous finding of Woubshet *et al.* (2017) reported that application of 150 kg ha^{-1} NPSB blended fertilizer with compost increase the grain yield by 4.8 t ha^{-1}. Klikocka *et al.* (2016) found that a positive reaction of N and S fertilization on grain yield, which was the highest grain yield (5.40 t ha^{-1}) was obtained due to application of 80 N kg ha^{-1} increasing by 1.30 t ha^{-1} (13.1%) with respect to the control and S fertilization increased grain yield by 3.58%. Besides, Khan *et al.* (2006) reported 43% raise in grain yield with the addition of 90 kg P and 60 kg ha^{-1} S. Likewise, according to Malakouti (2000) repotted that the grain yield increased due to application of boron was also witnessed by the combined application of boron with micro nutrients, with the benefits 4 to 11% wheat yield.

On the other hand, Brhan (2012) reported that treatments that received blended fertilizers (69 kg N ha^{-1} + 46 kg P_2O_5 + 22 kg S ha^{-1} + 0.3 kg Zn ha^{-1}) under row planting of tef is obtained 4155 kg ha^{-1} and increased 30% and 378% over treatments that receive urea and DAP under row planting and control plots, respectively. Increasing N rate shows increasing grain yield of tef. The result is also in line with previous findings of Haftamu *et al.* (2009) reported application of 69 kg N ha^{-1} gave optimum biomass and grain yields of tef.

At current studies Bekele and Getahun (2016) reported as nitrogen fertilizer increased yield attributes and grain yields of rice. In agreement with this result, Bereket *et al.* (2014) reported that increasing P rate from 46 to 69 kg P_2O_5 ha^{-1} increased grain yield of bread wheat by 6.8%. Similarly, Jarvan *et al.* (2012) reported that 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 ha^{-1} S.

The present study was in conformity with previous finding of Tareke *et al.* (2013) reported that tef yield could be increased 3-4 folds by using drilling of 2.5-5 kg ha^{-1} of seed rate. Similar findings were also reported by Fanuel *et al.* (2012) and Abreham (2014) found that lower seeding rates of tef gave the highest grain yield as compared to high seeding rates. Delesa

(2007) reported that low seeding rate increased grain yield due to increased yield components, which is in line with the present result.

Table 10. Mean interaction effect of NPSB fertilizer and seed rates on grain yield (kg ha^{-1}) of tef

Blended NPSB (kg ha^{-1})	Seed rates (kg ha^{-1})		
	3	5	7
0	1875^{f}	2283^{cdef}	2436^{bcde}
50	2092^{ef}	2433^{bcde}	2525^{bcde}
100	2200^{def}	2500^{bcde}	2657^{abc}
150	2246^{cdef}	2533^{bcd}	2818^{ab}
200	2348^{cde}	2975^{a}	2650^{abc}
LSD	434.1		
CV (%)	4.2		

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

4.4.8. Straw yield (kg ha^{-1})

Straw yield is an important component because farmers are also interested in straw for animal feed, as income source in addition to grain and use for plastering of wall. Analysis of variance showed that the straw yield of tef was highly significantly (P < 0.01) affected by the main effect of NPSB fertilizer and seed rate and the interaction effect was significant (P < 0.05) (Appendix Table 5). The highest straw yield (6192 kg ha^{-1}) was obtained at the combination of the highest rates (200 kg ha^{-1} blended NPSB) fertilizers with 7 kg seed rate ha^{-1} whereas the lowest straw yield (3472 kg ha^{-1}) was recorded in response to the application of zero level of blended NPSB fertilizer with 3 kg seed rate ha^{-1} (Table 10).

The significant increase in straw yield in response to the highest rate of application of blended NPSB fertilizer and seed rate might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to synergetic effect of the four nutrients and the highest seed rate produced higher plant population which enhanced growth and yield components thereby resulting in the highest above ground dry 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.

Similar results were found by Temesgen (2001); Legesse (2004); Mitiku (2008); and Okubay *et al.* (2014) 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. In line with this result, Kumar *et al*. (2006); and Otteson *et al*. (2007) reported that increasing sowing seed rate up to 150 kg ha^{-1} with optimum fertilizer application resulted in increased straw yield of wheat. Nasser and El-Gizawy (2009) reported increased straw yield of wheat with increase in NP fertilizers rates up to 90/45 kg ha^{-1}. Likewise, Bereket *et al*. (2014) reported highest straw yield of bread wheat (6827 kg ha^{-1}) at phosphorus rate of 92 kg P_2O_5 ha^{-1} and nitrogen rate of 138 kg N ha^{-1}.

The current studies agrees with the finding of Woubshet *et al.* (2017) reported that application of 150 kg ha^{-1} NPSB blended fertilizer with compost increase the straw yield by 5.9 t ha^{-1}.The result is in line with reports of Okubay *et al.* (2014) indicated that straw yield of tef was increased by the application of different rates of N fertilizer. The report of Dalal and Dixit (1987) and Bekele and Getahun (2016) showed that increasing N fertilizer increased straw yield of upland rice.

Table 11. Mean interaction effect of NPSB fertilizer and seed rates on straw yield (kg ha^{-1}) of tef

Blended NPSB (kg ha^{-1})	Seed rates (kg ha^{-1})		
	3	5	7
0	3472^{e}	4550^{bcde}	4950^{abcde}
50	3657de	4713^{abcde}	5242^{abc}
100	3910^{cde}	4858^{abcde}	6083^{a}
150	4152^{bcde}	5117^{abcd}	5650^{ab}
200	4492^{bcde}	5092^{abcd}	6192^{a}
LSD	706.3		
CV (%)	2.3		

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

4.4.9. Lodging index

Lodging index was highly significant (P < 0.01) on the main effects of blended NPSB fertilizer and seed rates rates as well as the interaction effect of two factors (Appendix Table 5). The highest lodging (74.33%) was recorded from the highest blended 200 kg NPSB fertilizer ha^{-1}

and 7 kg seed rates ha^{-1}, while the lowest lodging index (19.67%) was recorded from the control NPSB fertilizer and 3 kg ha^{-1} seed rate (Table 12). The highest lodging might be due to increasing rate in the combination of the highest rate of blended NPSB fertilizer and seed rates that enhanced fast vegetative growth, plant height and succulent stem elongation of tef and the wind prevailed in the study area during the 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) reported highest lodging of tef (74%) at N/P_2O_5 rate of 64/46 kg ha^{-1}. Likewise, Fayera *et al.* (2014) reported the highest lodging percentage (79.74%) of tef with the highest rate of NPK (138 kg N ha^{-1} combined with 55 kg P ha^{-1} and controlled kg K_2O 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 12. Interaction effect of NPSB fertilizer and seed rates on lodging index of tef

Blended NPSB (kg ha^{-1})	Seed rates (kg ha^{-1})		
	3	5	7
0	19.67^{ij}	28.67^{ghi}	36.67^{efg}
50	22.00^{ij}	35.33^{fgh}	44.67^{de}
100	27.67^{hij}	40.00^{ef}	54.67^{bc}
150	30.00^{ghi}	51.33^{cd}	61.33^{b}
200	28.67^{ghi}	57.33^{bc}	74.33^{a}
LSD	16.369		
CV (%)	16.2		

Means in columns and rows followed by the same letters for a factor are not significantly different at 5% level of significance; LSD $_{(0.05)}$ = Least Significant Difference at 5% level; CV = Coefficient of variation.

4.4.10. Harvest index

Harvest index is an indicator of dry matter partitioning towards the reproductive organs. The analysis of variance revealed that the main effects of blended NPSB fertilizer and seed rate had significant ($P<0.05$) effect on harvesting index (HI) while the interaction effect was not significant (Appendix Table 5). The highest harvest index (35.54) was obtained due to the 200 kg ha^{-1} blended NPSB fertilizer followed by 100 kg ha^{-1} NPSB whereas the lowest harvest index (31.37) was recorded with controlled kg ha^{-1} NPSB (zero treatment) (Table 9). Harvest index tended to increase with increased application of NPSB fertilizer until 200 kg NPSB ha^{-1} which might be attributed to greater photo assimilate production and its ultimate partitioning into grains compared to partitioning in to straw, i.e. proportionally higher grain yield than vegetative biomass yield.

In terms of seed rate, the highest harvest index (34.88) and the lowest harvest index (31.39) were obtained due to the 5 kg and 3 kg seed rate ha^{-1}, respectively (Table 9). The increment in harvest index at higher seed rate might be attributed to proper utilization of resources like nutrients, water, sun light and ultimate partitioning into grains compared to partitioning in to straw. The harvest indices obtained due to NPSB and seed rates in this study ranged from 31.37 to 35.54, which was similar results was agreed with the findings of Sharer *et al.* (2003) reported higher harvest index (0.39) under higher level of nitrogen and phosphorus (180/130 kg N/P ha^{-1}) than application of lower levels of the fertilizers.

4.5. Partial Budget Analysis

Partial budget analysis of the net benefits, total costs that vary and marginal rate of returns are presented in (Table 13). Information on costs and benefits of treatments is a prerequisite for adoption of technical innovation for farmers. The results in this study indicated that the application of blended NPSB fertilizer and seed rate resulted in higher net benefits than the unfertilized/control treatments (Table 13). As indicated in Table 13 the partial budget analysis showed that the highest net benefit (Birr 58882.85 ha^{-1}) was recorded at the rate of application of 200 kg blended NPSB with the 5 kg seed rate ha^{-1} followed by 150 kg blended NPSB with 7 kg seed rate ha^{-1} (Birr 50096 ha^{-1}), whereas the lowest net benefit (Birr 40222.35 ha^{-1}) was recorded from controlled (zero) fertilizer application and seed rate of 3 kg ha^{-1}.

According to CIMMYT (1988) suggestion, the minimum acceptable marginal rate of return should be more than 100%. In this study, even an application of 200 kg NPSB ha^{-1} with 5 kg seed rate ha^{-1} gave the maximum net benefit (Birr 58882.85 ha^{-1}), the marginal rate of return was in acceptable range with marginal rate of return (1449.01%). Therefore, on economic grounds, application of 200 kg NPSB ha^{-1} with seed rate of 5 kg ha^{-1} would be best and economical for production of tef in the study area and other areas with similar agro-ecological conditions.

Table 13. Summary of partial budget and marginal rate of return analysis for response of tef to blended NPSB fertilizers and seed rate in Duna District, Southern Ethiopia

Treatment		Unadjusted Grain Yield	Adjusted Grain Yield	Unadjusted Straw Yield	Adjusted Straw Yield	Total revenue (ETB ha^{-1})	Total Variable Cost(ETB ha^{-1})	Net Benefit Cost(ETB ha^{-1})	Marginal rates of return (%)
NPSB Rate (kg)	Seed Rate (kg)								
0	3	1875	1687.5	3472	3124.8	48412.35	8190	40222.35	0.00
50	3	2095	1885.5	3657	3291.3	53942.65	10090	43852.65	191.07
100	3	2200	1980	3910	3519	56693.25	10790	45903.25	292.94
150	3	2246	2021.4	4152	3736.8	57986.82	11490	46496.82	84.79
200	3	2348	2113.2	4492	4042.8	60722.86	12190	48532.86	290.86
0	5	2283	2054.7	4550	4095	59164.56	13650	45514.56	D
50	5	2433	2189.7	4713	4241.7	62960.1	15550	47410.1	99.76
100	5	2500	2250	4858	4372.2	64704.15	16250	48454.15	149.15
150	5	2533	2279.7	5117	4605.3	65689.78	16950	48739.78	40.8
200	5	2975	2677.5	5092	4582.8	76532.85	17650	58882.85	1449.01
0	7	2436	2192.4	4950	4455	63193.77	19656	43537.77	D
50	7	2525	2272.5	5242	4717.8	65577.6	21556	44021.6	25.46
100	7	2657	2391.3	6083	5474.7	69388.51	22256	47132.51	444.41
150	7	2818	2536.2	5650	5085	73052	22956	50096	423.35
200	7	2650	2385	6192	5572.8	69290.1	23656	45634.1	D

Where, D = dominated treatments. ETB ha^{-1} = Ethiopian Birr per hectare; Market price of tef = 27.30 ETB kg^{-1}; Market price of straw= 0.75 ETB kg^{-1}; Cost of blended NPSB fertilizer =14 ETB kg^{-1}; Cost of Urea (N-source) fertilizer = 12 ETB kg^{-1}, Labor cost for fertilizer application=5 persons ha^{-1}, each at 55 ETB day^{-1}.

5. SUMMARY AND CONCLUSION

Tef is one of the major staple and strategic food security crop in Ethiopia. However, tef yield in Ethiopia and the study zone are low as compared to the attainable yield because tef production is constrained by both biotic and abiotic factors such as diseases, insect pests, poor management practices, moisture stress, low soil fertility etc. Thus, addition of nutrients such N, P, S and B use of proper seed rates with important management practices to increase the productivity of tef. Thus, the present study was conducted to assess the effect of rates of seed and blended fertilizer (NPSB) on growth, yield components and yield of tef and to identify economically feasible rates of seed and blended NPSB in the study area.

Tef variety “Quncho (DZ-Cr-387 RIL355)” which was released by Debra Zeit Agricultural Research Center (DZARC) in 2006 cropping season was used as experimental material. Three level of tef seeding rates (3, 5 and 7 kg ha^{-1}) and five levels of blended NPSB (0, 50,100, 150, 200 kg ha^{-1}) fertilizer and 100 kg of urea ha^{-1} were used as treatments. The experiment was tested in factorial arrangement in randomized complete block design with three replications. The experiment was conducted at Semen Wagebeta Kebele Farmers’ Training Centre (FTC), in Duna District, Hadiya Zone, southern Ethiopia, during 2019 main cropping season.

Analysis of the results revealed that the dry biomass yield were significantly ($P < 0.01$) affected by main effect of NPSB as well as effect of seed rate on panicle length. However, days to heading, days to 90% physiological maturity, plant height and culm length were affected by main effects of blended NPSB fertilizer and seed rate. The highest total dry biomass yield (7885 kg ha^{-1}), panicle length (42.29 cm), was recorded at NPSB rate of 200 kg ha^{-1}. The maximum days of heading (63.56), days to 90% physiological maturity (103.56 days) were recorded at control NPSB, plant height (102.01 cm) and culm length (68.91 cm) were recorded at 200 NPSB and 150 NPSB kg ha^{-1}, respectively. On the other hand, the lowest total dry biomass yield (6200 kg ha^{-1}), panicle length (35.79 cm), were recorded at controlled level of NPSB rate. The minimum days of heading (52.22), days to 90% physiological maturity (92.89 days) were recorded at 200 NPSB, plant height (98.56 cm) and culm length (50.72 cm) were recorded at controlled NPSB kg ha^{-1}.

With regards to the effect of seed rate, highest total dry biomass yield (7773 kg ha^{-1}), panicle length (42.73 cm), was recorded at rate of 7, 3, kg ha^{-1} respectively. On the other hand, the lowest total dry biomass yield (6641 kg ha^{-1}), panicle length (39.23 cm), were recorded from 3 and 7 kg ha^{-1} seed rates respectively. While, maximum days of heading (63.53), days to 90% physiological maturity (102.73 days), plant height (103.26 cm) and culm length (67.49 cm) were recorded at 3, 3, 7 and 3 kg ha^{-1}, respectively, while the minimum day of heading (55.00), days to 90% physiological maturity (91.87 days), plant height (92.71 cm) and culm length (50.55) were recorded at NPSB rate of 0 and 7, 7, 3, and 7 kg ha^{-1}, of seed rates respectively. Generally, day of heading, days to 90% maturity, culm length and panicle length decrease while, plant height, total dry biomass increased with increasing seed rate.

The interaction of the two NPSB and seed rates also significantly affected grain yield, number of total tillers, number of productive tillers, straw yield and lodging percent. The highest grain yield (2975 kg ha^{-1}), number of total tillers (21.13 m^{-2}), number of productive tillers (20.13 m^{-2}), straw yield (6192 kg ha^{-1}) and lodging percent (74.33%) were recorded at combination of the highest rates of 200 kg NPSB fertilizer with 7 kg seed rate ha^{-1} while, highest grain yield were recorded at combination of 200 kg ha^{-1} NPSB fertilizer with 5 kg ha^{-1} .In contrast, the minimum grain yield (1875 kg ha^{-1}), number of total tillers (7.17 m^{-2}), number of productive tillers (6.01 m^{-2}), straw yield (3472 kg ha^{-1}) and lodging percent (19.67%) were recorded at combination of the zero level of NPSB fertilizer with seed rate 3 kg ha^{-1}.

The partial budget analysis revealed that combined applications of 200 kg blended NPSB fertilizer with seed rate of 5 kg ha^{-1} gave higher net benefit of 58882.85 Birr ha^{-1} with MRR of 1449.01% which is above the acceptable minimum range of MRR 100%, while the lowest net returns (40222.29 ETB ha^{-1}) was recorded with zero blended NPSB rate and 3 kg seed rate ha^{-1}. Therefore, from the result of present study that the application of the 200 kg ha^{-1} blended NPSB fertilizer in addition 100 kg N ha^{-1} with 5 kg ha^{-1} seed rate can be tentatively recommended for farmers for production of tef in the study area and other areas with similar agro-ecological conditions. However, since the experiment was conducted for one season at one location, it is suggested that the experiment has to be repeated over seasons and locations using this and other improved tef varieties in order to give a comprehensive recommendation.

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7. APPENDICES

Appendix Table 1. Mean monthly annual total rainfall and minimum and maximum temperatures of ten years (2009-2019); mean monthly minimum and maximum temperatures and total rainfall recorded in the experimental area during the experimental year of test crop (January 2019- November 2019)

	2009-2018 Meteorological Data			2019 Meteorological Data			
Months	Total rainfall (mm)	Min. Temp. (ºC)	Max. Temp. (ºC)	Total rain fall (mm)	Maxim umTem p. (ºC)	Minimum Temp.(ºC)	Average Temp. (ºC)
January	19.52	9.33	24.75	0.0	24.8	9.9	17.4
February	26.54	10.61	25.28	10.0	25.0	12.3	18.7
March	83.1	12.1	25.68	92.5	24.6	13.2	18.9
April	114.8	12.13	24.45	153.5	23.1	13.3	18.2
May	162.04	11.68	23.69	155.5	22.3	12.2	17.3
June	141.03	11.29	21.85	177.7	20.3	12.8	16.6
July	175.83	11.38	20.5	245.5	19.2	11.3	15.3
August	201.5	11.31	20.13	230.4	17.1	12.1	14.6
September	205.5	11.1	21.38	165.5	18.5	12.2	15.4
October	56.3	10.83	23.26	38.6	20.1	11.9	16.0
November	38	10.44	23.9	82.6	21.0	11.3	16.2
December	5.9	8.6	24.23	24.4	22.0	10.4	16.1
Total	1170.7			1376.2	258.0	142.9	200.5
Average	97.5	10.9	23.26	114.6	21.5	11.9	16.7

Source: National Meteorological Agency, Hawassa Branch (2019)

Appendix Table 2. Mean squares of ANOVA for day to heading (DH), physiological maturity (DPM) and grain filling (GF) of tef as affected by blended NPSB and seed rate

		Mean squares		
Source of variation	D.F	DH	DPM	DGF
Block	2	8.6	5.9	9.8
Blended NPSB	4	58.8^{**}	156.7^{**}	19.6^{*}
Seed rate (SR)	2	273.1^{**}	442.8^{**}	29.4^{*}
NPSBXSR	8	3.3^{NS}	4.96^{NS}	4.34^{NS}
Error	28	1.81	3.55	6.7
CV(%(		1.3	0.6	2.1

Where, D.F= degree of freedom, DH= Days to heading, DPM= Days to physiological maturity, DGF= Days of grain filling, ANOVA =Analysis of variance; NS= non-significant difference; ** and * significant at 1% and 5% level of significant, respectively.

Appendix Table 3. Mean squares of ANOVA for plant height, culm length and panicle length of tef as affected by blended NPSB and seed rate

		Mean squares		
Source of variation	DF	Plant height (cm)	Culm length (cm)	Panicle length (cm)
Block	2	3.8	9.96	5.31
Blended NPSB	4	393.11^{**}	178.45^{**}	29.98^{*}
Seed rate (SR)	2	342.34^{**}	996.72^{**}	244.82^{**}
NPSBXSR	8	10.35^{NS}	27.87^{NS}	5.3^{NS}
Error	28	19.84	26.19	3.6
CV		0.5	1.4	1.5

Where; ANOVA =Analysis of variance ** =highly significant and *=significant at 5% significance level, NS=none significant at 5% significance level and DF=degree of freedom.

Appendix Table 4. Mean squares ANOVA for numbers of total tiller, productive and non-productive tillers of tef as influenced by Blended NPSB and Seed rates

	DF	Mean squares		
Source of variation		Total tillers	Productive tillers	Non- productive tillers
Block	2	6.25	5.05	0.53
Blended NPSB	4	116.88^{**}	116.34^{**}	0.23^{NS}
Seed rate (SR)	2	113.85^{**}	130.91^{**}	0.15^{NS}
NPSBXSR	8	1.76^{**}	2.15^{**}	0.35^{NS}
Error	28	0.36	0.41	0.19
CV		4.6	4.4	10.9

Where; ANOVA =Analysis of variance ** =highly significant and *=significant at 5% significance level, NS=non significant at 5% significance level and DF=degree of freedom.

Appendix Table 5. Mean square ANOVA for panicle weight (PW), grain per panicle weight (GPW) lodging percentage (LGP) and thousand grain weight (TGW) of tef as affected by Blended NPSB fertilizer and seed rates

		Mean squares			
Source of variation	DF	PW (g)	GPW (g)	LGP	TGY(g)
Block	2	5.3	3.37	653.63	0.00018
Blended NPSB	4	29.98^{*}	0.63^{NS}	916.1^{**}	0.00096^{*}
Seed rate (SR)	2	244.82^{**}	20.86^{NS}	3128.9^{**}	0.00048^{NS}
NPSBXSR	8	5.3^{NS}	0.095^{NS}	98.1^{**}	0.00039^{NS}
Error	28	3.5	0.26	25.97	0.00031
CV		11.3	4.6	16.2	2.1

Where; ANOVA =Analysis of variance ** =highly significant and *=significant at 5% significance level, NS=none significant at 5% significance level and DF=degree of freedom

Appendix Table 6. Mean squares of ANOVA for aboveground dry biomass (AGB), grain yield (GY), straw yield (SY) and harvest index (HI) of bread wheat as affected by blended NPSB fertilizer and seed rate

		Mean squares			
Source of variation	DF	AGB	GY	SY	HI
Block	2	245354	156268	185248	43.79
Blended NPS	4	3647195**	270615**	125531**	23.63*
Seed rate (SR)	2	2760001*	1071143**	10710379 **	45.65*
NPSXSR	8	349578NS	12648**	130189*	2.33
Error	28	500552	18253	219798	6.97
CV		1.7	4.2	2.3	5.2

Where, D.F = degree of freedom, ANOVA =Analysis of variance; CV = coefficient of variation, NS = non-significant, **= highly significant, * = significant, different at 5% and 1%, respectively.

Testimonial letter

Date :September 14, 2020

To: School of Plant Sciences

Subject: **Graduate Student Adane Lambore**

I hereby certify that I have read and evaluated the thesis entitled "**Effect of Seed and Blended Fertilizer (NPSB) Rates on Yield and Yield Components of Tef (*Eragrostis tef /Zucc*./Trotter) in Duna District, Southern Ethiopia**" prepared under my guidance by Adane Lambore. I recommend that the thesis be submitted as fulfilling the thesis requirement for Master of Science degree in Agronomy and thus kindly request the school to make further academic scrutiny for the thesis defense.

The signed copy of this letter is deposited in the School.

With regards,

Yibekal Alemayehu (PhD)

Adviser

CC.

- **Mr. Adane Lambore**

September 6, 2020

To: The Chairman of SGS, of School of Plant Sciences

From: Jemal Abdulahi (PhD)

Co- advisor to an M.Sc. Thesis research

Subject: **Graduate Student Adane Lambore**

I kindly would like to remind you that I was a Co- advisor to an M.Sc. Thesis research of graduate student Adane Lambore entitled "**Effect of seed and blended fertilizer (NPSB) rates on yield and yield components of tef (*Eragrostis tef* /zucc./trotter) at Duna District, southern Ethiopia".**

I have read the thesis and found it is up to the mark.

Therefore, this is, to kindly request the SGC to allow him defend his thesis for the upcoming open Thesis defense examination.

With high regards,

CC

Mr Adane Lambore