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Effects of Nitrogen and Blended Fertilizers on Yield and Yield Components of tef [(*Eragrostis tef (Zucc*.) Trotter] in Central Highlands of Ethiopia

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ABSTRACT
Tef is a highly valued crop in the national diet of Ethiopians and the major crops grown in central highlands of Ethiopia. However, its productivity is constrained by low plant-available soil nutrients due to depleting soil organic matter content and long history of intensive cultivation. Therefore, a field experiment was carried out at Debrezeit agricultural research center in Ada'a district during the 2017 main cropping season with the objective of to assessing the effect of N and blended (NPSZnB) fertilizers on yield and yield components of tef, nutrient uptake and verifying economically feasible rates of N and blended NPSZnB fertilizers for high yield of tef production. The experiment consisted four levels of nitrogen (0, 46, 92 and 138 kg N ha^{-1}) and five levels of blended (0, 100, 150, 200 and 250 kg NPSZnB ha^{-1}) in factorial combinations using Kora tef variety as a test crop. The experiment was laid out in RCBD with three replication. The result revealed that the main effects of N rates were significant (P<0.01) in terms of total number of tillers, aboveground dry biomass and lodging index. The highest values were recorded at the rate of 138 kg N ha^{-1}. Similarly, the main effect of blended fertilizer was highly significantly (P<0.01) on aboveground dry biomass yield and straw yield, where by the highest value were recorded at the rate of 250 kg NPSZnB ha^{-1}. The interaction of N and blended fertilizer significantly (P<0.05) affected plant height, effective tillers, harvest index and days to heading. The highest plant height, effective tillers ,harvest index and days to heading were obtained at combined application of 138 kg N ha^{-1} and 200 kg NPSZnB ha^{-1}, 46 kg N ha^{-1} and 150 kg NPSZnB ha^{-1} 92 N kg ha^{-1} and 100 kg NPSZnB ha^{-1} ,and un-fertilized plot, respectively . The interaction also significantly (P<0.01) affected grain yield and the maximum (2002.5 kg ha^{-1}) was obtained at combined application of 92 kg N and 100 kg NPSZnB ha^{-1},Moreover, N,S,Zn and B uptake in grain and straw were significantly affected by the interaction of N and blended fertilizers rate. The highest N, Zn and Boron uptake in grain were obtained at the combined application of 92kg N and 100 kg NPSZnB ha^{-1} fertilizer rates. The post-harvest soil analytical result showed insignificant (P>0.05) influence of the fertilizers, except for the available Zn. Applying 100 kg blended NPSZnB ha^{-1} supplemented with 92 kg N ha^{-1} had the highest net benefit, relatively low variable cost together with highest and acceptable MRR for tef production in Ada'a district. However, since the experiment was conducted only for one season and one site, repeating the trial at different sites as well as on the same trial site would be important to draw sound recommendation.
Keywords: Blended fertilizer, Nitrogen, Nutrient uptake, Yield.

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1. INTRODUCTION

Tef is the only cereal crop member of the tribe Eragrostidae and genus Eragrostis which contains about 350 species Tef (Eragrostis tef /Zucc./Trotter) belonging to the grass family poaceae, is a C4, self-pollinated annual grass, 40– 80 cm tall **(Dejene & Lemlem, 2012).** It is believed to have been originated in Ethiopia between 4000 and 1000 BC **(Vavilov, 1951).**

Tef has as more food value than the major grains; like wheat, barley and maize. This is probably because it is always eaten in the whole grain form. The germ and bran are consumed along with the endosperm **(Demeke and Marcantonio, 2013).** In Ethiopia, Tef is a high value crop and it is primarily grown for its grain that is used for preparing injera (leavened bread), which is a staple and very popular food in the national diet of most Ethiopians. The vitamin content seems to be about average for a cereal. The level of minerals is also good. **Seyfu (1997)** reported that tef is predominantly grown in Ethiopia as a cereal crop and not as a forage crop. However, when grown as a cereal, farmers highly value the straw of tef and it is stored and used as a very important source of animal feed, especially during the dry season. Farmers feed tef straw preferentially to lactating cows and working oxen. Cattle prefer tef straw over other cereal straw and for this reason, its price is higher than that of other cereals.

Tef growing area occupies about (50,204,400.47 *ha*) of the total acreage of all the major cereals grown in Ethiopia **(CSA, 2017).** In Ethiopia, tef is mainly produced in Amhara and Oromia, with smaller quantities in the Tigray and SNNP regions. In Oromia Regional State of Ethiopia the major tef producing zones include the East Shoa, West Shoa, South West Shoa, North Shoa, East Wallega, Horo Guduroo Wallega, Jimma, Illubabor and Arsi are Potential area for tef production (**CSA, 2012).**

Tef in Oromia regional state of Ethiopia, where the current study was conducted, occupies about 1,441,029.78 ha of land annually with estimated production of 24,737,963.79 quintals **(CSA, 2017).**The average yield of tef in the region is also high (1.72 t ha^{-1}), compared to the national (1.66 t ha^{-1}). But still tef is low in productivity compared to the potential yield. These are due to lack of adequate synthetic-fertilizer input, limited return of organic residues and manure, and high biomass removal, erosion, and leaching rates.

Nitrogen is deficient in almost all soils and phosphorus (P) is also deficient in about 70% of the Ethiopia soils **(Tekalign *et al*., 2001).** Low availability of nitrogen and phosphorus has been demonstrated to be major constraint to cereal production due to soil erosion, intensive, unbalanced nutrient supply cultivation, low organic matter and absence of nutrient recycling. On the other hand, most of the area used for production of grains, especially tef, wheat and barley fall under the low fertility soils **(Hurni and Bruno 1990).**

The drive for higher agricultural production without balanced use of fertilizers created problems of soil fertility exhaustion and plant nutrient imbalances not only of major, but also of secondary and micronutrients **(Patel and Singh, 2009).** Previously, only nitrogen (N) and phosphorus (P) were considered to be the limiting nutrients in Vertisols of Ethiopia **(Tekalign *et al*., 2001)**. However, the results of national soil fertility mapping initiative indicated that other nutrients including K, S, Fe, Zn and B are also found to be deficient in these soils **(ATA, 2014)**

Nutrient mining due to sub optimal fertilizer use in one hand and unbalanced fertilizer uses on other have favored the emergence of multi nutrient deficiency in Ethiopian soils that in part may contributed to fertilizer factor productivity decline experienced over recent past **(Wassie and Shiferaw, 2011)**. Different research reports indicate that nutrients like K, S, Ca, Mg and all micro-nutrients except Fe are becoming depleted and deficiency symptoms are being observed on major crops in different areas of the country **(Asgelil *et al*., 2007 ; Wassie and Shiferaw, 2011).** 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, while some soils are also deficient in potassium, copper, manganese and iron, which all potentially hold back crop productivity despite continued use of N and P fertilizer as per the blanket recommendation.

Soil micronutrient deficiencies limit crop productivity and nutritional quality, which together may affect human health **(Alloway, 2008).** Insufficient micronutrient availability in soils in Ethiopia not only causes low crop productivity, but also poor nutritional quality of the crops.

Nutrients such as S, Zn, and B can often be included relatively cheaply in new fertilizer formula, when targeted to deficient soils; these nutrients can dramatically improve fertilizer-use efficiency and crop profitability **(John *et al*., 2000).** Balanced fertilizers containing N, P, K, S, B and Zn in blend form are recommended ameliorating site specific nutrient deficiencies and thereby increasing productivity **(ATA, 2014).** The need for site-specific fertilizer prescriptions is increasingly apparent, however, fertilizer trials involving multi-nutrient blends that include micronutrients are rare in Ethiopian context. Although there is general perception that the new fertilizer blends are better than the traditional fertilizer recommendation (urea and DAP), their comparative advantages are not explicitly examined and understood under various production environments.

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, Zn, B, etc.) makes little sense and, in fact, becomes counterproductive by reducing the efficiency of the nutrients that are applied **(FAO 2000).** Blended fertilizer and urea are customized to specific type of soils and crops as well. This helps to feed crops that Urea and DAP have not managed to nourish. Application of balanced fertilizers could be the basis to produce more crop output from existing land under cultivation and nutrient needs of crops according to their physiological requirements and expected yields **(Ryan, 2008).** Balanced fertilization not only guarantees optimal crop production, better food quality and benefits for the growers, but is also the best solution for minimizing the risk of nutrient losses to the environment. Based on the **EthioSIS (2014)** map of blended fertilizers containing N, P, S, Zn and B in blend were identified as deficient nutrients to *Ada'a* woreda of its surrounding village. However, the current blended fertilizer contain small amount of nitrogen as compared to the recommended nitrogen fertilizer rate for economical tef production.

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

- To know the interaction effects of N and blended fertilizer on growth, yield, yield components and nutrient uptake of tef
- To determine economically optimum N and blended fertilizer application rate for high grain yield of tef

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The field experiment was conducted during the 2017 cropping season at Debrezeit Agricultural Research Center (DZARC) located in Central highland of Ethiopia. The experimental site is located at latitude 08° 44' North and longtude 38°58' East, with an altitude of 1900 m above sea level. It is located at 47 km away from Addis Ababa on the road to Adama.

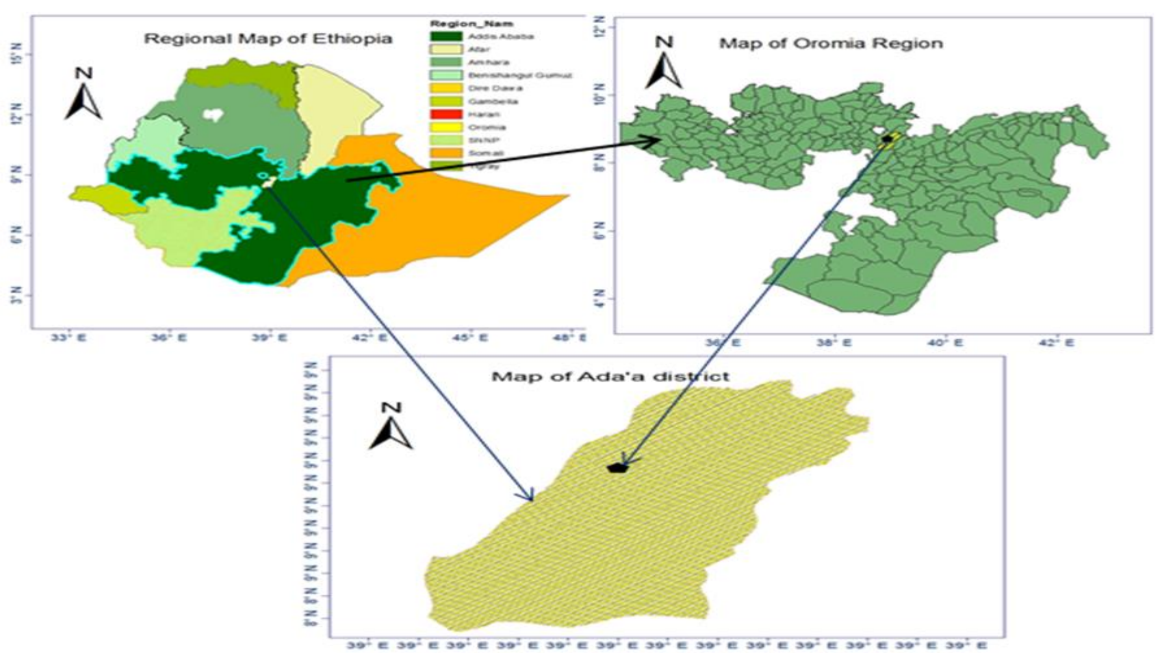

Figure 1. Map of the study area **(DZARC, 2017)**

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Data on rainfall, maximum and minimum temperatures during the experimental season and long-term average are given in the (Appendix 5). The rainfall distribution from August to December 2017 was 334 mm with an annual rainfall of 824.6 mm with an annual maximum and minimum temperature of 26.68 and 11.93 ^oC, respectively. The minimum and maximum temperatures and average rainfall of the cropping season were in line with 10 years average. The experimental site had a previous cropping history of cereals such as wheat and tef.

2.2. Experimental Materials

The seed of tef variety named 'Kora' from Debre Zeit Agricultural Research Center, which was reported to have a grain yield potential under farmer field condition of (2- 2.8) t ha^{-1} under rain-fed condition, was used for this study **(Kebebew *et al*.,2017).**

2.3. Experimental Design and Treatments

The treatments of the field experiment consisted five blended fertilizer (NPSZnB) levels (0, 100, 150, 200 and 250 kg ha^{-1}) and four urea (N) levels (0, 46, 92 and 138 kg ha^{-1}). The blended fertilizer (NPSZnB) with the formula (17.8N, 35.7P_2O_5, 7.7S, 2.2Zn, 0.1B) kg ha^{-1} used in this experiment was selected based on the soil information data of ETHioSIS map. The experiment was laid out in a factorial randomized complete block design with three replicate plots. The total treatments were twenty per replication. Each plot had an area of 3m X 4m (12 m^2) with thirteen rows. Spacing between blocks, plots and rows were 1m, 0.5m, and 15cm, respectively. Blended fertilizer was applied at planting and the N fertilizer (urea) was applied by splitting the dose into two, half at planting and the remaining half at mid-tillering. All agronomic practices were applied as per the recommendation.

2.4. Collection, Preparation and Analysis of Soil Samples

Prior to planting and fertilizer application, 20 random soil samples were collected from 0-20 cm depth using a soil auger from the entire experimental plots. Samples were thoroughly mixed and pooled. The composite soil sample was air dried in the laboratory, and sieved (2.0 mm) for analysis of soil texture, soil pH, OC, CEC, total N, available P, K, S, and micro nutrient (B and Zn). Soil analyses were carried out at DZARC, Horticop and Hawassa University. Similarly, after harvest, soil samples were also collected from each experimental plot for chemical analysis of the same parameters indicated above. Plant straw and grain samples were also collected and analyzed for N, P, S, Zn and B.

Particle size distribution (soil texture) was determined in the laboratory by the Bouyoucos hydrometer method (Bouyoucos, 1962) using sodium hexametaphasphate as dispersing agent. Soil textural class names were assigned based on the relative contents of the percent sand, silt, and clay separates using the soil textural triangle of the USDA.

Total nitrogen content was determined following the Kjeldahal method as described by Jackson (1958). Soil samples weighing 0.5-1 gm (according to the organic matter content) that passes through a 0.5 mm sieve were used. The samples were digested by 7 mL of concentrated H_2SO_4 for 3 hour, distilled and back titrated with 0.1 N of standard H_2SO_4 (Sahlemedhin and Taye, 2000).

The available phosphorus content of the soil was analyzed using 0.5M sodium bicarbonate extraction solution (pH 8.5) following the method of Olsen (Olsen *et al.*, 1954). Five grams of soil samples was shaken with 100 mL of 0.5M sodium bicarbonate extracting solution for 30 minutes and filtered. Three ml of the filtrate was mixed with 3 mL of mixed reagent and after the solution developed color determination by spectrophotometer at 882 nm wavelength.

The organic carbon determinations were made following the wet oxidation method of Walkley and Black (1934). The OM in one gram of soil previously grounded to pass 0.5 mm was oxidized by excess potassium dichromate in sulfuric acid (96 %) solution. The excess dichromate was titrated with 0.5 N ferrous sulphate after addition of water, phosphoric acid (85 %) and diphenylamine indicator. The OC content was calculated against the blank. CEC was determined by 1M buffered ammonium acetate extraction method and distillation of the ammonium saturated soil in a kjeldahl distillation apparatus while receiving the distillate in boric acid and then titrating with sulfuric acid (Chapman, 1965). The soil pH was measured using a glass combination pH meter in the supernatant solution of 1:2.5 soils to water solution ratio (FAO, 2008).

Available (S, B, & Zn) and exchangeable (K) of the soils were extracted by Mehlich-III multi-nutrient extraction method (Mehlich,1984) and were measured with their respective wave length range by Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) at Horticoop PLC Soil and Water Analysis Laboratory, Debre Zeit, Ethiopia.

2.5. Plant Tissue Analyses

Plants sampled for yield components at harvest were partitioned into straw and grains for the determination of total N, P, S, Zn and Boron contents in straw and grains using standard procedures. Both the grain and straw plant parts were air dried to a constant weight.

2.5.1. Determination of N Contents in Grain and Straw

The nitrogen content was determined using micro-Kjeldahl Method (Bremner and Mulvarey, 1982). About 0.3 g of grain samples and 0.30 g of straw were taken for analysis. N uptake in the grain was determined after multiplying nitrogen content of the grain by grain yield, and straw nitrogen uptake was also determined by multiplying nitrogen content of the straw by the straw yield (Hussain *et al*., 2011).

GNU (kg ha^{-1}) =GNU (%) x GY (kg ha^{-1})

Where, GNU = Grain nitrogen uptake

GY= Grain yield

GNC = Grain nitrogen concentration

GDW = Grain dry weight

SNU (kg ha^{-1}) = STNC (%) X STDW (kg ha^{-1})

Where, STNU = Straw nitrogen uptake

STNC = Straw nitrogen concentration

STDW = Straw dry yield

2.5.2. Determination of P Contents in Grain and Straw

The plant sample analysis for P was done at physiological maturity, for this,0.3 g of finely-ground tef was weighed and digested with a 2:1 mixture of nitric (HNO3) and perchloric acids (HC1O4).

The phosphorus in the solution was determined colorimetrically using molybdate and metavanadate for color development (Sahlemedehen & Taye, 2000). The reading was made at 460nm wavelength

2.5.3. Determination of S Contents in Grain and Straw

Available S extraction was done with 0.15 % $CaCl_2.2H_2O$ and measurement of sulfate concentration in the extracts by a turbidimeteric producers using barium chloride (FAO, 2008). Sulfur in grain and straw was determined turbidi-metrically using a spectrophotometer by di-acid (HNO_3–$HClO_4$) digestion as stated in FAO guide to laboratory establishment for plant nutrient analysis (FAO, 2008). Sulfur uptake in grain and straw was determined from the sulfur content of the respective parts after multiplying with the grain yield and straw yield, respectively (Hussain *et al*., 2011).

$\text{SSU (kg ha}^{-1}) = \text{SSC (\%) x SDW (kg ha}^{-1})$

Where, SSU = grain sulfur uptake

GSC=grain sulfur concentration

GDW = Grain dry weight

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$$\text{STSU (kg ha}^{-1}) = \text{STSC (\%) x STDW (kg ha}^{-1})$$

Where, STSU = Straw sulfur uptake

STSC = Straw sulfur concentration

STDW = above ground yield (Straw dry weight)

2.5.4. Determination of Zn & B Contents in Grain and Straw

For the determination of Zn and B concentrations in grains and straw, part of the sample digest was done by the wet digestion method.

Total Zinc was determined by DTPA (dietylene triamine penta acetatic acid) method (Lindsay and Norvell, 1978). The content of boron in sample digest used for macronutrient analysis used for B & the extract, B analyzed by colorimetric methods and subsequent measurement of B by colorimetry using Azomethine-H (Bingham, 1982). Boron and Zinc uptakes by grain and straw were also determined from the (B and Zn) contents of respective plant part after multiplying the respective concentrations by the grain yield and straw yield, respectively.

2.6. Plant Data Collection and Measurements

2.6.1. Phenologic data

Days to 50% panicle emergence (DPE): It is the number of days from emergence to heading of 50% of the plants in each plot. It was recorded by counting the number of days from emergence to heading (when 50% of the plants started to form panicles). Visual observation was used to determine heading of the plants.

Days to 90% physiological maturity (DTPM): Days to physiological maturity was determined as the number of days from emergence to 90% maturity based on visual observation, which was indicated by senescence of the leaves as well as free threshing of seeds from the glumes when pressed by thumb and the forefinger.

2.6.2. Growth parameters, yield and yield components

Plant height (PH): Plant height was measured at heading and physiological maturity from the ground level to the tip of panicle from ten randomly selected plants in each plot.

Panicle length (PL): is length of the panicle from the node, where the first panicle branches start, to the tip of the panicle as the average of ten selected plants per plot.

Total number of tillers: It was determine by counting the total number of tillers from pre-tagged ten plants from the net plot area.

Number of effective tillers (NET): The number of tillers was determined by counting the tillers. This had a panicle from the above pre tagged plants.

Biomass yield (BY): At maturity, the whole plant biomass including, leaves, stems, seeds etc. were harvested from the net plot area and air-dried, after which the weight were recorded.

Grain yield (GY): Grain yield was measured by harvesting the crop from the net middle plot area of 2 x 2m to avoid edge effects.

Harvest index (HI): Harvest index were calculated by dividing grain yield by the total above ground biomass yield.

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

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percentage were subjected to arcsine transformation described for percentage data by Gomez and Gomez (1984).

2.7. Statistical Analysis

All data obtained were analyzed using SAS (Statistical Analysis System) version 9.4 following the appropriate Procedures of RCBD as stated by Gomez and Gomez (1984) for a factorial experiment. Analysis of variance (ANOVA) was done to test the significance levels of variables, and Least Significant Difference (LSD) was used to separate treatment means at $p \leq 0.05\%$ (SAS Institute Inc., 2012).

2.8. Partial Budget Analysis

The economic analysis was performed to investigate the economic feasibility of the treatments. Partial budget, dominance and marginal were used. The average yield was adjusted downwards to reflect the difference between the experimental plot yield and the yield farmers expected from the same treatment. The average open market price (Birr kg^{-1}) for tef and the official prices of blended and N fertilizers were used for analysis. Labor costs involved for application of blended (NPSZnB) and N fertilizers were recorded and used for analysis. The days required to apply 100 kilograms of fertilizer was 3.2 man day with a rate of 34 birr per person. The current price of grain and straw yields of tef were valued at an average open market price at Debre Zeit, which were 22.50 ETB kg^{-1} and 2.65 ETB kg^{-1}, respectively.

The dominance analysis procedure as detailed in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The selected and rejected treatments using this technique are referred to as un-dominated and dominated treatments, respectively. The un-dominated treatments were ranked from the lowest (the farmers' practice) to the highest cost treatment. For each pair of ranked treatments, a % marginal rate of return (MRR) was calculated. The % MRR between any pair of un-dominated treatments denotes the return per unit of investment in fertilizer expressed as a percentage.

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3. RESULTS AND DISCUSSION

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

The results indicated that the soil texture was clayey (sand 9.38 %, silt 25.95% and clay 64.67%) with a neutral pH 6.73 Murphy (1968), The organic carbon content of the soil was 1.2% and the soil contained total N of 0.09%, available P (Olsen) of 12.74 mg kg^{-1} soil, available sulfur of 4.19 mg kg^{-1}, available zinc of 0.63 mg kg^{-1}, available boron 0.9 mg kg^{-1} and CEC of 55.22 cmol kg^{-1} soil (Table 1).

As per the ratings for Ethiopian soils by Murphy (1968), the pH of the experimental soil was within the range for productive soils. In accordance with Tekalign (1991), the organic carbon content and total nitrogen could be rated as low. According to Landon (1991) the CEC value of greater than 40 cmol kg^{-1} showing that the CEC value of the experimental soil was very high. Similarly, based on Olsen, *et al*. (1954), the P rating (mg kg^{-1}), available P content of the study was in the medium range.

Table 1: Selected Physico-chemical characteristics of the experimental soil before planting

Parameter	
Physical properties	Values
Texture Clay (%)	64.67
Silt (%)	25.95
Sand (%)	9.38
Textural class	Clay
Chemical properties	
pH	6.73
Total Nitrogen (%)	0.09
Available Phosphorus (mg kg^{-1})	12.74

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Available potassium (mg kg $^{-1}$)	510.15
Available Sulfur (mg kg $^{-1}$)	4.19
Available Zinc (mg kg $^{-1}$)	0.63
Available Boron (mg kg $^{-1}$)	0.9
Organic carbon (%)	1.2
CEC [Cmol (+)/kg)]	55.22

3.2. Effect of N and Blended Fertilizers on Soil Chemical Properties at Harvest

Soil pH, organic matter, CEC, available P, total N, Available Zn and available boron were measured to assess the postharvest status of the soil.

3.2.1. Soil pH

The analysis of variance showed that there were non-significant differences in soil pH values due to blended and N rates and their interactions. The soil pH was ranged from 6.78 to 6.92 across the whole experimental plots (Table 2), showing that application of N and blended fertilizer residuals did not influence the soil pH significantly. These may be due a one year fertilizer filed experiments, which may not influence soil pH.

3.2.2. Soil organic matter

Soil OM arises from the debris of green plants, animal residues and excreta that are deposited on the surface and mixed to a variable extent with the mineral component (White, 1997). According to Tekalign (1991), the entire plots had low OM content (Table 2). This is because of continuous cultivation without returning residue to the soil. Similarly, Fassil and Charles, (2009) reported that Vertisols of Ethiopia had low soil OM content. Other authors also reported low soil OM in Vertisols **(Giday et al., 2015).**

3.2.3. Cation exchange capacity

Cation exchange capacity (CEC) is also 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. It is also a major controlling agent of stability of soil structure, nutrient availability for plant growth, soil pH, and the soil's reaction to fertilizers and other ameliorants.
The analysis of variance showed non-significant differences (P>0.05) in CEC values among the blended and N fertilizer rates and their interactions (Appendix 1). Results showed that the cation exchange capacity of the whole experimental plots ranged from 44.89 - 51.85 cmol (+) kg^{-1} (Table 3). Landon (1991) classified CEC of <6, 6-12, 12-25, 25-40, >40 cmol (+) kg^{-1} very low, low, moderate, high and very high. Therefore, the CEC of the whole experimental plots could be rated as very high. However, the value of CEC was inconsistent with rate of both fertilizers types. The result is within the range reported by **Berhanu (1985),** which indicate CEC of 35-70 meq/100 g soil for nearly all the Vertisols of Ethiopia.

3.2.4. Total nitrogen

Total nitrogen measures the total amount of nitrogen present in the soil, much of which is held in organic matter. There was non-significant difference (P>0.05) in total nitrogen due to both the main and interaction effects with respect to total soil nitrogen at harvesting (Appendix 1).

Total N content of the soil, analyzed from composite samples per treatment tended to remain almost the same irrespective of different rates of N and blended fertilizer application. Total N content of the soil before planting was (0.095%) and it was ranged from 0.065 to 0.11% at harvest (Table 2). Similar values before planting and at harvest may be due leaching or de-nitrification soon after application (very volatile in nature), high uptake of N, mobility of N in soil, particularly due to high rainfall recorded during the cropping season. According to EthioSIS (2013) the optimum N level needed for crop production under most soils of Ethiopia is reported to be <0.2 % . The soil of the experimental site had low nitrogen and requires nitrogen application as tef is highly exhaustive crops for nitrogen and the production potential of them was highly affected by N deficiency. The result was in line with Tekalign Tadesse (1991) who classified soils based on their N content. Masresha (2014) also reported low amount of N content in soils which are cultivated repeatedly, due to N leaching and N mining. Most Ethiopian black soils are N-depleted and more than 50% of cultivated lands are N-responsive soils (Yihenew, 2002).

3.2.5. Available phosphorus

Post-harvest analysis of available phosphorus values were not significantly different (P>0.05) due to the main effects of nitrogen and blended fertilizer rates as well as their interaction effects (Appendix 1).

Available P contents of the experimental soil after harvest of the entire treatments were above the critical level except for the control plots. The highest mean value of available P (15.68 kg

P2O5 ha^{-1}) was obtained from 46 kg N ha^{-1} and the least (14.21 kg P_2O_5 ha^{-1}) was recorded from control plots. In addition, the residual P values due to the main effect of blended fertilizer almost similar. However, numerically the highest mean value (16.15 mg P_2O_5 kg^{-1}) was obtained from 100 kg ha^{-1} blended fertilizer followed by 250 kg ha^{-1}.While; the lowest (14.41 mg P_2O_5 kg^{-1}) was obtained from the control plots (Table 2). The value of available P before planting was lower as compared to the values at harvest. This implies that available P levels in plots that received P fertilizer were slightly higher than that of control (non-P). **EthioSIS (2014)** suggest optimum P content for most Ethiopian soil as 15 mg kg^{-1}. Based on this, the available phosphorous of the study area is optimum. This may be due to long term P fertilizer application.

3.2.6. Available Sulfur

The analysis of variance showed that available sulfur was not significantly (P>0.05) affected by both the main and interaction effects of blended and N fertilizer rates (Appendix 1).

Due to the main effect of blended fertilizer, numerically maximum residual was obtained from the highest rate (19.25 kg SO_4-S) of sulfur containing blended fertilizer. However, even by application of sulfur containing fertilizer, the value of residual available S was below the critical level. This may be due low initial sulfur and higher uptakes in grain and straw of tef. Based on Hariram and Dwivedi, (1994) soil classification for Sulfur values lies on very low range. The classification is <9 very low, 10-20 low, 20-80 optimum, and > 80 mg kg^{-1} high. So addition of fertilizer containing S is relevant. This low in sulfur content of the soil may be due to loss of organic matter, less sulfur deposition from the atmosphere and lacking of using S source mineral

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fertilizer. It was also related to continuous cultivation, which results in intensive mining of S from soil. This is similar with the report of Hillette (2015) which indicates soils around Bishoftu were deficient in sulfur content.

3.2.7. Available boron

The analysis of variance revealed no significant difference in concentration of B among N and blended fertilizer rate treatments and their interaction (Appendix 1).

Even though there was a non-significant difference among treatments, the highest mean value of residual available boron (0.62 mg kg^{-1}) in soil was obtained from 250 (44.5N, 89.25P2O5, 19.25S, 5.5 Zn and 0.25B) kg ha^{-1} blended fertilizer, while the lowest (0.33 mg kg^{-1}) was scored from the control and 100 kg ha^{-1} blended fertilizer application (Table 2). The field experiment showed as when the rate of blended fertilizer increased, available B of the soil also increased. Due to the interaction effects of N and blended fertilizer, numerically the highest mean value of residual available boron (1.1 mg kg^{-1}) was obtained from the combined application of 46 kg N ha^{-1} and 250 kg ha^{-1} blended fertilizer, Similar to the current laboratory result, **Rakesh *et al*. (2014)** reported that organic carbon, pH and status of available N, P, K, S and Zn in soil after harvest of crop did not differ significantly due to the application of NPKS and Zn..

Melich-III extracted available boron content of composite soil sample before planting and sample taken per treatments after harvest showed that B was in the experimental soil deficient. According to **Ethio-SIS (2013),** the critical B value for most Ethiopian soils is 0.8 mg kg^{-1}.

Therefore, the soil of the study area is deficit in B suggesting application of fertilizer which contains B.

3.2.8. Available potassium

Based on Melich-III extracted, mean value of available K was ranged from 514.64 to 490.49 mg kg^{-1} (Table 2). Exchangeable K was analyzed per treatment, but the value of K was almost comparable throughout treatments because K fertilizer source was not applied as a treatment or blanket recommendation. According to Ethiosis (2014), soil K value is classified as <90; very low, 90-190; low, 190-600; optimum and > 600 mg kg^{-1}; high. Therefore, K content of the study area was in optimum levels showing that there is no need of adding K fertilizer to the soil.

Table 2. Main effects of N and NPSZnB on available soil N, P, S and B at harvest

N rate (kg ha^{-1})	TN (%)	Av. P (mg kg^{-1})	Av. S (mg kg^{-1})	Av. B (mg kg^{-1})	Av. K (mg kg^{-1})	CEC cmol $_{(+)}$ kg^{-1}	pH	OC (%)
0	0.08	14.21	2.13	0.39	504.63	46.62	6.87	1.1
46	0.09	15.68	1.99	0.63	505.27	47.84	6.86	1.1
92	0.09	15.32	2.07	0.39	501.94	47.6	6.86	1.14
138	0.09	15.14	2.05	0.62	503.41	47.6	6.86	1.15
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns	ns
Blended (kg ha^{-1})								
0	0.08	14.41	1.92	0.50	502.87	47.36	6.85	1.08
100	0.08	16.15	1.91	0.33	501.27	48.39	6.86	1.1
150	0.09	14.80	2.14	0.62	503.40	47.95	6.88	1.15
200	0.09	14.84	2.09	0.55	506.61	46.79	6.84	1.13
250	0.09	15.22	2.24	0.62	504.91	46.61	6.87	1.14
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns	ns
C.V (%)	18.4	17.51	27.66	11.92	2.08	6.41	1.1	15.01

Where,TN=Nitrogen, Av.P=Available phosphorus, Av.S= Available sulfur, Av.B= Available Boron, exchangeable K=Potassium, CEC= Cation exchange capacity, LSD= Least Significant Difference at 5% level; CV= Coefficient of

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Variation; NS= non-significant. Means in columns followed by the same letters are not significantly different at 5% level of significance.

3.2.9. Available zinc

The analysis of variance showed that the available zinc content was highly significantly ($P < 0.01$) affected by the main effect of different rates of N and blended fertilizers and their interaction (Appendix 1). Increasing blended fertilizer rate from 0 to 250 kg ha^{-1} increased available Zn content. The highest mean value of available zinc (0.94 mg kg^{-1}) was obtained from (150 kg ha^{-1}) followed by the highest rate 250 kg ha^{-1} blended fertilizer and the lowest (0.66 mg kg^{-1}) was obtained from the control plots (Table 3).

The highest available zinc (1.22 mg kg^{-1}) was obtained from 150 kg ha^{-1} blended without N fertilizer, while the lowest (0.53 mg kg^{-1}) was obtained from combined application of 138 kg N ha^{-1} and 0 kg ha^{-1} blended fertilizer. The values of zinc obtained from fertilizer treated and control plots were generally low. This may be related to excessive cultivation and continuous utilization of NP fertilizers which do not provide Zn to soil. Zinc deficiency is also common on neutral to alkaline pH soils containing more than 1% organic matter. The result also supported by Asegelil et al. (2007) who reported Zn deficiency in 78.4% of the soil samples collected from Vertisols and Nitisols of Ethiopia. The Zn critical value for most Ethiopian soil as suggested by EthioSIS (2013) is 1.5 mg kg^{-1}. This shows that addition of fertilizer containing Zn is necessary for Vertisol. In accordance with Jones (2003), soil fertility indices for available zinc, zinc content of 0.0-0.9 as low, 1.0-1.5 marginal, and > 1.5 mg kg^{-1} high. Thus the available zinc content of the experimental soil (Table 3) was low.

Table 3.Interaction effects of N and blended fertilizer on soil Zn at harvest

	Available zinc (mg kg^{-1})					
Treatments	Blended (NPSZnB kg ha^{-1})					
N rates (kgha^{-1})	**0**	**100**	**150**	**200**	**250**	**mean**
0	0.63ij	0.63ij	1.22a	0.59k	0.76def	**0.77b**
46	0.8c	0.62jk	0.65hi	0.81c	0.74f	**0.72c**
92	0.66hi	0.78cde	1.17b	0.75ef	0.67gh	**0.81a**
138	0.53l	0.67gh	0.7g	0.67gh	0.79cd	**0.67d**
Mean	**0.66d**	**0.67d**	**0.71c**	**0.74b**	**0.94a**	
LSD (0.05) **N**			**0.06**			
B			**0.018**			
N*B			**0.036**			
C.V (%)			**2.94**			

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

3.3. Effects of N and Blended Fertilizers on Phenological Traits

3.3.1. Days to panicle emergence

Days to panicle emergence was not significantly different due to the main effects of nitrogen and blended fertilizers application, whereas the number of days taken to heading was significantly ($P<0.05$) affected by the interaction of nitrogen and blended fertilizers rates (Appendix 2).

The mean maximum (64) days for panicle emergence was observed under the control plots. The highest combined rates of 138 kg N + 200 kg NPSZnB ha^{-1} and 92 kg N + 200 kg NPSZnB ha^{-1}, minimized the days to panicle emergence date of heading by 14 and 13 days, respectively as compared to the control plots (Table 4). Application of N and blended fertilizer (N, P, S, B and Zn) hastened the days to Panicle emergence because the tef plants were able to take up sufficient

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nutrients from the soil which encouraged early establishment, rapid growth and development of crop. Assefa (2016) also indicated that as the rate of NP increased, the number of days elapsed to heading was shortened. Hence, the longest days to Panicle emergence was recorded in the control plots. Similar result was reported by Seifu (2018), the highest days to 50% panicle emergence (73 days) was recorded from the control plot, while the lowest (50 days) was recorded from the combined application of 138 kg N and 200 kg blended (NPSB ha^{-1}) fertilizers. In contrast to these results, increasing the rate of nitrogen application prolonged the days to panicle emergence of the tef plants (Abraha, 2013). This may be due to longer time required to establish, grow and complete the vegetative growth. In line with the current finding, application of N fertilizer reduced days to heading compared to unfertilized treatment in tef (Temesegen, 2012; Shiferaw, 2012).

Table 4. Number of days to Panicle emergence as affected by the main and interaction effects of N and blended fertilizer rates

	Days to panicle emergence					
Treatments	**Blended (NPSZnB kg ha^{-}1)**					
N rates (kgha^{-1})	0	100	150	200	250	Mean
0	64a	52cde	52cde	55bcde	56bc	64
46	52cde	53b-e	55bcd	54cde	54cde	52
92	51cde	53bcde	52cde	51cde	54bcde	51
138	53bcde	53bcde	52bcde	50e	57b	53
Mean	64	50	52	55	56	
LSD (0.05) N*B			**5.64**			
C.V (%)			**6.38**			

Where, LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation, Means in columns and rows followed by the same letters are not significantly different at 5% level of significance

3.3.2. Day to physiological maturity

The days to attain physiological maturity did not significantly differ due to the main and interaction effects of N and blended fertilizers (Appendix 2).

The lack of significant effect on days to heading and maturity might be due to the optimum levels of macro and micro nutrients affecting the Phenological parameters and also higher lodging problems for most of the treatments, which exposed the plant to false maturity. In general, results showed that nitrogen and blended fertilizer application had no significant effect on crop maturity (Table 5).

Table 5. Days to physiological maturity of tef as affected by the main effect of N and blended NPSZnB fertilizer rates

Treatments	Day to Physiological maturity
N rates (kg ha^{-1})	
0	102
46	102
92	101
138	101
LSD (<0.05)	**ns**
Blended fertilizer (kg ha^{-1})	
0	105
100	102
150	103
200	101
250	98

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LSD (<0.05)	**ns**
C.V (%)	**7.62**

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

3.4. Effects of N and Blended Fertilizers on Tef Growth, Yield and yield component Parameters

3.4.1. Plant height

The main effect of N ($P< 0.01$), Blended fertilizer as well as their interactions were showed significant ($P< 0.05$) influence on plant height of tef (Appendix 2).

The tallest plant (120.6 cm) was obtained at the rate of 138 kg N ha^{-1} which was statically at par with the rate of 46 and 92 kg N ha^{-1}.Whereas, the shortest plant height (97.4 cm) was obtained from the control plot (Table 6). This significant increment may be attributed to the fact that N usually favors vegetative growth of tef, resulting in higher stature of plants. A similar result was reported by Fissehaye *et al.* (2009) and Haftom *et al.* (2009) showing that tef plant height could be higher by applying high amount of N fertilizer (92 kg N ha^{-1}).

On the other hand, the longest plant (120.1 cm) and the shortest (105.8 cm) were recorded from 200 kg blended fertilizer ha^{-1} and control plots, respectively. Similar to this finding, Sate (2012) reported that plant height of tef was significantly affected by application of P and N with blended fertilizer. In contrast to this finding, Adera (2016) and Esayas (2015) **r**eported that plant height of tef was not significantly affected by the rate and type of different blended fertilizers. The lack of significance among the blended fertilizer treatments might be the constant amount of nitrogen in which the increase in nitrogen rate increases the plant height.

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The highest mean plant (126.33 cm) was recorded at the combined application of 138 kg N and 200 kg ha^{-1} blended fertilizer followed by138 kg N ha^{-1} and 100 kg ha^{-1} blended fertilizer **(**Table 6**)**.whereas, other treatment combinations were statistically at par each other. Similarly, Bakala (2018) reported application of blended fertilizer under balanced N increased plant height of maize. Generally, increased combined application of N and blended fertilizer showed inconsistent increment on plant height.

Table 6.Tef plant height as affected by the main and interaction of N and blended fertilizer rates

Treatments	**Plant height**					
	Blended (NPSZnB kg ha^{-1})					
N rates (kgha^{-1})	**0**	**100**	**150**	**200**	**250**	**mean**
0	76.9g	101.9f	106.3d-g	107.0c-f	103.8efg	97.4b
46	102.2fg	92.7g	120.3abc	113.3a-f	119.2a-d	114.5a
92	119.8a-d	117.2a-d	121.9ab	122.1ab	119.4a-d	120.1a
138	124.4ab	125.0a	125.5a-e	126.3a	111.0b-f	120.6a
Mean	105.8b	113.2a	117.2a	120.1a	113.4a	
LSD (0.05) N			**6.19**			
LSD (0.05) B			**6.92**			
LSD (0.05) N*B			**13.84**			
C.V (%)			**7.4**			

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

3.4.2. Panicle length

Panicle length was significantly (P< 0.01) affected by the main effect of N fertilizer application. However, the main effect of blended fertilizer and their interaction were non- significant (Appendix 2).

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The tallest panicle (43.8 cm) was observed at the rate of 138 kg N ha^{-1} which was statistically similar with 92 kg N ha^{-1}, while the shortest (37.52 cm) was obtained from the control plot (Table 7). Generally increasing application of N to 92 kg N ha^{-1} significantly increased panicle length, but further increasing N fertilizer did not consistently increases panicle length. In line with this result, Okubay et *al.* (2014) reported that tef panicle length increased in response to increasing rate of nitrogen application.

3.4.3. Total numbers of tillers

Total number of tiller per plant was highly significantly ($P<0.01$) affected by the main effect of N rate, while the main effect of blended fertilizer and their interaction effects were non-significant (Appendix 2).

The highest total number of tillers (6.33 $plant^{-1}$) was recorded at the rate of 138 kg N ha^{-1} and the lowest (4.54 $plant^{-1}$) was obtained from the control (Table 7). Increasing N levels from 0 to 138 kg N ha^{-1} resulted in linear and consistent increment of tiller number. However, total numbers of tillers at different rates of applied N were statistically at par except from the control plot. The possible reason for increment in number of tiller might be due to the more availability of N which played a positive role in cytokinin synthesis and cell division. Consistent with this result, Seifu (2018) and Haftamu *et al*. (2009) reported significantly higher number of total tillers in response to the application of N rate on tef

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Table 7. Tef TNT and PL as affected by the main effect of N and blended fertilizer rates

Treatments	Total No. of tiller plant^{-1}	Panicle length (cm)
N rates (kgha^{-1})		
0	4.54b	37.52c
46	5.48ab	41.79b
92	6.08a	43.72a
138	6.33a	43.83a
LSD (0.05)	**1.06**	**1.76**
Blended (NPSZnB) fertilizer (kg ha^{-1})		
0	5.15	40.72
100	5.22	41.32
150	6.11	43.29
200	5.54	41.93
250	6.02	41.74
LSD (0.05)	**Ns**	**ns**
C.V (%)	**25.61**	**5.71**

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

3.4.4. Numbers of Productive of tillers

Number of productive tiller was significantly ($P < 0.05$) influenced by the main effect of N and their interaction effects of N and blended fertilizer. However, this parameter was not significantly influenced by the main effect of blended fertilizer (Appendix 2).

The highest number of fertile tillers per plant (5.5) was recorded at the rate of 138 kg N ha^{-1}. while, the lowest (3.9) was obtained from the control plot. Effective tillers from plots treated with 46, 92 and 138 kg N ha^{-1} were in statistical parity, and only significantly differed from the control plot (Table 8). Consistent with this result, Haftamu *et al.* (2009) and Tekalign *et al.*

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(2000) reported significantly higher number of tillers in response to the application of N rate on tef. Mossedaq and Smith (1994) also revealed that tillering is enhanced by increased light and N availability during the vegetative growing period of the crop.

The highest number of effective tillers plant^{-1} (7.5) was recorded at the combined application of 46 kg N and 150 kg blended ha^{-1} which was statistical at par (T4, T14, T8, T10, T12, T15,T17 and T19) treatments, while, the lowest (2.7) was obtained from the control treatment (Table 8). This may be due to the promotion of vigorus vegetative growth by application of N and blended fertilizer. In agreement with the result of this study, Fayera *et al.* (2014) found that the highest productive tillers of tef under the application of 200 kg ha^{-1} (NPKSZnB) blended (14 N, 21 P2O5, 15 K2O, 6.5 S, 1.3 Zn and 0.5 B) + 23 kg N ha^{-1} fertilizer.

Table 8. Tef effective number of tiller per plant as affected by the main and interaction of N and blended fertilizer rates

Treatments	Number of effective tiller per plant					
	Blended (NPSZnB kg ha^{-1})					
N rates (kgha^{-1})	**0**	**100**	**150**	**200**	**250**	**Mean**
0	2.7f	3.4ef	3.9def	4.4c-f	5.2b-e	**3.9b**
46	4.0def	4.0def	7.5a	4.3c-f	3.9def	**4.7ab**
92	5.0b-e	4.7b-f	4.4c-f	5.4a-e	7.0ab	**5.3a**
138	6.4abc	5.8a-d	5.6a-e	5b-e	4.7b-f	**5.5a**
Mean	**4.5**	**4.5**	**5.3**	**4.8**	**5.2**	
LSD (0.05) N			**1.01**			
N*B			**2.27**			
C.V (%)			**28.23**			

Where, LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation; NS= non-significant. Means in columns and rows followed by the same letters are not significantly different at 5% level of significance

3.4.5. Grain yield

Grain yield of tef was highly significantly (P < 0.01) influenced by the main effect of N fertilizer rate and its interaction with blended (NPSZnB), while, the main effect of blended fertilizer was not significantly (P>0.05) influenced grain yield of tef (Appendix 3).

The highest grain yield (1572.2 kg ha^{-1}) was obtained at the rate of 92 kg N ha^{-1} which was statistically similar with 138 kg N ha^{-1}, while the smallest (861.2 kg ha^{-1}) was obtained from the control treatment (Table 9). Moreover, increased application of N to 92 kg N ha^{-1} significantly increased grain yield but further increasing N fertilizer rates linearly decreased grain. This may be attributed to the asynchrony in the time of availability of sufficient amounts of the nutrient in the soil proportionate with the demand of the plant for uptake. High response to N is understandable because total N in most Vertisols is low (Table 1). Because of rapid nitrification, most of the N added as fertilizer containing NH_4 or NH_2 is subject to leaching or denitrification soon after application. Ammonia fixation also affects fertilizer efficiency in heavy Vertisol (Finck and Venkateswarlu, 1982). Studies on response of tef to N application by Abraha (2013) found that N application significantly increased grain yield. Increased grain yield due to increased N application was also reported for different cereal crops.

The highest grain yield (2002.5 kg ha^{-1}) was recorded at the combined application of 92 kg N and 100 kg ha^{-1} blended fertilizer, which was statically at par with the combined rate of 138 kg N ha^{-1} without blended fertilizer and 92 N kg and 200 kg NPSZnB ha^{-1}, respectively. However, the other treatment combinations of N and blended fertilizers resulted in statistically similar

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performance each other. Whereas, the lowest (333.33 kg ha^{-1}) was obtained from the control (Table 9). The grain yield increment from plot treated with N and blended fertilizer might be due to the contribution of balance nutrient (macro and micro nutrient) present in fertilizers which increased yield attributes through more uptakes of all the nutrients and increased translocation of photosynthetic materials from source to sink. On the other hand, the lower grain yield of tef in this study at the highest combined rate of 138 kg N and 250 kg NPSZnB ha^{-1} may possibly be attributed to excess supply of the nutrient that favours more vegetative growth of plant parts leading to lodging before the translocation of dry matter to grain.

In conformity with this finding, Tagesse *et al.* (2018) and Seifu (2018) reported the highest grain yield was obtained at 200 kg blended NPS ha^{-1} supplemented with 92 kg N ha^{-1}. Similarly, Jarvan *et al*. (2012) reported that the 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.

Table 9**.**Tef grain yield as affected by the main and interaction of N and blended fertilizer rates.

Treatments	Grain yield (kg ha^{-1})					
	Blended (NPSZnB kg ha^{-1})					
N rates (kgha^{-1})	**0**	**100**	**150**	**200**	**250**	**mean**
0	333.3j	758.3h	975.8ghi	1132.5e-i	1105.8f-i	**861.2c**
46	890.0hi	1252.5c-h	1268.3 c-h	1553.3abc	1301.7c-g	**1253.2b**
92	1395.0b-e	2002.5a	1425.8b-f	1612.5abc	1425.0b-f	**1572.2a**
138	1725.0ab	1532.5bcd	1550.0abc	1205.0d-h	1236.7c-h	**1449.8a**
Mean	**1085.8**	**1386.5**	**1305**	**1375.8**	**1267.3**	
LSD (0.05) **N**			**181.55**			
B			**202.09**			
N*B			**405.97**			

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C.V (%)	**19.13**

Where, LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation NS= non-significant. Means in columns and rows followed by the same letters are not significantly different at 5% level of significance

3.4.6. Above ground biomass

The analysis of variance showed highly significantly (P<0.01) difference in above ground dry biomass yields due to the main effect of N and blended fertilizer, and their interactions was non-significant (Appendix 3).

The highest biomass yield (9516 kg ha^{-1}) was recorded at the highest N rate (138 kg N ha^{-1}) which statistically at par with 92 kg N ha^{-1} with mean aboveground biomass yields of (9043 kg ha^{-1}), the lowest dry biomass yield (5016 kg ha^{-1}) was obtained from the control plot (Table 10). Higher above ground dry biomass yield obtained from larger amounts of nitrogen may be due to the increased investment of assimilates to leaves and stems that finally increase dry matter yield. Similar results was reported by Cassman et al. (2003) in which the average maize stover yield increased for the N and green manure treatments ranged with yield increments of 25 to 75% and 6 to 68% over the control treatments, respectively, due to increased N application.

Dry biomass yield was also significantly (P<0.05) influenced by the main effect of blended fertilizer rate application. The highest (8604.2 kg ha^{-1}) above ground dry biomass yield was obtained at 250 kg ha^{-1} (182.5 kg N+89.25 kg P2O5 + 19.25 kg S +5.5 kg Zn +0.25 kg B) blended fertilizer.

The result was in conformity with the findings of Adera (2016) and Bereket *et al.* (2014) which showed that above ground dry biomass yield was significantly affected by application of blended

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fertilizer. Others authors also reported that application of 120 kg ha^{-1} NPS fertilizer produced the maximum biomass yield of tef (eg.Wakjira, 2018).

3.4.7. Lodging index

Data recorded on lodging percentage was transformed by Arcsine transformation method to reduce variation among means. Lodging index was highly significantly ($P < 0.01$) affected the main effect of N fertilizer rate, and significantly ($P<0.05$) influenced by the main effect of blended fertilizer, while, the interaction effects was non-significant (Appendix 3).

The highest lodging index 44.53 (48.73 %) was obtained from application of 138 kg N ha $^{-1}$ and the lowest 20.22 (14.33 %) from the control plot (Table 10). Marked increases in lodging index due to the increased application of nitrogen fertilizer were observed. This may be due to increasing rate of total nitrogen that enhanced fast vegetative growth, plant height and succulent stem elongation of tef. According to Bekabil *et al.* (2011) almost all tef varieties are susceptible to lodging. However, there is trade-off between fertilizer use and lodging as fertilizer leads to increase in the number of panicles and grains per panicle, which in turn increases the weight of the stem and the likelihood of lodging. This result is consistent with that of Abraha (2013) who reported that lodging in cereals is considered to be caused by high rate of nitrogen fertilizer application. Similarly, Tekalign *et al.* (2000) obtained significant differences in lodging percentage of tef due to N application above the rate of 60 kg ha^{-1}. This result is consistent with the suggestion of Brady and Weil (2002) that excess N application causes high vegetative growth, and enlargement of stem cells that consequently leads to weak stem and lodging.

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The highest lodging index 37.2 (38.92 %) was obtained from 150 kg ha^{-1} blended fertilizer, while the lowest 26.29 (22.33%) was from the control plot. This result was in line with the findings of Shiferaw (2012) who 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 0 kg K_2O ha^{-1}) application.

Table 10. Above ground biomass and lodging index as affected by the main N effect and blended fertilizer rates

N rate (kg ha^{-1})	Above ground biomass yield Kg ha^{-1}	Lodging index (%)
0	5016c	14.33 (20.219c)
46	7716b	32.27 (34.23b)
92	9043.3a	38.4 (37.97b)
138	9516a	48.73 (44.52a)
LSD (<0.05)	**702.02**	**6.04**
Blended fertilizer (NPSZnB) kg ha^{-1}		
0	6437c	22.23 (26.29b)
100	7533.3b	32.25 (34.14a)
150	8104ab	38.91 (37.63a)
200	8437.5a	35.58 (36.2a)
250	8604.2a	37.08 (36.9a)
LSD (<0.05)	**784.88**	**6.76**
C.V (%)	**12.14**	**23.89**

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

3.4.8. Harvest index

Harvest index of tef was significantly (P < 0.01) influenced by the interaction effects of N and blended fertilizer rates and significantly (P<0.05) influenced by blended fertilizer. Whereas, the main effect of N fertilizer was non-significant (Appendix 3).

The highest harvest index (0.22) was recorded at the combined rates of 100 kg NPSZnB and 92 kg N ha^{-1} fertilizers, while the lowest harvest index (0.12) was recorded from the control (Table 11). This implies that harvest index is the balance between the productive parts of the plant and the reserves which form the economic yield, greater improvement in grain yield compared to the corresponding increase in straw yield contributed to the increase in harvest index across the increasing levels of N and blended fertilizer. This result is supported by the findings of Tagesse *et al.* (2018), where harvest index was significantly affected by the interaction of blended NPS and supplemental N rates.

Table 11. Harvest index of tef as affected by the main and interaction of N and blended fertilizer rates

	Harvest index					
Treatments	**Blended (NPSZnB kg ha^{-}1)**					
N rates (kgha^{-1})	0	100	150	200	250	mean
0	0.13d-f	0.16abc	0.18abc	0.19ab	0.18abc	0.17
46	0.15a-d	0.19ab	0.16b-e	0.17bcd	0.15b-f	0.16
92	0.18abc	0.22a	0.16b-e	0.17bcd	0.16bcde	0.18
138	0.19ab	0.17bcd	0.15b-f	0.13d-f	0.12f	0.15
Mean	0.16b	0.18a	0.16ab	0.17ab	0.15b	

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	N	**ns**
LSD (0.05)	**B**	**0.02**
	N*B	**0.039**
C.V (%)		**14.4**

Where, LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation, NS= non -significant. Means in columns and rows followed by the same letters are not significantly different at 5% level of significance.

3.5. Effects of N and Blended Fertilizer Application on Nutrient (N, P, S, Zn and B) uptake

3.5.1. Phosphorus uptake

Phosphorus uptake in straw and grain were significantly ($P<0.01$) affected by the main effect of N fertilizer, while main effect of NPSZnB had a significant ($P<0.01$) effect on straw P uptake. But the main effect of NPSZnB in grain and the interactions effect of N and NPSZnB in grain and straw were non-significant (Appendix 4)

Application of 128 kg N ha^{-1} gave maximum P uptake (18.80 kg ha^{-1}) in straw, while the minimum P uptake (9.5 kg ha^{-1}) was recorded from the control (Table 12). The result also indicated that increasing N rates till to 92 kg ha^{-1}, significantly increased straw p uptake, but beyond 92 kg ha^{-1} straw P uptake did not statistically increased. Moreover, the highest grain P uptake (5.11 kg ha^{-1}) was obtained from 92 kg N ha^{-1}, while the lowest was scored (2.69 kg ha-1) from the control plot (Table 12). Moreover, the values of grain P uptake statistically similar at all N rates, except that of the control (Table 12)

Application of 250 kg NPSZnB ha^{-1} gave the highest (17.07 kg ha^{-1}) straw P uptake and which was statically different only from the control plots (11.73 kg ha^{-1}) (Table 12).

Table 12 . Tef grain and straw P uptake as affected by N and blended fertilizer rates.

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Treatments N rate (kg ha-1)	P straw uptake kg ha^{-1}	P grain Uptake kg ha^{-1}
0	9.50c	2.69b
46	14.04b	4.68a
92	17.00a	5.11a
138	18.80a	5.01a
LSD (0.05)	**2.44**	**1.38**
Blended NPSZnB (kg ha^{-1})		
0	11.73c	3.54
100	13.81bc	5.12
150	15.19ab	4.04
200	16.38ab	4.24
250	17.07a	4.92
LSD (0.05)	**2.73**	**Ns**
C.V (%)	**22.29**	**42.12**

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

3.5.2. Nitrogen uptake

Analysis of variance showed that nitrogen uptake in straw and grain were significantly ($P < 0.01$) affected by the main effect of N fertilizer rates. Moreover, main effect of blended fertilizer also significantly ($P<0.01$) influenced straw N uptake. The interaction of N and blended fertilizer significantly ($P<0.05$) affected straw and grain N uptake. However, Blended fertilizer in grain didn't show significant effect (Appendix 4).

The Combined application of 138 kg N ha^{-1} and 250kg NPSZnB ha^{-1} gave maximum N straw uptake (91.14 kg ha^{-1}) as compared to other treatments, whereas the minimum N straw uptake (18.66 kg ha^{-1}) was obtained from the control plot (Table 13).

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The highest N uptake in grain (31.53 kg N ha^{-1}) was obtained at the combined application of 92 kg N and 100 kg NPSZnB ha^{-1}, which had 83.13%, grain N uptake advantage over the control (Table 13). This was in line with highest biological yield also observed in this plots, while the lowest N grain uptake (5.32 kg N ha^{-1}) was obtained from the control plot. Similar to this finding, Lemlem *et al.* (2015) reported that application of blended fertilizer, DAP and Urea fertilizer increased the nitrogen, zinc and sulfur uptakes by tef grains.

3.5.3. Sulfur uptake

It is evident from the data presented in Appendix 5&6, significant ($P<0.01$) variation in grain and straw S uptake exist due to main effect of N application. Moreover, the main effect of NPSZnB ($P<0.01$), and interaction of NPSZnB and N significantly ($P<0.05$) influenced straw S uptake. However, main effect of NPSZnB on grain S uptake was not significant (Appendix 4 & 5).

The maximum amount of straw and grain S uptakes (35.9 and 14.7 kg ha^{-1}) were obtained under the rate of 138 kg N with 250 kg NPSZnB ha^{-1} and sole 138 kg N ha^{-1} application, respectively (Table 13). The lowest straw and grain S uptakes (3.4 and 2.2 kg ha^{-1}) were obtained from the control treatment, respectively .The combined application of 138 kg N with 250 kg NPSZnB ha^{-1} and sole 138 kg N ha^{-1} application improved straw and grain S uptakes in tef by 90.5 and 85.0% over the control, respectively. The increase in available S in soil and its absorption by the plant with the addition of N and NPSZnB might be due to the release of more soil S from the adsorption site because of ion exchange synergistically (Gowda et al., 2001). The present result is in agreement with the findings of Bakala (2018) which showed that synergistic effect of

NPSZnB and N at higher rate due to utilization of large quantities of nutrients, which might have resulted in better plant nutrient uptake.

Table 13. N and S uptakes by tef grain and straw as affected by N and blended fertilizer rates.

		N uptake (kg ha^{-1})		S uptake (kg ha^{-1})	
N (kg ha^{-1})	NPSZnB (kg ha^{-1})	Straw	Grain	Straw	grain
0	0	18.66j	5.32g	3.43k	2.23g
	100	34.67hi	8.097g	7.86f-k	5.42fg
	150	32.33i	16.953ef	5.33jk	5.72efg
	200	33.31i	16.357ef	6.99h-k	7.46cdef
	250	24.05ij	16.27ef	11.73e-k	6.03ef
46	0	32.84i	11.65fg	6.37ijk	5.95ef
	100	35.68hi	20.39cde	8.82f-k	8.13bcdef
	150	47.51gh	21.397cde	15.16d-h	9.97bcd
	200	52.58efg	23.917bcd	12.98e-j	11.39ab
	250	63.69cde	18.607de	21.41bcd	10.25bc
92	0	49.55fg	20.83cde	15.76defg	7.73 cdef
	100	52.10efg	**31.53a**	17.47de	10.48bc
	150	58.78c-g	25.21a-d	8.91f-k	9.31bcde
	200	56.67d-g	26.33abc	**19.94cde**	11.56ab
	250	58.42c-g	22.63cde	19.08cde	11.41ab
138	0	62.49c-f	29.89ab	14.34d-i	14.70a
	100	66.48bcd	25.11a-d	14.93d-h	8.76bcdef
	150	79.98ab	21.8cde	28.42ab	8.82bcdef
	200	71.14bc	20.13cde	26.63bc	7.46cdef
	250	91.14a	20.07cde	35.97a	6.48def

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LSD (0.05)	**13.54**	**6.74**	**8.38**	**3.62**
C.V (%)	**16.06**	**20.82**	**29.67**	**26.18**

Where, LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation; NS= non-significant. N,=Nitrogen= sulfur, Means in columns followed by the same letters are not significantly different at 5% level of significance.

3.5.4. Zinc uptake

The ANOVA result showed highly significant (P<0.01) effects due to main effect of NPSZnB and N application rates as well as their interaction on grain and straw Zn uptake of tef (Appendix 5).

Significantly the highest Zn uptake in grain (0.54 kg ha^{-1}) was obtained at rate of 92 kg N and 100 kg NPSZnB ha^{-1}, while the lowest (0.09 kg ha^{-1}) was obtained from the control treatment (Table 14). In the case of straw zinc uptake, the highest uptake 1.13 kg ha^{-1} was scored at the combined rate of 92 kg N ha^{-1} and 250 kg ha^{-1} blended fertilizer, while the lowest (0.2 kg ha^{-1}) was obtained from the control plots (Table 14). Application of 92 kg N wirh100 and 250 kg NPSZnB ha^{-1} blended fertilizer increased Zn uptake in grain and straw by 83.3 and 82.3% compared to the control. Similarly, **Dagne (2016)** reported that application of blended fertilizer increased zinc uptake maize.

3.5.5. Boron uptake

Grain and straw B uptakes were significantly (p<0.01) influenced by the main effects of N. Moreover, the main effect of NPSZnB (p<0.01) on straw and the interactions of N with NPSZnB on grain and straw were significant (p<0.01). However, main effect of NPSZnB on grain was not significant (Appendix 5).

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The highest and the lowest straw B uptakes (0.58 and 0.17 kg ha^{-1}) were obtained from the combined application 138 kg N and 100 kg NPSZnB ha^{-1} blended fertilizer and the control plot, respectively. The maximum grain B uptake (0.19 kg ha^{-1}) was recorded at 92 kg N and 100 kg NPSZnB ha^{-1}, while the lowest (0.03 kg ha^{-1}) was from the control plot (Table 14).

Table 14. Zn and B uptakes by tef grain and straw as affected by N and blended fertilizer rates.

		Zn uptake (kg ha^{-1})		B uptake (kg ha^{-1})	
N (kg ha^{-1})	NPSZnB (kg ha^{-1})	Straw	Grain	Straw	Grain
0	0	0.20g	0.09h	0.17f	0.03i
	100	0.28g	0.2gh	0.29e	0.05hi
	150	0.33fg	0.26efg	0.25ef	0.08fgh
	200	0.56de	0.31cdef	0.39d	0.08fgh
	250	0.32g	0.30c-g	0.29e	0.07gh
46	0	0.52e	0.24fg	0.27e	0.07gh
	100	0.48ef	0.34b-e	0.39d	0.09d-g
	150	0.53de	0.28d-g	0.43cd	0.10c-g
	200	0.68cd	0.30c-g	0.45 bcd	0.13bc
	250	1.12a	0.38b-e	0.45bcd	0.1b-g
92	0	0.54de	0.3bcd	0.46 bcd	0.12b-e
	100	0.85b	0.54a	0.44cd	0.19a
	150	0.59e	0.42b	0.44cd	0.11b-f
	200	1.04a	0.43b	0.48bcd	0.13b
	250	1.13a	0.35b-e	0.58a	0.12bcd
138	0	0.58de	0.43b	0.45bcd	0.13b
	100	0.86b	0.39bc	0.58a	0.10b-g
	150	0.61cde	0.38bcd	0.52abc	0.090c-g

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	200	0.68cd	0.31c-f	0.49abc	0.08e-h
	250	0.76bc	0.36b-e	0.54ab	0.11b-g
LSD (0.05)		0.12	0.11	0.093	0.034
C.V (%)		19.41	19.41	13.54	20.50

Where, LSD= Least Significant Difference at 5% level; CV= Coefficient of Variation; ns= non-significant. Means in columns followed by the same letters are not significantly different at 5% level of significance.

3.6. Partial Budget Analysis

Attainment of maximum profitability lies not only in reducing use of N and blended fertilizers per unit area but also in lowering costs per unit crop production through higher yields. Farmers are profit-oriented, and therefore, they are interested in net returns than the gross returns. To assess the cost and benefit associated with different treatments, the partial budget analysis technique of **CIMMYT (1988)** was applied. From the final yield and straw data, the gross yields of twenty treatments were obtained. Then the recommended level of 15% was reduced from all treatments to obtain net grain yield and the recommended level of 15% was reduced from all treatments to obtain net stover yield. Net yield was multiplied by market price to obtain gross field benefit. All variable costs were calculated based on the current price of the fertilizers as per the information obtained from local markets and unions. The cost of Urea and blended fertilizers were 8.67 and 11.42 Birr kg^{-1}, respectively. The selling price of tef at the local market around Bishoftu area was taken as Birr 22.5 kg^{-1} for grain yield and birr 2.65 kg^{-1} for straw yield. Variable costs were summed up and subtracted from gross benefits, which were taken as net benefit. The highest net benefit of (61,634) Birr ha^{-1} was obtained from the combined application

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of 92 kg N ha^{-1} and 100 kg blended (NPSZnB) ha^{-1}, while the lowest net benefit Birr 13,683 ha^{-1} was obtained from the control plots (Table 15).

Although the calculation of net benefits accounts for the costs that vary, it is necessary to compare the extra (or marginal) costs with the extra (or marginal) net benefits. The process of calculating the marginal rates of return (MRR) of alternative treatments, proceeding in steps from the least costly treatment to the most costly, and deciding if they are acceptable to farmers, is called marginal analysis (CIMMYT, 1998). According to the dominance analysis on mean value over control, sixteen treatments were dominated by other treatments, hence, eliminated from further economic analysis. The highest MRR% (29476.4) was attained from treatment combination of 92 N kg ha^{-1} and 100 kg ha^{-1} blended fertilizer followed by 92 kg N ha^{-1} (20600.2) as compared to other to get more profit as described in table (15). This implies that for every one birr invested in Urea and blended fertilizer application, farmers can expect to recover the 1 birr ha^{-1} and obtain an additional 294.76 birr ha^{-1}.

Table 15. Summary of partial budget analysis of the effects of blended and N fertilizer rates application on tef

Treatments							
N rate Kg ha^{-1}	Blended Kg ha^{-1}	AGY (kg ha^{-1})	ASY (kg ha^{-1})	TR Birr ha^{-1}	TVC Birr ha^{-1}	Net benefit Birr ha^{-1}	MRR (%)
0	0	283	1983	13683	0	13683	
46	0	757	4202	33125	976	32149	1892.365
0	100	645	3464	27861	1251	26610	D
0	150	829	3633	33283	1876	31407	D
92	0	1186	5614	48891	1952	46939	20600.2
46	100	1065	4531	42308	2227	40081	D
0	200	963	4208	38601	2502	36099	D
46	150	1078	5793	46597	2852	43745	D

138	0	1466	6396	58754	2927	55826	16022.68
0	250	940	4373	38513	3113	35400	D
92	100	1702	6345	64836	3202	61634	29476.4
46	200	1320	6542	55346	3477	51869	D
92	150	1212	6509	52374	3828	48546	D
46	250	1106	6402	49246	4089	45157	D
138	100	1303	6560	54933	4178	50754	D
92	200	1371	6775	57404	4453	52951	D
138	150	1318	7183	57268	4804	52464	D
92	250	1211	6510	52357	5065	47292	D
138	200	1024	6484	47328	5429	41899	D
138	250	1051	7661	51710	6041	45670	D

Where, AGY= Adjusted Grain Yield, ASY= Adjusted Straw Yield, TR= Total Revenue, TVC=Total Variable Cost and MRR= marginal rate of return.

4. CONCLUSION AND RECOMMENDATIONS

The treatments of the field experiment consisted four N levels (0, 46, 92 and 138 kg ha^{-1}) and five blended fertilizer levels (0, 100, 150, 200 and 250 kg/ha). The blended fertilizer NPSZnB with the formula (17.8N, 35.7P2O5, 7.7S, 2.2Zn, 0.1B) kg ha^{-1} used in this experiment was selected based on the soil information data of ETHioSIS map. The experiment was laid out in a factorial randomized complete block design with three replicate plots. The tef variety used in the experiment was Kora (DZCR-387) which is widely adopted in the study area. The analytical results of physic-chemical properties of the soil before planting indicated that the experimental soil was clayey in texture, neutral in reaction (pH 6.73), low in OC (1.2 %), low in total N (0.09%), low in available S (4.19 mg kg^{-1}), low in available Zn (0.63 mg kg^{-1}), low in available B (0.9 mg kg^{-1}) , medium in available P (12.74 mg kg^{-1}) and available K (510.15 mg kg^{-1}).

The total number of tillers, above ground dry biomass yield and lodging index were highly significantly ($P<0.01$) affected by the main effect of N fertilizer rate and was significantly ($P<0.05$) influenced the panicle length, while the above ground dry biomass yield and lodging index were significantly influenced by the main effects of blended fertilizer.

The analysis of variance showed that N,S and Zn grain uptakes were highly significantly ($P<0.01$) affected by the interaction effects of Urea and blended fertilizer, While N,S, Zn and B uptakes were significantly ($P<0.05$) affected by the interaction effects of N and blended fertilizer rates. The post-harvest soil analysis results did not show significant change for nitrogen, phosphorus, sulfur and boron when compared to the respective results before planting. However, available zinc was significantly influenced by treatments. Generally, as the rates of N and blended fertilizers increased the number of total tillers, productive tillers, aboveground dry biomass yield, grain yield and nutrient uptake of N, S, Zn and B were increased.

The economic analysis showed that combined application of 100 kg blended fertilizer ha^{-1} supplemented with 92 kg N ha^{-1} provided relatively high net benefit (61,634 ETB ha^{-1}) and hence these could be the best rate to apply. Marginal rate of analysis from undominated treatments also indicated that for each one birr invested in purchase or production of fertilizers it was possible to recover one birr plus an extra of 294.76 birr ha^{-1} as the fertilizer application changed from unfertilized plot to 92 kg N ha^{-1} combined with 100 kg ha^{-1} blended fertilizer. Therefore, we recommend the treatment (92 kg N + 100 kg NPSZnB kg ha^{-1}) with high marginal rate of return, high net benefit and relatively small total cost of production for tef production in the study area.

Furthermore, emphasis and consideration required to the issue in the future research study

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- Since the experiment was conducted only for one season and one site, repeating the trial at different sites as well as in the same trial site would be important in order to draw sound recommendation.
- Since, the soil is dominantly Vertisols, N is the limiting nutrient in the study area, therefore, more attention must be given in additional to blended fertilizer
- Blended fertilizer didn't gave a clear response for yield and components of tef without the addition application of urea fertilizer.

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