

*Full Length Research Paper*

# **Validation of blended NPSB fertilizer rates on yield, yield components of Teff [*Eragrostis tef* (Zuccagni) Trotter] at vertisols of Hatsebo, Central Tigray, Ethiopia**

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Application of unbalanced nutrition was the main yield limiting factor in the study area. Hence, an experiment was conducted during the 2017 cropping season on farmers' fields to validate and determine optimum blended fertilizer rate for teff production. Eight levels of NPSB (0, 25, 50, 100, 150, 200, 250 and 300 kg ha<sup>-1</sup>) and recommended NP (100 kg ha<sup>-1</sup> urea and 100 kg ha<sup>-1</sup>TSP) were used as treatments and set in randomized complete block design with three replications. All the fertilizers were applied at planting but nitrogen was top dressed in two time split. Surface soil samples was collected before teff sowing and after harvest; with total nitrogen, available phosphorus, extractable sulfur and boron found to be at low level. Application of different blended NPSB fertilizer rates significantly affected crop phenology, yield and yield components of teff. Highest mean teff grain yield (2803.09 kg ha<sup>-1</sup>) was obtained in response to 250 kg ha<sup>-1</sup>NPSB with 62.5 and 33.4% yield increment over the control and recommended NP. Similarly, the highest straw yield was also obtained from plot treated with that rate and it has 80 and 44.4% yield increment over the control and the recommended NP, respectively. The partial budget analysis also revealed that marginal rate of return was highest (1179.5%) at a rate of 250 kg ha<sup>-1</sup>NPSB+46 kg N ha<sup>-1</sup> from which better biomass and economic advantage was attained. Hence it could be concluded that it is possible for optimum teff yield to be attained using 250 kg ha<sup>-1</sup>NPSB+46 kg N ha<sup>-1</sup>.

**Key words:** *Eragrostis tef*, blended fertilizer, yield components, NP fertilizer, Laelay Maichew.

## **INTRODUCTION**

*Teff* (*Eragrostis tef*) is endemic to Ethiopia and its major diversity is found only in Ethiopia. As with several other crops, the exact date and location for the domestication of *teff* is not known. However, there is no doubt that it is a very ancient crop in Ethiopia, where domestication took

place before the birth of Christ (Seyfu, 1997). Vavilov (1951) has identified Ethiopia as the center of origin and diversity of *teff*. Hence, Ethiopia is the appropriate and most important center for the collection of *teff* germplasm (Seyfu, 1993). When compared with other food crops

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grown in the country, it is highly-valued by farmers and consumers because *teff* is nutritionally rich and free of protein gluten (Ketema, 1991; Hailu and Seifu, 2001; Merga, 2018).

Soil fertility reduction is one of the major challenges to crop production and productivity in Ethiopia (Amsal and Tanner, 2001). Even the unparalleled rise in population is the root cause of the soil fertility reduction, soil erosion, over cultivation of farm land, inadequate applications of organic and inorganic fertilizers, decreasing or abandoning of useful traditional soil restoration practices and is also one of the causes of declining soil fertility (Hirpa et al., 2009).

A variety of studies were conducted by various organizations to explore fertility status of Ethiopian soils and concluded that, N and P nutrients were the only limiting nutrients in most Ethiopian soils (Assefa et al., 2016). Subsequently, crop response experiments to fertilizers conducted on-stations and on-farmers' fields revealed that applications of these inputs have appreciably improved the yields of crops and thus the use of N and P fertilizers by farmers have been recommended (NFSAP, 2007). Application of fertilizers containing N and P [urea and diammonium phosphate (DAP)] as a blanket recommendation [(100 kg DAP (18-46-0) and 100 kg urea (46-0-0)] began in the late 1960s (Wassie and Tekalign, 2013) to improve the productivity of the soil. However, this blanket fertilizer recommendation failed to take into consideration differences in resource endowment (soil type, labor capacity, climate risk) or make allowances for dramatic changes in input/output price ratio, thereby discouraging farmers from fertilizer application. Moreover, the nutrients in the blanket recommendation are not well balanced for agronomic improvement and its continued use gradually exhausted soil organic matter (IFPRI, 2010).

Depletion of soil nutrients other than N and P could be additional reason for the observed decrease in yield gains (Wassie and Tekalign, 2013). The soil fertility mapping project in Ethiopia reported that deficiency of K, S, Zn, B and Cu in addition to N and P in major Ethiopian soils were common (Ethio-SIS, 2014). Similarly, seven soil nutrients (N, P, K, S, Fe, Zn and B) were found to be deficient in the soils Tigray region (Ethio SIS, 2014).

Balanced fertilizers containing these deficient nutrients in blend form have been recommended to solve site specific nutrient deficiencies and thereby increase crop production and productivity (ATA, 2014). By considering the extent of deficiency of the 7 soil nutrients; it was found that Tigray soils require more fertilizer types. The major recommended blended fertilizers for Tigray region are NPS, NPSB, NPSZn, NPSZnB, NPSFeZn and NPSFeZnB (EthioSIS, 2015).

Apart from the blanket recommendation of nitrogen and phosphorus, the effect of other fertilizers on yield, yield components, and overall performance of *teff* were unknown, even though new blended fertilizers such as NPSB (18.7N + 37.4 P<sub>2</sub>O<sub>5</sub> + 6.9 S + 0.25 B) (ATA, 2014)

are currently being used by the farmers in the study area. In addition to this, the amount of N in the blended NPSB is small as compared to the requirement of *teff*. Thus, there is need to supplement with nitrogenous fertilizer in the form of urea.

Laelay Maichew district is one of the Tigray districts included in the EthioSIS fertilizer recommendation. Accordingly Hatsebo kebele soil has N, P, S and B nutrients deficiency; as a result, the NPSB blended fertilizer type is recommended to improve sustainable soil production of the kebele (EthioSIS, 2014). Therefore, this study was conducted to validate and determine the optimum rate of the newly recommended blended NPSB fertilizer type at kebele level for optimum *teff* production.

## MATERIALS AND METHODS

### Description of the study area

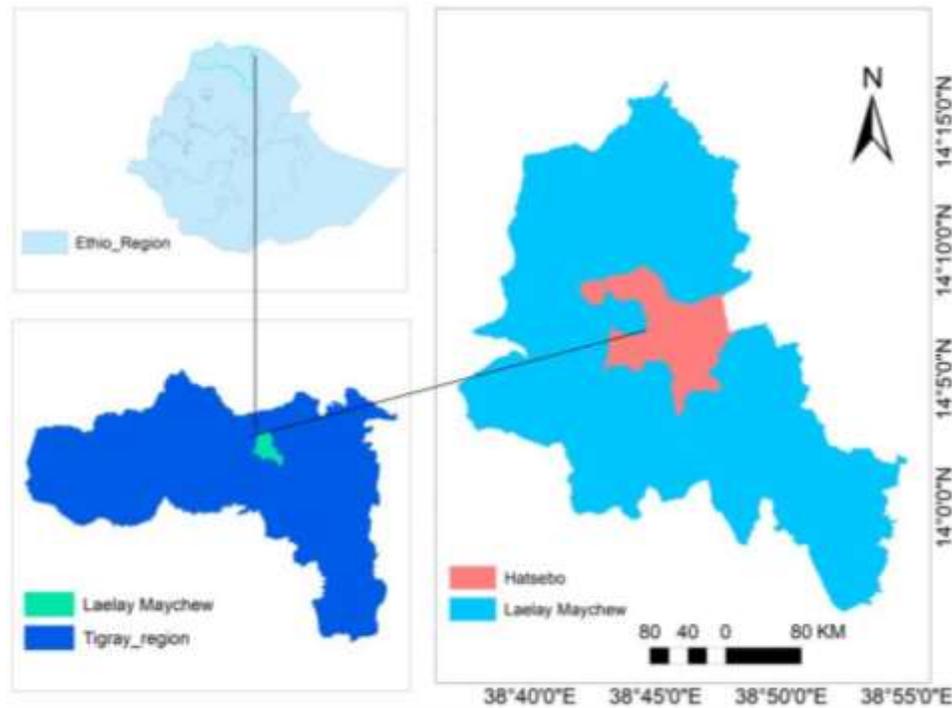
The study was conducted in Central Zone of Tigray Region, at Laelay Maichew district, Hatsebo kebele, on farmers' fields in 2017 main cropping season. Hatsebo kebele is located at 14° 05' 29.22" N and 38° 46' 48.67" E (Figure 1) towards east just about 5 km away from the Axum city (zone capital city), 260 km from Mekelle (the capital city of Tigray region) and 1025 km from Addis with elevation of 2078 masl. Soils of Hatsebo kebele are dominant by black Soil/Vertisols, which covers about 40% of the total area. Others are 21% red clay soil, 19% loam soil and the rest 20% course textured soil according to the classification made by FAO guideline for soil profile description (FAO, 2014).

The soil is low in soil organic matter content and macro-nutrients such as N, P, and S and micro nutrient B (EthioSIS, 2014). The area is characterized by mixed farming crop-livestock production system. Most of the middle altitude crops such as *teff* (*E. tef*), wheat (*Triticum aestivum*), fababean (*Vicia faba* L.), and chickpea (*Cicer arietinum* L.) are commonly grown in most parts of the district. The area is characterized by mono modal rainfall pattern and received annual rainfall of 783 mm with average annual maximum and minimum temperatures of 28 and 13°C, respectively during the cropping season (Figure 2). According to the ten year meteorological data, the annual rainfall of the area ranges from 547 to 1027 mm (Figure 3).

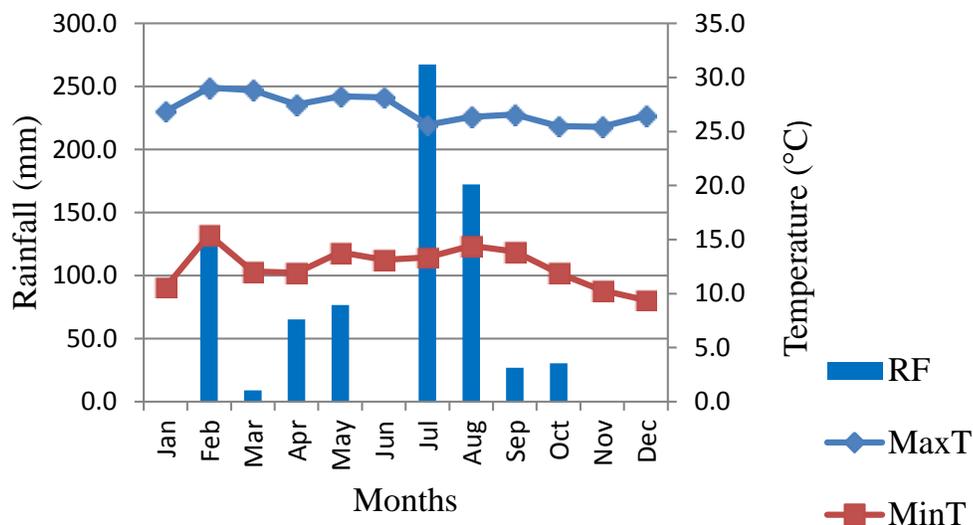
### Experimental procedures, layout and treatments

The experiment was laid out in randomized complete block design (RCBD) with nine treatments, eight levels of NPSB and one NP (0, 25, 50, 100, 150, 200, 250, 300 kg NPSB ha<sup>-1</sup> and blanket recommended NP at rate of 64 kg N ha<sup>-1</sup> and 46 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>). The plot size was 3 m x 3 m replicated three times. The spacing between replication and plots was 1 m and 0.5 m respectively. The plots in each replication were represented randomly for each treatment.

The eight blended NPSB fertilizer rates were compared to each other and with the blanket recommended NP fertilizer to determine one best fitted rate. Since, nitrogen is the most limiting factor for plant growth and is found in a very low amount in the blended fertilizer (46 kgNha<sup>-1</sup>), it was top dressed in two split (1/3 at 14 days after planting and 2/3 at 45 days after planting) for all treatments except for control and recommended NP but blended fertilizers was applied at sowing time. The test crop was also planted in rows with 1 m x 0.5 m x 20 cm spacing between blocks, plots and row plants



**Figure 1.** Location map of the study area.



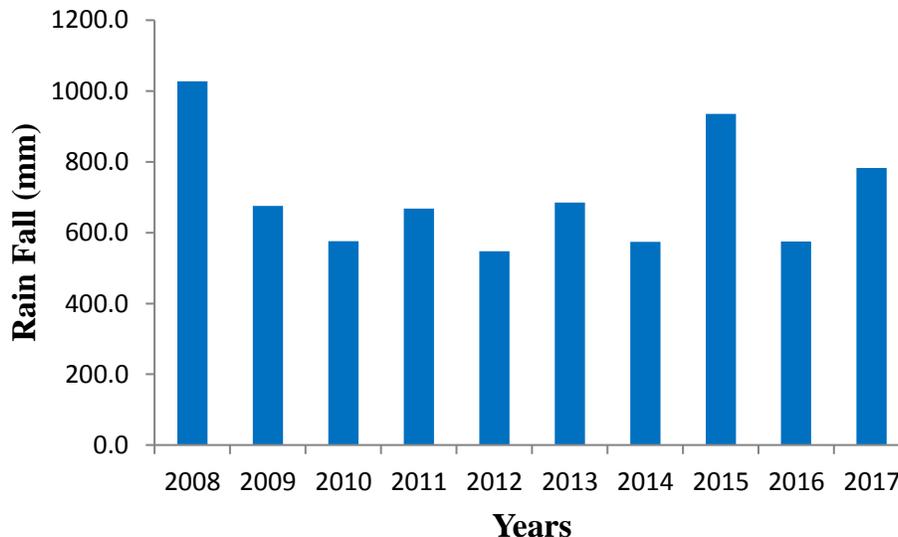
**Figure 2.** Rainfall, maximum and minimum temperatures recorded during the cropping season. Source: EMSA (Ethiopian Meteorological Service Agency) Tigray branch (2017).

respectively. Quncho variety was tested at seed rate of 5 kg. All crop management practices were applied as per the recommendation for the *teff* crop.

#### Soil sampling and preparation

One fresh profile with 1.5 m width by 1.5 m length and 2 m depth

was opened for the experimental field. Samples were taken from all identified layers for characterization of selected physical and chemical properties according to FAO guidelines (FAO, 2014). One disturbed composite soil sample was collected at 0-20 cm depth based on zigzag sampling method before planting to assess what the soil had and 27 representative soil samples were collected after harvest from the total of 27 experimental plots using zigzag sampling method from 0-20 cm depth. The collected soil samples



**Figure 3.** Ten years annual rainfall of the study area.  
Source: EMSA (Ethiopian Meteorological Service Agency) Tigray branch (2017).

after harvested were analyzed for TN, available P, extractable S and Extractable B.

The collected samples were properly labeled, packed and transported to Mekelle Soil Research Center Laboratory. The surface and profile soil samples collected from the experimental field were air-dried, crashed and allowed to pass through 2-mm sieve; and for further analysis of TN and OC, were allowed to pass through 0.5-mm sieve (FAO, 2008).

### Soil analysis

Soil samples collected before planting were subjected to analysis of texture, bulk density, pH, EC, OC, TN,  $P_{av}$ ,  $S_{ext}$ ,  $B_{ext}$  and Cation Exchange Capacity (CEC) and after harvest were analyzed for T N, OC,  $P_{av}$ ,  $S_{ext}$  and  $B_{ext}$  following the standard procedure.

### Data collection and measurements

**Grain yield (t/ha):** Grain yield data for each plot was recorded by weighing the grain harvested from each net plot after trashing/separating the seed from its straw and after the seeds were thought to be completely dried and finally the result was converted to quintals per hectare.

**Straw yield (kg/ha):** Straw yield was calculated by subtracting grain yield from the total above ground biomass (biomass yield) from each net plot. After that it was converted to quintals per hectare.

**Lodging index (LI):** This was estimated using the method of Caldicott and Nutall (1979) which gives an index based on both the degree (angle of leaning) on a 0-5 scale and severity percent for each degree of lodging.

### Data analysis

The collected agronomic data were subjected to statistical analysis

like analysis of variance. Analysis of variance (ANOVA) was performed using SAS version 9.1 (SAS, 2009) statistical software programs. Significant difference between and among treatment means was assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez, 1984).

### Economic analysis

Economic analysis was performed using partial budget analysis to investigate the economic feasibility of the treatments which were tested in the experiment. Marginal rate of return (MRR) was calculated as the change in net revenue (NR) divided by the change in total variable cost (TVC) of the successive treatments (CIMMYT, 1988). Labor cost was calculated as 60 ETB per day per person and revenue was calculated by assuming 23.8 ETB  $kg^{-1}$  of *teff* grain yield, 3.1 ETB  $kg^{-1}$  for straw yield and costs of fertilizers (1457.20 ETB NPSB, 1251.65 ETB urea, and 1667.10 ETB TSP) per 100 kg of each was calculated based on the last year price. According to this manual, experimental yields are often higher than the yields that farmers could expect using the same treatments; hence in economic calculations, researchers have judged that farmers using the same technologies would obtain yields adjusted by 10% lower than those obtained by the researchers if the experiments are planted on representative farmers' fields (CIMMYT, 1988).

## RESULTS AND DISCUSSION

### Soil characteristics of the study area

#### Soil physical properties

Particle size analysis results of the study area indicates that, clay particles dominated the soil and its textural class was categorized as clayey, with a percentage of sand (16%), silt (26%) and clay (58%) (Table 1).

**Table 1.** Selected physical and chemical properties of the soil before sowing.

S/N	Parameter	Value	Rating	Source
1	BD (gcm <sup>3</sup> )	1.34	Good soil	Hazelton and Murphy (2007)
2	Sand (%)	16		
3	Silt (%)	26		
4	Clay (%)	58		
5	Texture class	Clayey		
6	pH(H <sub>2</sub> O)	7.1	Neutral	Tekalign (1991)
7	EC(dSm <sup>-1</sup> )	0.41	Low/non saline	London (1991)
8	OC (%)	0.64	Low	Tekalign (1991)
9	TN (%)	0.091	Very low	Tekalign (1991)
10	P <sub>av</sub> (mg kg <sup>-1</sup> )	4.17	Very low	Olsen et al. (1954)
11	S <sub>ext</sub> (mg kg <sup>-1</sup> )	4.28	Low	Hazelton and Murphy (2007)
12	B <sub>ext</sub> (mg kg <sup>-1</sup> )	0.319	Low	Berger and Truog (1939)
13	CEC cmol(+)/kg <sup>-1</sup>	56.4	Very high	Landon (1991)

BD= Bulk density, pH= Power of hydrogen, EC= Electrical conductivity, OC= Organic carbon, TN= Total nitrogen, P<sub>av</sub>= Available phosphorus, S<sub>ext</sub>= Extractable sulfur, B<sub>ext</sub>= Extractable boron and CEC= Cation exchange capacity.

Therefore, according to FAO (2014) report, the soil is categorized as vertisols. In line with this study, Berhanu (1985) reported that Vertisols in Ethiopia generally contain more than 40% clay in their surface horizons. Bulk density of the experimental soil was also found to be 1.34 gcm<sup>-3</sup> before sowing *teff* (Table 1). The soil of the study area is found to be good for cereal crops root development, because bulk density is below the critical value (1.4 g cm<sup>-1</sup>) restricting plant root development (Hazelton and Murphy, 2007).

Generally, according to Lal (1979), the normal range of soil physical properties in relation to plant growth are bulk density: 0.7-1.8 gcm<sup>-3</sup>, porosity: 0.3-0.7 m<sup>3</sup>m<sup>-3</sup>, and volumetric soil moisture content: 0-70%. Therefore, soil of the study area was within the range of good soil for crop production.

### Soil chemical properties

The pH value of the study area was found 7.1 (Table 1). According to London's (1991) ratings, soils having pH value in the range 5.5 to 7.5 are considered suitable for most agricultural crops. Therefore, the soil of the area lied at this range. Similarly, the electrical conductivity of the area before sowing was 0.41 dsm<sup>-1</sup> and this indicates a non-saline soil (Marx and Stevens, 1999). In line with this findings, London (1991) also reported that the EC value measured at 0.41 dsm<sup>-1</sup> level indicates the concentration of soluble salts are below the levels at which growth and productivity of most agricultural crops are affected due to soil salinity.

The OC and TN in soil before sowing was 0.64 and 0.091% respectively (Table 1). According to the Tekalign (1991) rating, OC and TN of the study area were rated as low and very low respectively. Low TN content of the soil

could also be attributed to the low soil OC content. Whenever the soil has C: N ratio less than 25:1, it goes through mineralization (Mohanty et al., 2011). Accordingly, the soil of the study area has good mineralization rate, because the C: N ratio is 7:1 which thereby improves nutrients availability for plant growth.

There was low available P before sowing (4.17 mg kg<sup>-1</sup>) which was rated as very low (Olsen et al., 1954). Therefore, the area demands high amount of available P from applied NPSB fertilizers. The extractable S and B values before sowing were 4.28 and 0.319 mg kg<sup>-1</sup>, respectively (Table 1). Soil S<sub>ext</sub> was found to be low in rating as suggested by Hazelton and Murphy (2007). The low soil sulfur in the study area may be due to its low OC content in line with Shaun et al. (2012) who indicated that the lower organic matter contents cause more likely S decreasing. Similar to N and P, S was also the limiting nutrient for optimum crop production on soils of the study site (EthioSIS, 2015). Based on the rating suggested by Berger and Truog (1939), the experimental area is also deficient in B. The cation exchange capacity of the soil before sowing was 56.4 cmol(+)/kg<sup>-1</sup> which is very high (Landon, 1991). High CEC of the soil should be due to higher clay content of the soil as the soil OC content was found very low for the study site.

Total nitrogen content after harvest was highly influenced by the applied levels of the fertilizers. The higher N was obtained at the higher treatment levels (Table 2) and the residual amount of TN was rated as low (Tekalign, 1991). This might be due to the lodging effect and decreased uptake beyond 250 kgha<sup>-1</sup>NPSB.

There was highly significant difference among the treatments effect on P levels after harvest. The higher available P<sub>av</sub> (8.13 mg kg<sup>-1</sup>) was obtained at 300 kgha<sup>-1</sup>NPSB and this was higher than the P that was available before sowing (Table 2). This was due to residual effect

**Table 2.** Residual soil chemical properties of the soil after harvest.

Treatment (NPSB-N) (kg ha <sup>-1</sup> )	TN	P <sub>av</sub>	S <sub>ext</sub>	B <sub>ext</sub>
0-0	0.041 <sup>cd</sup>	2.597 <sup>ed</sup>	0.708 <sup>g</sup>	0.050 <sup>c</sup>
Rec.NP (46-46)	0.060 <sup>cb</sup>	2.427 <sup>e</sup>	0.940 <sup>fg</sup>	0.090 <sup>c</sup>
25-46	0.020 <sup>d</sup>	3.193 <sup>ed</sup>	1.200 <sup>fg</sup>	0.210 <sup>b</sup>
50-46	0.025 <sup>d</sup>	3.100 <sup>ed</sup>	1.727 <sup>de</sup>	0.270 <sup>ba</sup>
100-46	0.061 <sup>cb</sup>	3.120 <sup>ed</sup>	2.037 <sup>cde</sup>	0.290 <sup>ba</sup>
150-46	0.075 <sup>b</sup>	4.100 <sup>cd</sup>	2.457 <sup>cd</sup>	0.300 <sup>ba</sup>
200-46	0.082 <sup>b</sup>	5.500 <sup>cb</sup>	2.747 <sup>cb</sup>	0.310 <sup>a</sup>
250-46	0.111 <sup>a</sup>	6.133 <sup>b</sup>	3.600 <sup>b</sup>	0.340 <sup>a</sup>
300-46	0.124 <sup>a</sup>	8.100 <sup>a</sup>	4.610 <sup>a</sup>	0.334 <sup>a</sup>
LSD <sub>(0.05)</sub>	0.024	1.645	0.931	0.097
P-value	<0.0001	<0.0001	<0.0001	<0.0001
CV (%)	12.43	13.52	14.63	13.98

TN= Total nitrogen, P<sub>av</sub>= Available phosphorus, S<sub>ext</sub>= Extractable sulfur and B<sub>ext</sub>= Extractable boron.

of P applied within the blended fertilizer, and since P has low mobility, it remains in higher amount. According to Olsen et al. (1954), the range of available P after harvest was rated as medium.

The value for extractable S was also highly influenced by the levels of fertilizer applied and the highest (4.61 mg kg<sup>-1</sup>) was obtained at higher blended NPSB fertilizer levels (Table 2). Soil S<sub>ext</sub> was found to be low in accordance to the rating suggested by Hazelton and Murphy (2007). The low soil sulfur in the study area may be due to its low OC content (Shaun et al., 2012). The extractable boron (B<sub>ext</sub>) after harvesting was 0.34 mg kg<sup>-1</sup> (Table 2) which is rated under low level (Berger and Truog, 1939).

## Effects of blended fertilizer rates on growth parameters

### Days to 50% heading and 90% physical maturity

The effects of blended NPSB fertilizer rates was found to highly significantly (P<0.01) influence days to *teff* panicle emergence. The delayed days to 50% panicle emergence (66.33 days) was recorded on the control plot, while the promoted days (56 days) was recorded for the highest blended NPSB fertilizer rate plus 46 kg N ha<sup>-1</sup> fertilizers (Table 3). The hastened panicle emergence as a result of highest rates of NPSB could be due to the effect of these nutrients on early establishment, rapid growth and development of crop. The application of supplementary N hastened the days to heading possibly because the *teff* plants were able to take up sufficient N from the soil and also because N may have enhanced the uptake of other nutrients such as P and S which might speed up growth and development of the crop Temesgen (2001). This result is consistent with the result of Getahun

et al. (2018) and Tadele et al. (2019) who reported that the heading of *teff* plants was accelerated as NP rate increased from zero to 69 kg N ha<sup>-1</sup> and 30 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> and from 0-69 kg N ha<sup>-1</sup> fertilizer applications. This result is in contrast with Legesse (2004) who reported that N fertilization at the rate of 46 kg N ha<sup>-1</sup> significantly delayed the heading stage of *teff* as compared to the control.

Physical maturity (90%) also shows the same trend as the other traits, as there was highly significant difference among the treatments. The late maturity (113.67 days) was obtained at the control plot, while the hastened physical maturity (106.33 days) was recorded at the highest fertilizer rate 300 kg NPSB ha<sup>-1</sup> (Table 3). The enhanced maturity with the increasing level of blended NPSB fertilizer could be due to the presence of balanced nutrients in the blended fertilizer. The result of the present study is in contrast with the result of Fenta (2018) which reported that as the rate of N increased from 0 to 69 kg N ha<sup>-1</sup>, days to maturity of *teff* was significantly delayed.

### Plant height and head length

The analysis of variance showed that there was significant difference among the effect of the treatments (P≤0.05) on plant height and head length. The highest plant height (120.67bcm) was obtained from the plot treated with 250 kg NPSB ha<sup>-1</sup>rate, while the shortest plant height (84.87 cm) was in response to the control treatment (Table 3).

The highest plant height obtained at the higher blended fertilizer levels might be due to the vital role of N applied for elongation and vegetative growth. This result was in agreement with the research findings of Okubay et al. (2014) where the maximum *teff* plant height (112.33 cm)

**Table 3.** Days to 50% heading and 90% maturity, plant height and head length of *teff* as influenced by blended NPSB fertilizer.

Treatments (NPSB-N) (kg ha <sup>-1</sup> )	DH (days)	DPM (days)	PH (cm)	HL (cm)
0-0	66.33 <sup>a</sup>	113.67 <sup>a</sup>	84.87 <sup>d</sup>	34.47 <sup>b</sup>
Rec.NP(46-46)	60.00 <sup>bcd</sup>	107.33 <sup>cd</sup>	109.80 <sup>bc</sup>	43.80 <sup>a</sup>
25-46	61.00 <sup>b</sup>	109.67 <sup>b</sup>	104.67 <sup>c</sup>	44.60 <sup>a</sup>
50-46	60.33 <sup>bc</sup>	108.33 <sup>bc</sup>	113.60 <sup>ab</sup>	44.00 <sup>a</sup>
100-46	58.67 <sup>cde</sup>	107.33 <sup>cd</sup>	114.07 <sup>ab</sup>	44.20 <sup>a</sup>
150-46	58.00 <sup>def</sup>	107.67 <sup>cd</sup>	110.40 <sup>bc</sup>	43.33 <sup>a</sup>
200-46	57.33 <sup>ef</sup>	106.67 <sup>cd</sup>	115.40 <sup>ab</sup>	45.20 <sup>a</sup>
250-46	57.00 <sup>ef</sup>	106.67 <sup>cd</sup>	120.67 <sup>a</sup>	45.67 <sup>a</sup>
300-46	56.00 <sup>f</sup>	106.33 <sup>d</sup>	116.13 <sup>ab</sup>	43.53 <sup>a</sup>
LSD <sub>(0.05)</sub>	59.41	108.19	109.96	43.20
P-value	<.0001	<.0001	<.0001	0.0023
CV (%)	1.30	0.62	2.71	6.06

DH= Days to 50% heading, DPM= Days to 90% physiological maturity, PH= Plant height, PL= Panicle Length, LSD= Least significant difference, CV= Coefficient of variance and NS = Non-significant; means followed by the same letters are not significantly different ( $P \leq 0.05$ ) according to LSD Tests.

was obtained from the application of the highest rate (69 kg N ha<sup>-1</sup>) whereas the lowest plant height was obtained from the control plot. It is also in line with the report of Wakene et al. (2014) who stated that plant height of barley was increased with increasing rates of N from 0 to 69 kg ha<sup>-1</sup>. But in contrast with this finding, increasing the rate of NPSB application from 0 to 150 kg ha<sup>-1</sup> did not significantly affect the height of *teff* plants.

Meanwhile, panicle length shows no statistical difference between the treatments except with control plot. Accordingly, the plots treated with 250 kg ha<sup>-1</sup> NPSB have the highest panicle height (45.67 cm) but plot which received no fertilizer gave the lowest panicle length (Table 3).

Similar to plant height, panicle length also increased with increasing N fertilizer rate. In line with this result, Getahun et al. (2018) reported that the longest panicle length (39.9 cm) was obtained from the application of 69 kg N ha<sup>-1</sup> while the shortest (31.6 cm) was recorded from the control.

### Effects of blended fertilizer rates on yield components

#### Tillering capacity

The analysis of variance shows that there was no significant difference except with the control plot on both total number of tillers and productive/effective tillers. The highest number of total tillers was (1593 plants) which was obtained from plots treated with 300 kg NPSB ha<sup>-1</sup>, and productive tillers (12.67 plants) from plot received 250 kg NPSB ha<sup>-1</sup>. However, the lowest numbers of total and productive tillers were obtained from the unfertilized plots (Table 4).

The increased total number of tillers on plots treated with blended fertilizer than in the unfertilized plot might be due to the profound effect of balanced nutrition for root development and braches. This result is in agreement with that of Haftamu et al. (2009) and Fenta (2018) who reported that application of blended fertilizer (69 kg N ha<sup>-1</sup> + 46 kg P<sub>2</sub>O<sub>5</sub> + 22 kg S ha<sup>-1</sup> + 0.3 kg Zn ha<sup>-1</sup>) brought significant increase in total tillers (15 tillers per plant) of *teff* as compared to 5 tillers per plant of unfertilized plot.

#### Grain yield

Grain yield of *teff* was highly significantly ( $P \leq 0.05$ ) influenced by the rates of blended NPSB fertilizer applied. The highest grain yield (2803.09 kg ha<sup>-1</sup>) was recorded as a result of 250 kg ha<sup>-1</sup> of NPSB whereas, the lowest yield (1051.11 kg ha<sup>-1</sup>) was obtained from the control plot (Table 5). The maximum yield has 62.5% yield increment over control and 33.4% over the blanket NP fertilizer recommendation.

The highest grain yield (28.03 quintal ha<sup>-1</sup>) overwhelmed the national average yield (16.64 quintal ha<sup>-1</sup>) (CSA, 2017). This could be due to the combined effect of nutrients like N, P, S and B in blended fertilizer which might have enhanced growth and development of crop compared to the rest of the treatments. It was also the improved number of effective tillers per plant (Table 4) and higher panicle length (Table 3) obtained at the plot treated with 250 kg NPSB ha<sup>-1</sup> might have contributed more to the cumulative effect towards enhanced yield.

The response of *teff* for blended fertilizer rates did not show consistent variation among treatments but it indicated the importance of the macro and micro nutrients. In line with this study, Lemlem (2012) reported that application of blended fertilizer and urea significantly

**Table 4.** Tillering capacity per plant of *teff* as influenced by NPSB fertilizer rate.

Treatment (NPSB-N) (kg ha <sup>-1</sup> )	NT	NET
0-0	8.87 <sup>c</sup>	5.47 <sup>c</sup>
Rec.NP(46-46)	13.93 <sup>ab</sup>	10.80 <sup>ab</sup>
25-46	13.60 <sup>abc</sup>	10.20 <sup>ab</sup>
50-46	13.07 <sup>abc</sup>	10.07 <sup>ab</sup>
100-46	10.40 <sup>bc</sup>	7.67 <sup>bc</sup>
150-46	15.27 <sup>ab</sup>	11.87 <sup>a</sup>
200-46	15.20 <sup>ab</sup>	12.40 <sup>a</sup>
250-46	15.47 <sup>a</sup>	12.67 <sup>a</sup>
300-46	15.93 <sup>a</sup>	12.47 <sup>a</sup>
LSD <sub>(0.05)</sub>	13.53	10.40
P-value	0.0009	<.0001
CV (%)	12.89	12.23

NT= Number of tillers per plot, NET= Number of effective tillers, LSD= Least significant difference and CV= Coefficient of Variance; means followed by the same letters are not significantly different ( $P \leq 0.05$ ) according to LSD Tests.

increased the N, P, K, Zn, Mg and S concentration of *teff* grains and also increased grain yield in Regosols and Vertisols.

The increased grain yield might be due to effect of balanced nutrients on improving crops agronomic performance thereby enhancing nutrient use efficiency (Fayera et al., 2014). Decline in grain yield might be related to the reductions observed in the content of the panicle (filled seed per panicle) with increased N rates in the blended fertilizer and consequently decreased grain yield ha<sup>-1</sup> (Reinke et al., 1994).

### Straw yield

The analysis of variance showed that straw yield was highly significantly affected ( $P \leq 0.05$ ) by the different NPSB blended fertilizer rates. The highest straw yield was obtained in response to applying 250 kg ha<sup>-1</sup> (Table 5) which is higher by about 80 and 44.4% as compared to the *teff* straw yield obtained in response to unfertilized plot and the plot received the blanket fertilizer recommendation (46 N and 46 P<sub>2</sub>O<sub>5</sub> kg ha<sup>-1</sup>). Increasing the rates of blended fertilizer rates from 0 to 250 kg ha<sup>-1</sup> significantly enhanced *teff* straw yield. This might be due to plants grown on plots treated with higher rate of N for their vegetative growth, higher P phosphorus for their good root development, higher level of S for high number of tillering and B for its higher cell division; it also contributed to increasing the total number of tillers per plant and influenced the straw yield (Fageria et al., 2011).

The plots treated with blended fertilizer scored higher straw yield due to the contributed combined effect of balanced fertilization. The highest plant height and tillers

also have great contribution to higher straw yield. Fageria et al. (2011) also indicated that application of S enhanced the photosynthetic assimilation of N in crops. Hence, application of N and S increased the net photosynthetic rate which in turn increased the dry matter as 90% of dry weight considered to be derived from products formed during photosynthesis.

Abdo (2009) respectively reported highest straw yield of durum wheat and *teff* in response to nitrogen applied at higher rate up to 69 kg N ha<sup>-1</sup>. In agreement with this result, Haftom et al. (2009) found increasing biomass with increasing rate of nitrogen along with the highest biomass yield (4724.07 kg ha<sup>-1</sup>) of *teff* in response to the application of 69 kg N ha<sup>-1</sup>.

### Lodging index

The lodging index of *teff* was highly significantly ( $P \leq 0.05$ ) affected by the different rates of blended NPSB fertilizer. Increasing fertilizer rate enhanced lodging index of *teff* crop across all the fertilizer levels. The lowest lodging index was observed in plants grown under the control plot (unfertilized plot) and the higher lodging index was observed under plot that received 300 kg ha<sup>-1</sup> NPSB fertilizer (Table 5).

The lodging index of plants grown on plots treated with 300 kg ha<sup>-1</sup> NPSB exceeded that of those grown on plots treated with 0 kg ha<sup>-1</sup> by 99.3% which means that there was higher lodging problem with the application of higher fertilizer rates. *Teff* lodging with increased fertilizer rate could be due to the profound effect of high N supply within the NPSB on enhancing vegetative growth thereby leading to bending of the weak stem of the plant due to

**Table 5.** Grain and straw yield of *teff* as influenced by NPSB.

Treatment (NPSB-N) (kg ha <sup>-1</sup> )	GY (kg ha <sup>-1</sup> )	SY (kg ha <sup>-1</sup> )	LI (%)	HI (%)
0-0	1051.11 <sup>e</sup>	1549.7 <sup>f</sup>	0.04 <sup>f</sup>	40.48 <sup>a</sup>
Rec.NP(46-46)	1867.62 <sup>c</sup>	4299.5 <sup>d</sup>	26.20 <sup>c</sup>	30.27 <sup>b</sup>
25-46	1339.17 <sup>d</sup>	3328.6 <sup>d</sup>	6.80 <sup>e</sup>	28.69 <sup>b</sup>
50-46	1631.64 <sup>c</sup>	4068.8 <sup>d</sup>	11.00 <sup>ed</sup>	28.66 <sup>b</sup>
100-46	2288.10 <sup>b</sup>	5879.3 <sup>c</sup>	13.27 <sup>d</sup>	28.05 <sup>b</sup>
150-46	2356.37 <sup>b</sup>	6044.3 <sup>c</sup>	25.00 <sup>c</sup>	28.03 <sup>b</sup>
200-46	2484.75 <sup>b</sup>	6558.9 <sup>c</sup>	47.03 <sup>b</sup>	27.47 <sup>bc</sup>
250-46	2803.09 <sup>a</sup>	7730.5 <sup>a</sup>	51.80 <sup>ab</sup>	26.61 <sup>bc</sup>
300-46	2393.39 <sup>b</sup>	7633.7 <sup>a</sup>	57.07 <sup>a</sup>	23.87 <sup>bc</sup>
LSD <sub>(0.05)</sub>	247.44	438.94	26.47	4.14
P-value	<.0001	<.0001	<.0001	<.0001
CV (%)	4.273347	2.932170	7.57	4.97

GY= Grain yield, SY= Straw yield, LI = Lodging index, HI = Harvest index; variable means followed by the same letters are not significantly different ( $p \leq 0.05$ ) according to LSD tests.

the sheer load of the canopy. These results therefore, revealed that increasing the rate of N within the blended fertilizer leads to the detrimental effect of crop losses due to lodging. Seyfu (1993) reported that lodging in cereals is considered to be caused by high rate of nitrogen fertilizer application.

### Harvest index

Generally, harvest index (HI) indicates the balance between the productive parts of the plant and the reserves, which form the economic yield. High harvest index indicates the presence of good partitioning of biological yield to economical yield. The analysis of variance revealed that, there was significant difference among the treatments in harvest index of *teff* and as the level of the fertilizer increases the harvest index decreased. Therefore, the highest harvest index was obtained at control plot (Table 5). In line with this, Tadele et al. (2019) reported that the highest *teff* HI was obtained on lower rate of fertilizer application. However, this result contradicts with the results reported by Lawrence et al. (2008) that harvest index in maize increased when N rate increased.

### Partial budget analysis

As indicated in Table 6, the highest net benefit of 76,356.2 ETBha<sup>-1</sup> with marginal rate of return (MRR) of 1179.5% was obtained in response to application of 250 kg blended NPSB ha<sup>-1</sup> (46 kg N ha<sup>-1</sup> was top dressed). However, the highest marginal rate of return (2323.9%) was obtained in response to 100 kg ha<sup>-1</sup> NPSB for the district. According to the manual for economic analysis of CIMMYT (1988), the recommendation is not necessarily

based on the treatment with the highest marginal rate of return. For farmers who use no fertilizer, investing in 100 kg ha<sup>-1</sup> NPSB gives a very high rate of return, but if farmers stopped there, they would miss the opportunity for further earnings, at an attractive rate of return, by investing an additional fertilizer. Farmers will continue to invest as long as the returns to each extra unit invested (measured by the marginal rate of return) are higher than the cost of the extra unit invested (measured by the minimum acceptable rate of return).

Thus, applications of 250 kg blended NPSB ha<sup>-1</sup> plus 46 kg N ha<sup>-1</sup> is economically beneficial as compared to the other treatments in the study area because the highest net benefit and the marginal rate of return were above the minimum level (100%).

### Conclusions

The study revealed that, the blended NPSB fertilizer has potential advantages over the blanket NP fertilizer recommendation for *teff* production on Vertisols of central zone, Laelay Maichew district. Depending on the results of this study, the following conclusions can be forwarded. Based on the soil analytical results, soil status of the study area before planting were 0.09%, 4.17 mg kg<sup>-1</sup>, 4.28 mg kg<sup>-1</sup> and 0.319 mg kg<sup>-1</sup> for TN, available P, extractable S and extractable B respectively. These results are rated as low; therefore, the area is deficient in these plant nutrients.

Days to 50% heading was highly significantly ( $p \leq 0.05$ ) affected by rates of blended fertilizer application. Plants grown at the rate of 300 kg ha<sup>-1</sup> NPSB had significantly hastened days to panicle emergence than those grown at the other rates. The number of days to 50% heading recorded over all the treated plots was significantly lower than the unfertilized plot and recommended NP. The plot

**Table 6.** Partial budget analysis of blended fertilizer rates for grain and straw yield of *teff*.

TRT	Grain yield		Straw yield		Gross revenue (GR) sum (1+2)	Costs			Net Revenue [TR-TVC]	MRR (ratio) [(Rt <sub>2</sub> -Rt <sub>1</sub> )/(Ct <sub>2</sub> -Ct <sub>1</sub> )]	MRR (%)
	Adj. yield	Total revenue (1)	Adj. yield	Total revenue (2)		Fertilizer cost [Birr]	Transport and application cost [Birr]	Total variable cost (TVC) [Birr]			
Control (0,0)	946.0	22514.8	1394.7	4323.6	26838.4	0	0	0	26838.4	0.00	0.0
25NPSB + 46N	1205.3	28686.1	2995.7	9286.7	37972.8	1615.95	60	1675.95	36296.8	5.64	564.4
50NPSB + 46N	1468.4	34947.9	3661.9	11351.9	46299.8	1980.25	120	2100.25	44199.5	18.63	1862.5
100NPSB + 46N	2059.3	49011.3	5291.4	16403.3	65414.6	2708.85	180	2888.85	62525.8	23.24	2323.9
Rec.NP(100:100)	1680.8	40003.0	3869.6	11995.8	51998.8	2918.75	180	3098.75	48900.0	D	D
150NPSB + 46N	2120.7	50472.7	5439.9	16863.7	67336.4	3437.45	240	3677.45	63658.9	1.44	144.0
200NPSB + 46N	2236.2	53221.6	5903.0	18299.3	71520.9	4166.05	300	4466.05	67054.9	4.31	430.6
250NPSB + 46N	2522.8	60042.6	6957.5	21568.3	81610.9	4894.65	360	5254.65	76356.2	11.79	1179.5
300NPSB + 46N	2154.1	51267.6	6870.3	21297.9	72565.5	5623.25	420	6043.25	66522.3	D	D

Adj. = Adjusted MRR= Marginal rate of return, Rt<sub>1</sub>= Net revenue of treatment one, Rt<sub>2</sub> = Net revenue of treatment two, Ct<sub>1</sub> = Total cost of treatment one and Ct<sub>2</sub> = Total cost of treatment two.

treated with 300 kg ha<sup>-1</sup> NPSB was 15.6% hastened over control and 7% over recommended NP to complete 50% heading. Similarly, 90% physical maturity was also significantly affected by the levels of blended fertilizers. The early maturity was obtained at a rate of 300 kg ha<sup>-1</sup> NPSB (106.33 days), which is faster than plots that received no fertilizer by about 5%.

Blended fertilizer also highly significantly ( $P \leq 0.05$ ) influenced plant height and panicle length. It had yield increment by 29.7 and 24.5% compared to control and 9 and 4.1% on recommended NP respectively. The highest plant height and panicle length were recorded at 250 kg ha<sup>-1</sup> blended fertilizer. The highest grain yield (2803.09 kg ha<sup>-1</sup>) was recorded at the application of 250 kg ha<sup>-1</sup> NPSB and with increment of 62.5% over control and of 33.4% over recommended NP (blanket recommendation). Similarly, the highest straw yield (7730.5 kg ha<sup>-1</sup>) was recorded at the application rate of 250 kg ha<sup>-1</sup> NPSB with yield increment of 80% over control and 44.4% over the recommended NP. The lowest yield was recorded

on control plot in all physical and yield parameters.

Generally, the overall yield performance of the crop was satisfactory under blended fertilization. The highest grain yield (2803.09 kg ha<sup>-1</sup>) obtained at 250 kg ha<sup>-1</sup> under blended fertilizer is higher than the national average yield (1664 kg ha<sup>-1</sup>) and the highest straw yield (7730.5 kg ha<sup>-1</sup>) obtained at 250 kg ha<sup>-1</sup> blended fertilizer was very promising for animal fating.

### Recommendations

- (1) Blended fertilization is more important to produce high *teff* production than that of the recommended NP.
- (2) Blended fertilizer (NPSB) at a rate of 250 kg ha<sup>-1</sup> NPSB + 46 kg N ha<sup>-1</sup> for *teff* production on vertisols should be used as a bench mark.
- (3) Impacts of the additional nutrients (sulfur and boron) in the blended fertilizer seem more significantly valued in increasing the biomass

production of *teff*. Thus, a further study across different years, locations and soils is very important.

(4) Additional studies are also needed on the impact of these blended fertilizers on straw and grain quality of *teff*.

### CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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