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Response of Tef [*Eragrostis tef (*Zucc.) Trotter] Varieties to Different Blended NPSZnB Fertilizer Rates in Haro Limmu District, Western Ethiopia : A Pilot Study

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Tef (Eragrostis tef (Zucc.) Trotter] plays a crucial role in achieving food and nutritional security in Ethiopia being predominant staple food. Lack of high yielding varieties suitable to the area and inadequate site-specific blended fertilizers are the major constraints to higher tef productivity. Hence, a field experiment was conducted during 2020 main cropping season to identify high yielding variety and determine economically feasible blended NPSZnB fertilizer rate at Farmers Training Center in Ucha Kebele, Haro Limmu district. Experiment included five different NPSZnB fertilizer rates (0, 50,100, 150 and 200 kg ha^{-1}) and three Tef varieties (Negus, Tesfa and local). Treatments were factorially combined and laid out in randomized complete block design with three replications. Results revealed that thousand seed weight of Tef was significantly influenced by main effect of varieties, blended NPSZnB fertilizer rates and their interactions. Panicle length, dry biomass yield, lodging index, grain yield, straw yield and harvest index of Tef were significantly (P<0.001) affected by main effect of blended NPSZnB fertilizer rates and the interactions of the two factors, while the panicle length, dry biomass yield, lodging index and grain yield, straw yield and

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harvest index of Tef were significantly (P<0.01; 0.05) affected by main effect of varieties respectively. Highest (118.20 cm) plant height, dry biomass yield (9. 64 t ha^{-1}), straw yield (7.02 t ha^{-1}), grain yield (2.62 t ha^{-1}), thousand seed weight (0.42 t ha^{-1}) and harvest index (27.1%) were recorded from Tesfa variety with 150 kg NPSZnB ha^{-1} blended fertilizer rate. Similarly, the highest (7.42 t ha^{-1}), straw yield, dry biomass yield (9.76 t ha^{-1}), grain yield (2.34 t ha^{-1}), thousand seed weight (0.4 g) and panicle length (44.20 cm) were recorded from Tesfa variety with application of 200 kg NPSZnB ha^{-1} blended fertilizer rate and the highest total number of tillers (10.1) and effective number of tillers (9.7) were recorded with 150 kg NPSZnB ha^{-1} blended fertilizer rate. Grain yield of Tef showed increment by 91.22% with the application of 150 kg NPSZnB ha^{-1} with Tesfa variety over the control. Highest net profit of ETB 83229.4 with marginal rate of return of 1553.71% was recorded from Tesfa variety with application of 150 kg NPSZnB ha^{-1} blended fertilizer rate. Therefore, farmers of the study area should use Tesfa variety based on the grain yield and net profitability benefits achieved with 150 kg NPSZnB ha^{-1} fertilizer rate to enhance Tef production and productivity.

Keywords: Tef; varieties; NPSZnB rates; yield.

1. INTRODUCTION

Tef (*Eragrostis tef (*Zucc.) Trotter*] is one of the most important cereal crops and predominant staple food in Ethiopia.* Tef is grown annually on 3.1 million hectares area in Ethiopia with a total production of 5.73 million tons at an average productivity of 1.85tha^{-1}. It is grown by more than 7.15 million households and constitutes the major staple food grain for over 50 million Ethiopians [1].

Oromia National Regional State is among the most important teff growing areas of the country which accounts for 1,487,970.57 ha of area coverage annually with expected production of 28,090,978.41 quintals and average productivity of 1.88 t ha^{-1}. Besides, the total production of teff in East Wollega Zone 77,398.35 hectares of land used for teff production and 1.5 million quintals of teff was produced with productivity of 2.033 tha^{-1} of yield [1].

Tef productivity is constrained by a number of problems, lack of site-specific fertilizer recommendation and high yielding varieties are crucial in the study area. Soil fertility problem is one of the major causes of temporal and spatial yield variability [2]. Lack of appropriate blends fertilizer and lack of micronutrients in fertilizer blends are the national problem which is major constraints to crop productivity. It is vital to increase the productivity along with desirable attributes through production management practices and application of other sources of nutrients beyond the blanket recommendation of DAP and urea alone for Tef production in Vertisols [3].

Lack of location specific recommendation, lack of improved Tef varieties, variability of weather conditions and low soil fertility status are the major constraints that limit Tef productivity in the study area. Hence, introducing best performing Tef variety and use of optimum fertilizer rate has a dominant implication to improve production and productivity of Tef.

Besides, currently there is limited information of site-specific recommendation of NPSZnB fertilizer rate for Tef production in the study area, especially for recently released improved Tef varieties. Hence, there is a need to assess the response of Tef varieties and determining optimum blended NPSZnB fertilizer rates for enhancing Tef yield. Therefore, this experiment was carried out to evaluate the effect of blended NPSZnB fertilizer rates, to identify the best performing Tef varieties and to determine economically optimum blended NPSZnB fertilizer rate for Tef production in Haro Limmu district.

2. MATERIALS AND METHODS

The field experiment was conducted from July to December, 2020 main cropping season under rain fed conditions at *Ucha kebele* on farmers training center (FTC) in Haro Limmu district, East Wollega zone of Oromia Regional National State. Haro Limmu is one of the 17 districts in East Wollega zone; it is located between 9^o 50 30 N - 9^o 55 0 latitude and 36 7 0- 3617 30 E longitude and a distance of about 20 km from Haro Limmu district in the west direction and with a total land area of 1235.895 km^2.

The district town is located at 491 km from west of Addis Ababa and about 165 km from Nekemte zonal town. Geographically, the district is situated at altitude of 1000 to 2232 m above sea level and the topography of the district is estimated to be 20% mountains, 22% valley and 53% plane (HLDANR, 2020). The major soil type of the study area is Nitisols. The soil is clay textured with pH of 5.68, low available of P (7.7 ppm), available S (18.64 ppm) and low available Zn (<0.32 ppm). The experimental site was under wheat cultivation during the previous season.

The agro-climate zone of the district includes highland 0%, midlands 65% and lowland 35%. The total annual rainfall of the study area for 2020 was ranging between 1200-1400 mm and per year with the minimum and maximum temperature of 15 and 27^0c, respectively (HLWANR, 2020). The rainfall of the district was started from April and extended up to mid-November during crop growing period. The area is characterized by heavy and erratic rainfall distribution. The area has crop-dominated mixed crop-livestock farming system. The land is continuously exploited and is poor in fertility and particularly very low in organic matter as crop residues are not left in the fields after harvest basically for straw utilization.

2.1 Experimental Materials

The Tef varieties Negus (DZ-Cr-429 RIL 125) and Tesfa (DZ-Cr-457RIL-181) which were released from Debre Zeit Agricultural Research Center in 2017 and local cultivar were used for the experiment. Negus is very white seeded and high yielding variety, Tesfa is white seeded and high yielding variety resulting from a simple cross and released as an alternative variety and Guyo cultivar is locally cultivated seed (Table 1). The seeds of Tef varieties were obtained from Debre Zeit Agricultural Research Center [4]. Blended NPSZnB (17.8% N, 35.7% P_2O_5, 7.7% S, 2.2% Zn and 0.1% B) and urea fertilizers were used as a source of nitrogen.

2.2 Treatments and Experimental Design

The treatment included control (without external fertilizer application) and blended NPSBZn fertilizer rates plus Urea (100 kg ha^{-1}). The experimental design used for this experiment was Randomized Complete Block Design (RCBD) with factorial arrangement of three varieties (Negus, Tesfa and local) and five blended fertilizer rates (0, 50, 100, 150 and 200 kg ha^{-1}) with three replications. The gross experimental area was 37 m x 8 m (296 m^2); each plot area was 2 m X 2 m (4 m^2) and net plot size of 1.4 m x 1.8 m (2.52 m^2) with 10 rows. The spacing between rows, plots and blocks were 0.20 m, 0.5 m and 1 m, respectively. By excluding the two outer rows from both sides of a plot and 0.1 m row length on both ends of each plant, row of each plot to avoid border effects resulting in to a net plot size. The blended NPSZnB fertilizer with the formula (17.8%N, 35.7%P_2O_5,7.7%S, 2.2%Zn and 0.1%B) kg ha^{-1} used in this experiment was selected based on the soil information data of ETHioSIS map. Blended NPSZnB fertilizer rates are applied at sowing time for all plots except control. Supplementary nitrogen fertilizer in the form of Urea was applied in two splits times to maintain the N requirement of the crop.

The experimental field was prepared following the conventional tillage practice. Accordingly, experimental field were ploughed four times with oxen to a fine tilth and the plots was leveled manually. As per the design, a field layout was made and each treatment was assigned randomly to the experimental units within a block.

Table 1. Description of Tef varieties used for the study

Description	Agronomic characteristics of varieties and cultivar		
	Local	Negus	Tesfa
Altitude (m.a.s.l)	1750-2232	1800-2650	1800-2650
Rain fall (mm)	1200-1400	950-1800	950-1800
Year of release	Unknown	2017	2017
Seed colors	Mixed	White	White
Seed rate(kg ha^{-1})	10	10	10
Grain yield on station (t ha^{-1})	-	2.4 - 3.3	2.3 - 3.0
Grain yield on farm (t ha^{-1})	0.65 -1.09	2.1- 2.6	2.1 - 2.7

All blended NPSZnB fertilizer rates and half of the urea fertilizer (50 kg ha^{-1}) was applied in basal application at sowing time for all plots and incorporated into the soil. The remaining 50 kg ha^{-1} of urea was applied at mid tillering stage of the crop (30 days after sowing) in the soil as side-dressing (5 cm away from plants) by making a shallow along the teff row to avoid the contact and then covered with soil. All other agronomic practices were properly carried out as per the recommendation of the crop.

Tef seed was sown on August 10, 2020 manually drilled uniformly at the rate of 10 kg ha^{-1} in 2 m long rows at a depth of about 3 cm in each plot placed 20 cm apart and weeds were removed by hand weeding on September 10, 2020 at maximum tillering and booting stages of growth. Harvesting was done manually on December, 2020 using hand sickles when senescence of the leaves took place as well as the grains came out free from the glumes and when pressed between the forefinger and thumb. The harvested total biomass yields were sun dried for three to five days till constant weight. The total dry matter was weighed by using field balance. Threshing and winnowing were done manually on mat. After threshing, the grain yield was weighed using sensitive digital balance.

Each phenological, crop growth, yield and yield related parameters were measured from each net plot across the treatment level by using the following sampling and analytical procedures.

2.3 Data Collected

Days to 50% panicle emergence: 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: Number of days from sowing up to the date when 90% of the plants reached physiological 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.

Plant height: It was measured at physiological maturity from the ground level to the tip of the main shoot panicle on ten pre-tagged random samples of plants in the central rows of the net plot area.

Panicle length: The length of the panicle from the node where the first panicle branches were emerged to the tip of the panicle was measured the main shoot panicle for ten pre-tagged random samples of plants in the central rows of the net plot area.

Number of total tillers: It was counted at physiological maturity by counting all the tillers in 0.5 m length from two central rows of the net plot areas.

Number of productive tillers: It were recorded by counting the tillers from an area of 0.5 m length from two rows of net plot at maturity stage.

1000-seed weight: It were recorded by carefully counting a random sample of the small grains harvested from the net plot area and weighing them using a digital balance.

Dry biomass yield: The weight (kg) of the whole above-ground plant biomass including, leaves, stems, seeds and chaff of all the crops harvested from the net plot area after sun drying was recorded at maturity and was converted as tha^{-1}.

Grain yield: It was taken as the weight (kg) of the grains harvested from the net plot area after threshing and sun-drying to about 12.5% moisture content. It was converted to grain in t ha^{-1}.

Straw yield: After threshing and measuring the grain yield; the straw yield was obtained by subtracting the grain yield from the total above-ground biomass yield.

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

Lodging index: The degree of lodging was assessed just before the time of harvest by visual observation based on the scales of 1-5 where 1 (0-15^o) indicates no lodging, 2 (15-30^o) indicate 25% lodging, 3 (30-45^o) 50% indicate lodging, 4 (45-60^o) indicate 75% lodging and 5(60-90^o) indicate 100% lodging (Donald, 2004). The scales were determined by the angle of inclination of the main stem from the vertical line to the base of the stem by visual observation. Each plot was evaluated 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.

2.4 Statistical Analysis

The collected data were analyzed using the General Linear Model (GLM) procedure (SAS version 9.0) [5]. Mean values were separated according to following the standard procedure given by Gomez and Gomez [6]. Whenever the effects of the treatments were found to be significant, the means were compared using 5% level of Least Significant Difference [7].

2.5 Economic Analysis

Economic analysis was conducted as per the partial budget analysis procedure described by CIMMYT [8]. Economic analysis of Tef production was done to identify the profitability fertilizer rates for the tested Tef varieties. This analysis was performed in order to evaluate the economic feasibility of the treatments at the minimum rate of return 50 to 100% [8]. Grain and straw yield of Tef from experimental plots was adjusted down ward by 10% for management and plot size differences to regulate the difference between the experimental yield and the yield that farmers could expect from the same treatment. Farm gate prices of Tef in Ethiopian birr were the average price of one month from the time of crop harvesting.

Partial budget analysis was done to obtain the highest net benefit and the lowest net benefit return among treatments. The dominant market values of the inputs at the time of use were taken into consideration for working out the cost of cultivation (cost of NPSBZn 19.0871 ETB kg^{-1}, Urea 16.2151 ETB kg^{-1}, Negus and Tesfa and Local Tef seed 37.50 and 29.4 ETB kg^{-1} respectively, market price of Tef grain 41 ETB kg^{-1}, sale price of Tef straw 1.50 ETB kg^{-1}) were considered and other input costs used as constant for all treatments.

3. RESULTS AND DISCUSSIONS

3.1 Dry Biomass Yield

The main effect of NPSZnB fertilizer rates, varieties and interaction of the two factors had highly significant (P<0.001) effect on dry biomass yield of Tef . The maximum (7.34 t ha^{-1}) dry biomass yield was recorded from Tesfa variety while the minimum (6.54 t ha^{-1}) dry biomass yield was obtained from Negus variety (Table 2).

The highest (9.76 t ha^{-1}) dry biomass yield was obtained from Tesfa variety with application of 200 kg NPSZnB ha^{-1} blended fertilizer rate, which statistically similar with Tesfa variety with 150 kg NPSZnB ha^{-1}; and Negus variety with 150 and 200 kg NPSZnB ha^{-1} blended fertilizer rates. While the lowest (2.77 t ha^{-1}) dry biomass yield was recorded from local cultivar at control plots (Table 2). Application of blended 200 kg NPSZnB ha^{-1} fertilizer rates on Tesfa variety produced higher dry biomass, which is 71.62% over the control treatment on local cultivar.

This positive response interaction of blended NPSZnB fertilizer rates with Tesfa variety to dry biomass yield of Tef might be due to increased synthesis and translocation of assimilates to leaves and stems that ultimately increase dry matter yield. This result agreed with Fageria et al. [9] reported that the increase in dry biomass at the highest rates of NPS might have resulted from improved root growth and increased uptake of nutrients favoring better growth of the crop due to synergetic effect of the three nutrients. Similarly, Adera [10] reported that dry biomass yield was significantly affected by application of blended fertilizer.

Table 2. Interaction effect of varieties and blended NPSZnB fertilizer rates on dry biomass yield (t ha^{-1}) of Tef in Haro Limmu district

Varieties	NPSZnB fertilizer rates (kg ha^{-1})					
	0	**50**	**100**	**150**	**200**	**Mean**
Negus	3.02^{e}	5.27^{d}	7.65^{c}	8.33^{abc}	8.45^{abc}	6.54
Tesfa	3.02^{e}	5.55^{d}	8.73^{abc}	9.64^{ab}	9.76^{a}	7.34
Local	2.77^{e}	5.79^{d}	6.07^{d}	7.93^{c}	8.17^{bc}	6.68
Mean	2.93	5.54	7.48	8.64	8.79	
LSD (5%)	1.51					
CV (%)	13.58					

Means with the same letter(s) in the same columns and rows of each parameter are not significantly different at 5% probability level

3.2 Lodging Index

The main effect of NPSZnB fertilizer rates, varieties and interactions of the two factors had highly significant ($P<0.001$) effect on lodging index of Tef (Table 3). The highest lodging index (43.20%) was recorded from local cultivar while the lowest (32.26%) lodging index was obtained from Negus variety. Conventional cultivar is tall in stature and prone to lodging in comparison with the improved genotypes, which are medium in stature and have stiff straw and consequently are less prone to lodging.

The highest lodging index (65.00%) was recorded from local cultivar; which is statistically at parity with Tesfa variety when applied with 200 kg ha^{-1} blended fertilizer rate, while the lowest (9%) lodging index was obtained from Tesfa variety without fertilizer application. Application of blended 200 kg NPSZnB ha^{-1} fertilizer rates on local cultivar led to higher lodging index, which is 86.15% over the control treatment.

The increasing lodging index with increasing blended NPSZnB fertilizer rates could be attributed from an increase of plant height; since plant height and lodging index are positively correlated due to this reason the plants tend to lodge. This may be due to increasing rate of total nitrogen that enhanced fast vegetative growth, plant height and succulent stem elongation of Tef. This result is consistent with the suggestion of Kinfe [11], who reported that excess N application causes high vegetative growth, and enlargement of stem cells that consequently leads to weak stem and lodging. Likewise, Teshome [12], who reported highest lodging of Tef (38.92%) at 150 kg ha^{-1} of blended fertilizer rates.

Similarly, Fayera et al. [13] reported that the highest (79.74%) lodging percentage of Tef was recorded in the highest rate of NPK application though the rate reported earlier is much higher (138 kg N/ha+55 kg P/ha) than the present result. Although lodging does little harm to total biomass yield, it is known to cause serious economic losses by reducing yield and quality of both grains and straw in small grains particularly Tef as reported by Kebebew [14].

3.3 Grain Yield

Grain yield is the result of different inputs, agronomic practices, environment effects and genetic differences. The main effect of blended NPSZnB fertilizer rates and interaction of the two factors had highly significant ($P<0.001$) effect on grain yield of Tef and main effect of varieties had significant ($P<0.05$) effect on grain yield of Tef (Table 4). The highest (1.57 t ha^{-1}) grain yield was recorded from Tesfa variety while the lowest (1.27 t ha^{-1}) grain yield was obtained from local cultivar (Table 4). This is because of genotypic deferential in terms of yielding ability. As compared to other varieties and Tesfa is high yielding than local cultivar.

The interaction of blended NPSZnB fertilizer and varieties were significantly affected the mean grain yield of Tef. Significantly, a higher (2.62 and 2.34 t ha^{-1}) grain yield was recorded from Tesfa variety with application of 150 and 200 kg NPSZnB ha^{-1} blended fertilizer rates respectively; while the lowest (0.23 t ha^{-1}) grain yield was obtained from Tesfa variety at control plots (Table 4). Tesfa variety with 150 and 200 kg NPSZnB ha^{-1} blended fertilizer produced a higher grain yield, which exceeds by 91.22% and 90.17% over unfertilized Tesfa variety. Grain yield of Tef showed the progressive increments

Table 3. Interaction effect of varieties and blended NPSZnB fertilizer rate on lodging index (%) of Tef in Haro Limmu district

Varieties	NPSZnB fertilizer rates (kg ha^{-1})					
	0	50	100	150	200	Mean
Negus	10.66^{fg}	24.66^{ef}	38.66^{cde}	49.00^{bc}	40.00^{cd}	32.26
Tesfa	9.00^{g}	25.33^{def}	43.33^{bc}	48.33^{bc}	55.00^{ab}	36.53
Local	12.00^{fg}	39.00^{cde}	47.00^{bc}	53.00^{abc}	65.00^{a}	43.20
Mean	10.55	29.66	43.00	50.10	53.33	
LSD (5%)	14.98					
CV (%)	23.99					

Means with the same letter(s) in the same columns and rows of each parameter are not significantly different at 5% probability level

on all varieties with increased application of blended NPSZnB fertilizer rates up to 150 kg NPSZnB ha^{-1}. However, further application of beyond 150 kg NPSZnB ha^{-1} fertilizer showed a declining trend on Tef grain yield due to attributed to excess supply of the nutrient that favors more vegetative growth of plant parts leading to lodging before the translocation of dry matter to grain.

The higher Tef yield obtained might be due to the synergic effect of optimum level of nutrient and improved variety of Tef. These might have increased nutrients availability, photosynthesis, and greater mobilization of photosynthates towards reproductive structures of improved variety Tesfa, which contributed to respond and produce higher yields than unfertilized plots. In conformity Kinfe (2019) reported that the highest grain yield (2269.80 kg ha^{-1}) was obtained from plots treated with 150 kg NPS ha^{-1} plus basal application of Zinc and Boron which increased over the control by 321.42% and lowest (538.60 kg ha^{-1}) was found from control. Likewise, Teshome (2018) reported that application of 100 kg NPSZnB ha^{-1} fertilizer produced the highest (1386.5 kg ha^{-1}) grain yield of Tef, while the lowest (1085.8 kg ha^{-1}) grain yield was obtained under the control treatment.

3.4 Straw Yield

The straw yield of Tef was significantly affected by the main factors of varieties ($p<0.05$), blended NPSZnB fertilizer rate ($p<0.001$) and the interaction of blended NPSZnB fertilizer with varieties ($p<0.001$) (Table 5). The highest (5.75 t ha^{-1}) grain yield was recorded from Tesfa variety while the lowest (4.43 t ha^{-1}) grain yield was obtained from local cultivar (Table 5). This difference in straw yield might be due to the genetic makeup of the varieties.

The highest (7.42 t ha^{-1}) straw yield was recorded from Tesfa variety with application of 200 kg NPSZnB ha^{-1} blended fertilizer rate, which was statistically at par with 100 and 150 kg NPSZnB ha^{-1} on the same variety and Negus variety and local cultivar with 150 and 200 kg NPSZnB ha^{-1} fertilizer rate. While the lowest (0.23 t ha^{-1}) straw yield was obtained from local cultivar with unfertilized plots (Table 5). Application of blended 200 kg NPSZnB ha^{-1} fertilizer on Tesfa variety gave 96.78% higher straw yield over NPSZnB un-fertilized treatment with local cultivar. The increment of straw yield could be due to the vegetative growth as the result of high N-level from 200 kg NPSZnB ha^{-1} and the synergic effect with improved variety. The highest plant height and tillers also have great contribution to higher straw yield. Therefore, low straw yield in unfertilized plots might have been due to reduced leaf area development resulting in reduced radiation interception and, consequently, low efficiency in the conversion of solar radiation.

This result agreed with Teshome [12] who reported that straw yield of Tef was significantly affected by application of blended fertilizer which exceeds 7% and 490% over the recommended NP and control plots respectively. Similarly, Tekle and Wassie [15] reported that straw yield of Tef was found to be highest in blended fertilizers as compared to control treatments and recommended rate blanket NP applications. Likewise, Fayera et al. [13], who reported that the highest (5852.8 kg ha^{-1}) straw yield of Tef was obtained in response to the application of higher rates 200 kg NPSZnB $ha^{-1}$of blended fertilizer application. Straw yield of Tef has to be considered while evaluation of any agronomic practice as its importance has become as equal as its grain yield as it is preferred as animal feed during dry period and also sold at reasonable price.

Table 4. Interaction effect of varieties and blended NPSZnB fertilizer rates on grain yield (t ha^{-1}) of Tef in Haro Limmu district

Varieties	NPSZnB fertilizer rates (kg ha^{-1})					
	0	50	100	150	200	Mean
Negus	0.39^{ef}	0.83^{de}	1.86^{c}	1.98^{bc}	1.70^{c}	1.35
Tesfa	0.23^{f}	0.87^{d}	1.78^{c}	2.62^{a}	2.34^{ab}	1.57
Local	0.39^{ef}	1.03^{d}	1.58^{c}	1.82^{c}	1.54^{c}	1.27
Mean	0.34	0.91	1.74	2.14	1.86	
LSD (5%)	0.43					
CV (%)	18.67					

Means with the same letter(s) in the same columns and rows of each parameter are not significantly different at 5% probability level

Table 5. Interaction effect of varieties and blended NPSZnB fertilizer rates on straw yield (t ha^{-1}) of Tef in Haro limmu district

Varieties	NPSZnB fertilizer rates (kg ha^{-1})					
	0	50	100	150	200	Mean
Negus	0.26^{e}	4.44^{d}	5.79^{bcd}	6.35^{ab}	6.70^{ab}	5.18
Tesfa	0.27^{e}	4.64^{cd}	6.90^{ab}	7.02^{ab}	7.42^{a}	5.75
Local	0.23^{e}	4.76^{cd}	4.48^{d}	6.07^{abc}	6.62^{ab}	4.43
Mean	0.76	4.61	5.72	6.48	6.91	
LSD (5%)	1.43					
CV (%)	16.35					

Means with the same letter(s) in the same columns and rows of each parameter are not significantly different at 5% probability level

3.4 Harvest Index

Harvest index is the physiological ability of a cultivar to convert the dry matter into economic yield. The main effects of NPSZnB blended fertilizer rates ($p<0.001$), varieties ($p<0.05$) and interactions of the two factors ($p<0.001$) significantly affected harvest index of Tef (Table 6).

The highest (27.10%) harvest index was recorded from Tesfa variety with application of 150 kg NPSZnB ha^{-1}, which was statistically at par with the same variety with 200 kg NPSZnB ha^{-1} and local cultivar with 100 and 150 kg NPSZnB ha^{-1} fertilizer rate; while the lowest (8.12%) harvest index was recorded from Tesfa variety with control plots (Table 6). Application of blended 150 kg NPSZnB ha^{-1} fertilizer on Tesfa variety gave higher harvest index 70.03% over the control treatment. The higher harvest index recorded from an application of 150 kg NPSZnB ha^{-1} fertilizer might be due to greater photo assimilates production and its ultimate partitioning to the grains compared to the partition to the straw at the optimum supply of blended NPSZnB fertilizer rate with new variety that can increase thousand seed weight. This result agrees with Tekle and Wassie, [15] who reported that harvest index of Tef was found to be highest in blended fertilizer treatments.

3.5 Thousand Seed Weight

The main effect of varieties, blended NPSZnB fertilizer rates and interactions of the two factors had highly significant ($P<0.001$) effect on thousand seed weight (Table 7). The highest (0.32 g) thousand seed weight was recorded from Tesfa variety, while the lowest (0.24 g) thousand seed weight was obtained from local cultivar (Table 7). This could be due to difference in grain filling period of the varieties as a result it leads to decrease grain weight of Tef.

The highest (0.42 g and 0.40 g) 1000-seed weight were obtained from Tesfa variety with application of 150 and 200 kg NPSZnB ha^{-1} respectively, which is statistically at par with Negus variety at 200 kg NPSZnB ha^{-1} blended fertilizer rate, while lightest (0.16 g) thousand seed weight were recorded from local cultivar at unfertilized plots (Table 7). When the blended fertilizer is optimum for plant utilization, a major part of the product of photosynthesis is retained

Table 6. Interaction effect of varieties and blended NPSZnB fertilizer rates on harvest index (%) of Tef in Haro Limmu district

Varieties	NPSZnB fertilizer rates (kg ha^{-1})					
	0	50	100	150	200	Mean
Negus	13.34^{fg}	15.84^{ef}	25.38^{abc}	23.83^{abcd}	20.60^{bcde}	19.80
Tesfa	8.12^{g}	16.43^{ef}	20.70^{bcde}	27.10^{a}	24.20^{abcd}	19.31
Local	14.45^{efg}	18.24^{def}	26.30^{ab}	24.00^{abcd}	19.06^{cdef}	20.41
Mean	11.97	16.83	24.12	24.97	21.28	
LSD (5%)	6.39					
CV (%)	19.26					

Means with the same letter(s) in the same columns and rows of each parameter are not significantly different at 5% probability level

in the shoot for the generation of shoot tissue and filling of the food stored by translocation of assimilation from the shoot to the grain. Under such conditions only a minor fraction of assimilates will be diverted to the root while the rest is utilized mostly for production of economic yield.

Thousand seed weight is an important yield determining component which is reported to be a genetic characteristic of a plant and therefore rarely influenced by the environmental factors. This result is in harmony with Tekle and Wassie [15] who reported that the application of blended fertilizers significantly increased thousand seeds weight as compared to the control.

3.6 Pearson Correlation between Phenology, Growth, Yield and Yield Components of Tef

Correlation analysis results revealed that the days to 50% heading was positively and significantly correlated with days to 90% physiological maturity (0.61). There was a significant and positive correlation between growth, seed yield and yield components of Tef. Significantly positive associations of grain yield with effective number of tillers produced per plant (0.82), total number of tillers produced per plant (0.82), dry biomass yield (0.89), lodging index (0.78), harvest index (0.86) plant height (0.79), panicle length (0.68), straw yield (0.80) and thousand seed weight (0.82) (Table 8).

These observed positive correlation between grain yield and parameters like, plant height, panicle length, total number of tillers, effective number of tillers, dry biomass yield, thousand seed weight and harvest index indicated the application of appropriate level of blended NPSZnB fertilizer with the suitable strains when combined with improved variety could result in improvement of the above parameters which contributed grain yield improvement. The result shows that the applied fertilizers have positive contribution to the economic yield. This result was supported by the recent findings of Teklay and Girmay [16] who reported that strong significant positive correlation of grain yield with plant height, panicle length, panicle seed weight, straw yield and harvest index was observed on Tef.

This means that with increasing value of these traits, the grain yield increases and vice versa. In addition, grain yield had non-significant and negative correlation with days to 50% heading (-0.70) and days to physiological maturity (-0.43). In a previous study, similar results have been reported by Amare and Mulatu [17].

3.7 Economic Feasibility of Blended NPSZnB Fertilizer Rates on Net Profitability of Tef Production

The improved variety with application of optimum blended NPSZnB fertilizer rate treatments resulted in higher net benefits than the local cultivar with below and above optimum application of NPSZnB blended fertilizer rate. Application of blended 150 kg NPSZnB ha^{-1} of fertilizer Tesfa variety gave the highest net benefits (ETB 83229.4 ha^{-1}) with a marginal rate of return of (1553.71%). In contrast, the lowest net benefit of (13572 ETB ha^{-1}) was obtained from Tesfa variety with control plots (Table 9). This implies that farmers in the study area would be better of applying blended 150 kg NPSZnB ha^{-1} fertilizer rate on Tesfa variety to increase Tef grain yields and income of the farmers.

Table 7. Interaction effect of varieties and blended NPSZnB fertilizer rates on thousand seed weight (g) of Tef in Haro Limmu district

Varieties	NPSZnB fertilizer rates (kg ha^{-1})					
	0	50	100	150	200	Mean
Negus	0.18^{g}	0.23^{f}	0.31^{cd}	0.35^{b}	0.38^{ab}	0.29
Tesfa	0.18^{g}	0.25^{ef}	0.34^{bc}	0.42^{a}	0.40^{a}	0.32
Local	0.16^{g}	0.25^{ef}	0.24^{f}	0.26^{def}	0.28^{de}	0.24
Mean	0.17	0.24	0.29	0.34	0.35	
LSD (5%)	0.04					
CV (%)	9.38					

Means with the same letter(s) in the same columns and rows of each parameter are not significantly different at 5% probability level

Table 8. Estimate of correlation coefficients among response of Tef varieties across various blended fertilizer rates

	DH	DPM	PH	PL	TNT	ET	LI	DBY	GY	SY	HI	TSW
DH												
PM	0.61											
PH	-0.54^{**}	-0.36^{*}										
PL	-0.42^{*}	-0.24	0.90^{**}									
TNT	-0.64^{**}	-0.54^{**}	0.67^{**}	0.54^{**}								
ET	-0.65^{**}	-0.56^{**}	0.67^{**}	0.55^{**}	0.99^{**}							
LI	-0.58^{**}	-0.35^{*}	0.82^{**}	0.75^{**}	0.54^{**}	0.55^{**}						
DBY	-0.76^{**}	-0.52^{**}	0.78^{**}	0.65^{**}	0.77^{**}	0.77^{**}	0.79^{**}					
GY	-0.70^{**}	-0.43^{*}	0.79^{**}	0.68^{**}	0.82^{**}	0.82^{**}	0.78^{**}	0.89^{**}				
SY	-0.75^{**}	-0.52^{**}	0.73^{**}	0.60^{**}	0.71^{**}	0.71^{**}	0.76^{**}	0.98^{**}	0.80^{**}			
HI	-0.52^{**}	-0.24	0.64^{**}	0.57^{**}	0.61^{**}	0.61^{**}	0.65^{**}	0.61^{**}	0.86^{**}	0.47^{**}		
TSW	-0.75^{**}	-0.66^{**}	0.69^{**}	0.54^{**}	0.86^{**}	0.86^{**}	0.64^{**}	0.86^{**}	0.82^{**}	0.83^{**}	0.56^{**}	

*Where, DH=Days to 50% heading, DPM=Days to Physiological maturity, PH=Plant height in centimeter, PL= length in centimeter, TNT=Total number of tillers, ET=Effective tillers, LI=Lodging index, DBY= dry biomass yield, SY=Straw yield, HI=Harvest index, TSW=Thousand seed weight, ** and * correlation is significant at 1% and 5% level of significance, respectively*

Table 9. Summary of economic feasibility analysis of Tef varieties as influenced by blended NPSBZn fertilizer rates

Fertilizer rates (kg ha^{-1})		AGY	ASY	TR	TVC	NR	ΔTVC	ΔNR	MRR (%)
NPSBZn	Urea	(t ha^{-1})	(t ha^{-1})	(ETB ha^{-1})	(ETB ha^{-1})	(ETB ha^{-1})			
0	0	0.30	0.68	13572	0	13572	0		
50	46	0.82	4.15	39804	2575.8	37228.2	2575.8	23656.2	918.4
100	46	1.56	5.15	71931	3530.4	68400.8	954.4	31172.6	3266.2
150	46	1.92	5.83	87714	4484.6	83229.4	954.2	14828.6	1553.71
200	46	1.67	6.22	77964	5438.9	72525.1	954.3	-10704.3	D

Where, Cost of NPSBZn 19.087 ETB kg^{-1}, Urea 16.215 ETB kg^{-1}, Negus seed and Tesfa 37.5 ETB kg^{-1} and Local 29.4 kg^{-1}, Sale price of Tef grain 41 ETB kg^{-1}, Sale price of Tef straw 1.5 ETB kg^{-1}, AGY=Adjusted grain yield by 10% down in t ha^{-1}, ASY=Adjusted straw yield by 10% down in tha^{-1}, D = Dominated

This result was in line with Firehiwot, [18] who reported that estimated net income for mineral fertilizer is attractive as compared to growing wheat without application of fertilizer. Similarly, Yared et al. [19] reported that the highest net benefit 46996.74 ETB ha^{-1} with MRR of 45110.56% was obtained in response to application of 69/69 kg NP ha^{-1}. However, the lowest net benefit ETB 26874.99 ha^{-1} was obtained from the treatment without application of both N and P fertilizer. Therefore, application of blended 150 kg NPSZnB ha^{-1} fertilizer rate with using improved variety Tesfa was economically profitable and recommended for Tef production in the study area and similar agro ecologies.

4. CONCLUSIONS

To conclude, the varieties and blended NPSZnB fertilizer rates affect all phenology, growth, yield and yield related parameters of Tef. Among the varieties used for study Tesfa variety is the best performing in the study area. Application of blended 150 kg NPSZnB ha^{-1} fertilizer rate on Tesfa variety improved growth, yield and yield components of Tef; and produced highest yield (2.62 t ha^{-1}) with net benefit of ETB 83229.4 ha^{-1} and with a marginal rate of return (1553.71%) in the study area. Therefore, Tesfa variety with application of 150 kg NPSZnB ha^{-1} blended fertilizer rate was recommended for the study area. However, in the absence of Tesfa variety, Negus variety with 150 kg NPSZnB ha^{-1} fertilizer rate can be considered an alternative variety to be recommended for the farmers in Haro Limu district and other areas with similar agro-ecological conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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