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Evaluating the response of blended fertilizer (NPSB) application on teff (*Eragrostis tef* /Zucc./Trotter) nutrient uptake at central Tigray, North Ethiopia

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Teff [*Eragrostis tef* (Zucc.) Trotter] is originated in Ethiopia, and it is self-pollinated, cereal crop. Teff can grow in low and/or excessive moisture conditions than other cereals are dejected under these conditions. Regardless of its immense overall national food security of the country its productivity is relatively low. Poor soil fertility, erratic rainfall, and suboptimal management practices could be among the main factors to be responsible. To maintain high crop production balanced inorganic fertilizers are important because they supply the required nutrients in a readily available form for immediate plant use. Field experiment was conducted during 2017 cropping season at central Tigray, northern Ethiopia to evaluate nutrient uptake of teff under blended fertilization. Treatments were eight levels of NPSB (0, 25, 50, 100, 150, 200, 250 and 300 kg ha^{-1}) and one recommended NP (100 kg ha^{-1} urea and 100 kg ha^{-1} TSP). The experiment was set in a randomized complete block design with three replications. Application of blended fertilizer has brought a significant effect in the teff yield and yield components. Similarly, NPS concentration, N uptake, P uptake, S uptake and grain protein content had been highly significantly (P<0.001) affected by the levels of NPSB. Maximum teff total nutrient uptake of 205.51 kg ha^{-1} for N, 19.09 for P and 23.18 for S, respectively. Generally, grain yield, NPS uptake and grain protein content showed increased trend until the level of 250 kg NPSB ha^{-1}, but it starts to fall beyond that level.

Key words: *Eragrostis tef*, blended fertilizer, yield, yield components and nutrient uptake.

INTRODUCTION

Crop yield per area (amount of crop harvested per amount of land cultivated) is the most commonly used impact indicator for agricultural productivity activities. The results of the year 2017/18 (2010 E.C.), season post-harvest crop production survey indicate that a total land area of about 12,677,882.27 ha are covered by grain crops that is cereals, pulses and oilseeds, from which a total volume of about 306,126,383.06 quintals of grains

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are obtained, from private peasant holdings. Out of the total grain crop area, 80.71% (10,232,582.23 hectares) was under cereals. Teff, covered 23.85% (about 3,023,283.50 hectares) areas. As to production teff is 2nd after maize which contributed 17.26% (52,834,011.56 quintals) into the national economy (CSA, 2017/18).

Teff [*Eragrostis tef* (Zucc.) Trotter] is originated in Ethiopia, and it is self-pollinated, C-4 cereal crop belongs to the genus Eragrostis under the family Poaceae (Paff and Asseng, 2018). Teff can grow in low and/or excessive moisture conditions than other cereals are dejected under these conditions (Hunter et al., 2007). Teff grows well on a range of soils, including Veritsols, which can become saturated by high precipitation (Lemlem et al., 2015). Teff requires only a reserved amount of fertilizer (Twidwell et al., 2002), and it affected by few insect and disease as a result it requires modest pesticide input. Regardless of its immense importance in the national economy, teff productivity is relatively low. Poor soil fertility, erratic rainfall, and suboptimal management practices could be among the main factors to be responsible (Tarekegne, 2010). Soil nutrient status is widely embarrassed by the inadequate use of synthetic and organic fertilizers and by loss of nutrients mainly due to erosion and leaching (Getachew et al., 2014). Many smallholder farmers do not have access to synthetic fertilizer because of its high price, lack of credit facilities, poor distribution, and other socio-economic factors. Consequently, crop yields are low, and the sustainability of the current farming system is at risk. To maintain high crop production level, the nutrient status of the soil has to be maintained by addition of organic and inorganic fertilizers. Inorganic fertilizers are supply the required nutrients in a readily available form for immediate plant use (Fayera et al., 2014). It is well known that fertilization is essential for improving the nutrient-use efficiency of teff. Nitrogen, phosphorus and sulfur are the primary nutrients affecting teff straw and grain yields as well as quality (Girma and Raun, 2011). A vast of research activities was conducted to determine optimum rate of different nutrients on response to many cereal crops including teff. However, studies on nutrient up take and nutrient use efficiency were very few. Therefore, this study was conducted to evaluate the nutrient (NPS) of teff at Hatsebo kebelle for quincho teff variety with blended (NPSB) fertilization.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Central Zone of Tigray Region, at Laelay Maichew district, Hatsebo kebelle, in 2017 cropping season. Hatsebo kebelle is located at 14^0 05' 29.22'' N and 38^0 46' 48.67'' E (Figure 1) towards east just about 5 km away from the Axum (capital city of central zone of Tigray regional state), with elevation of 2078 masl. Soils of Hatsebo kebelle 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, 2015). The area is characterized by mixed farming crop-livestock production system. Most of the middle altitude crops such as teff *(Eragrostis tef*), wheat (*Triticum aestivum*), fababean (*Vicia faba* L.), and chickpea (*Cicer arietinum* L.) are commonly grow in most parts of the district. The area is characterized by mono modal rainfall pattern and received annual rainfall of 783mm and the average annual maximum and minimum temperatures were $28^oC$and 13^oC, respectively during the cropping season (Figure 2A). According the ten year meteorological data the annual rainfall of the area ranges from 547 to 1027 mm (Figure 2B).

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^{-1} and blanket recommended NP at rate of 46 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1}). 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 evaluate the NPS uptake under blended fertilization. Since, nitrogen is the most limiting factor for plant growth and found in a very low amount in the blended fertilizer (46 kg N ha^{-1}) 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, respectively. Quncho variety was tested at seed rate of 5 kg ha^{-1}. All crop management practices were applied as per the recommendation for the teff crop.

Soil sampling preparation and analysis

One disturbed composite soil sample was collected at 0-20 cm depth based on zigzag sampling method before planting. 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 and crashed and allowed to pass through 2 mm sieve and for further analysis for TN and OC allowed to pass through 0.5 mm sieve (FAO, 2008). The collected soil samples 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).

Plant tissue sampling and analysis

After maturity, 10 non-border plant leaf samples were randomly collected from each experimental plot and it was partitioned into grain and straw. After partitioned into grain and straw the plant sample was washed with distilled water to clean the samples from contaminants such as dust before grinding. The grain and straw samples (after washing) were separately air dried. After drying, the plant tissue samples were grinned and passed through 0.5 mm sieve for N, P and S analysis. Nutrient concentration in the teff plant was obtained from the analysis of grain and straw.

Nitrogen, P and S uptake (kg ha^{-1}) was calculated by multiplying the nutrient concentration of the straw and grain by respective straw and grain yield. Total N, P and S uptake, of the whole biomass was

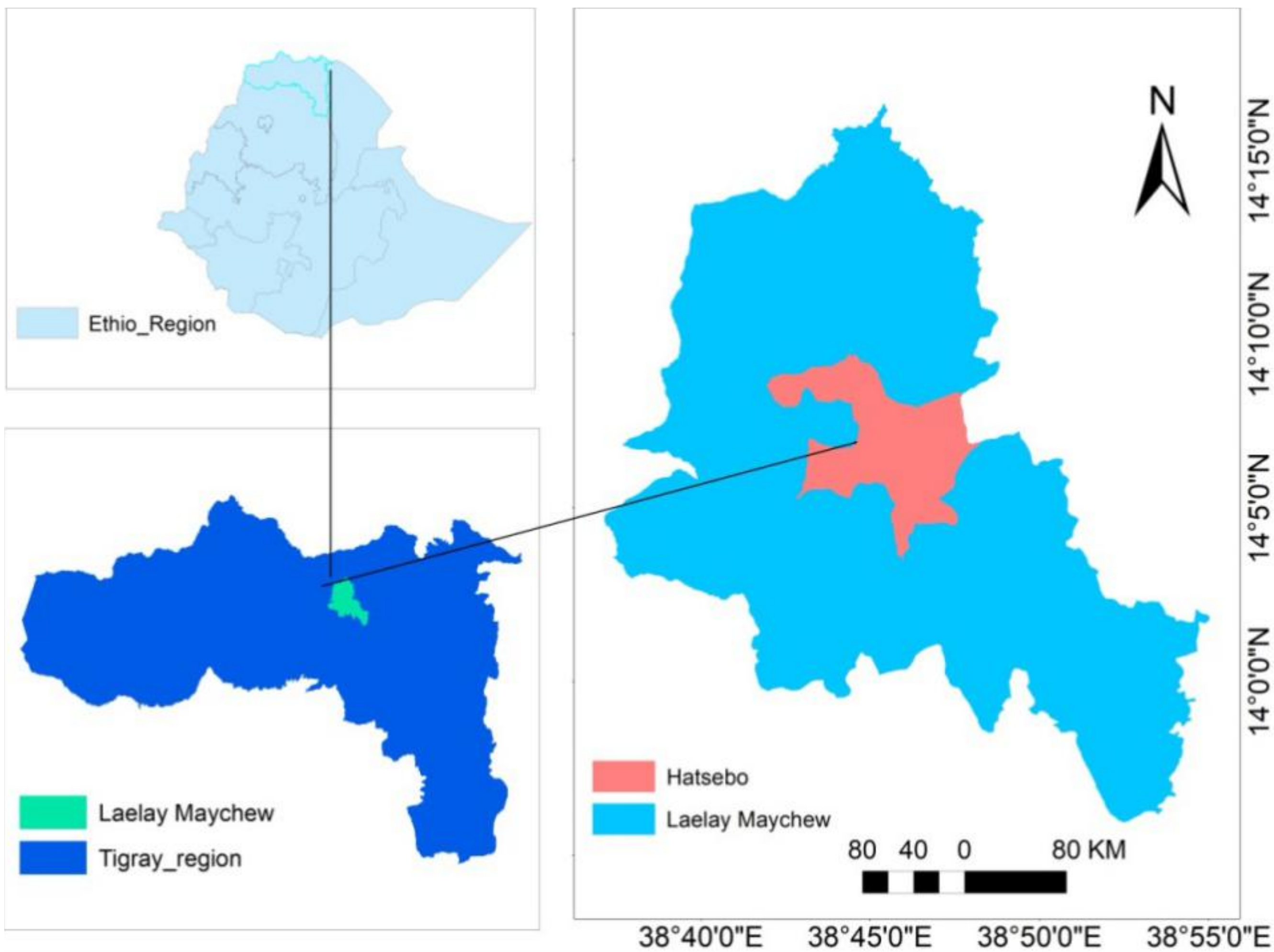

Figure 1. Location map of the study area.
Source: (Berhe et al, 2020).

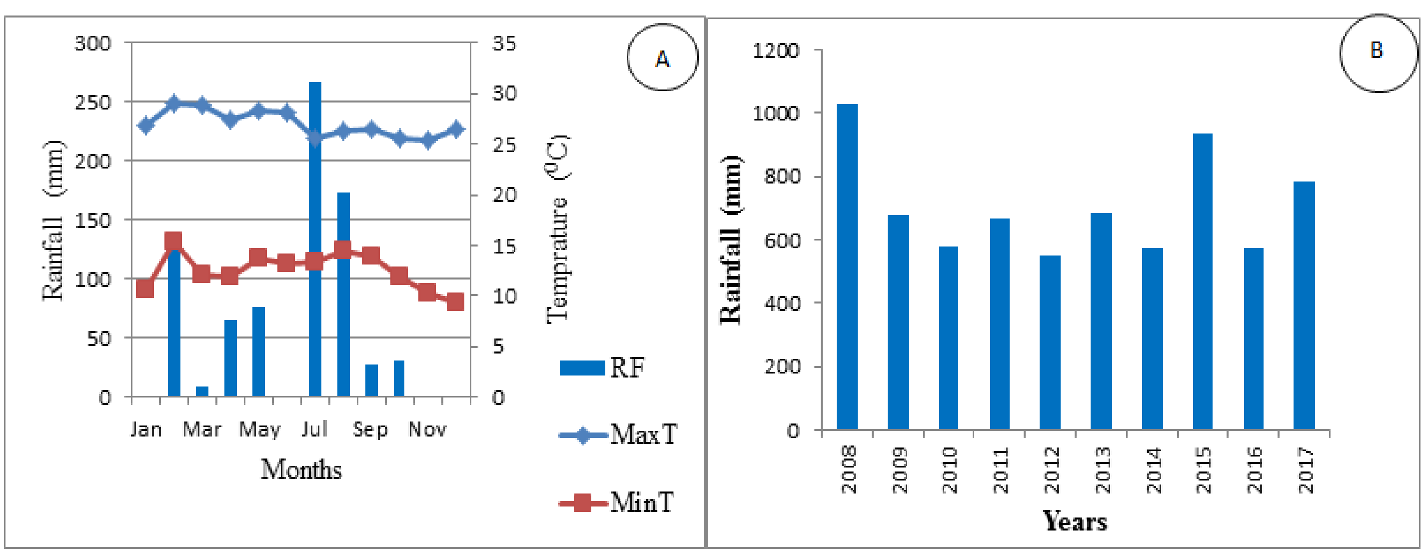

Figure 2. 10 year rainfall data, maximum and minimum temperatures recorded during the cropping season.
Source: Ethiopian meteorological service agency Tigray branch.

calculated by summing up the N, P and S uptake of grain and straw (Bowen and Zapata, 1991).

Data collection and measurements

Grain yield (kg ha^{-1})

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^{-1})

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.

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).

Grain, straw and total NPS uptake

The uptake of nutrient was calculated by multiplying the grain and straw yield (kg ha^{-1}) with their nutrient concentration in (%) of each treatment as follows:

a) N uptake of grain or straw (kg ha^{-1}) = Yield of grain or straw (kg ha^{-1}) x N concentration of grain or straw (%) x 100
b) Total N uptake = N uptake of grain + N uptake of straw
c) P uptake of grain or straw (kg ha^{-1}) = Yield of grain or straw (kg ha^{-1}) x P concentration of grain or straw (%) x 100
d) Total P uptake = P uptake of grain + P uptake of straw
e) S uptake of grain or straw (kg ha^{-1}) = Yield of grain or straw (kg ha^{-1}) x S concentration of grain or straw (%) x 100
f) Total S uptake = P uptake of grain + S uptake of straw

Grain protein content

Grain protein content was calculated by multiplying the N concentration of grain yield with 5.7 factor (Ref.?). As N concentration increases the grain protein content also rises up (AACC, 2000).

% Protein - % Nitrogen in grain x 5.7

RESULTS AND DISCUSSION

Soil characteristics of the study area

Soil physical properties

As particle size analysis result of the study area indicates that, the soil is dominated by clay particles and its textural class is clayey, with a percentage of sand (16%), silt (26%) and clay (58%), (Table 1). Therefore, according to FAO (2014) report, the soil is categorized as vertisols. Bulk density of the experimental soil was also found to be 1.34 g cm^{-3} before sowing teff (Table 1) and it is good for cereal crops root development, because bulk density is below the critical value (1.4 g cm^{-3}) 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 g cm^{-3}, porosity 0.3-0.7 m^{3} m^{-3}, 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 Landon (1991) rating, soils having pH value in the range of 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 dS m^{-1} and this indicates a non-saline soil (Marx and Stevens, 1999). In line with this findings Landon (1991) also reported, the EC value measured at 0.41 dS m^{-1} 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, thereby improve nutrients availability for plant growth and get better for nutrient uptake.

There was very low available P before sowing (4.17 mg kg^{-1}) (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^{-1}, respectively (Table 1). Soil S_{ext} was found to be low as rating 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). The cation exchange capacity of the soil before sowing was 56.4 cmol(+)kg^{-1} 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.

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

SN	Parameter	Value	Rating	Source
1	BD (g cm^{-3})	1.34	No restricting plant root development	Hazelton and Murphy (2007)
2	Sand (%)	16		
3	Silt (%)	26		
4	Clay (%)	58		
5	Textural class	Clayey		
6	Ph(H_2O)	7.1	Neutral	Tekalign (1991)
7	EC(ds m^{-1})	0.41	Low/non-saline	London (1991)
8	OC (%)	0.64	Low	Tekalign (1991)
9	TN (%)	0.091	Very low	Tekalign (1991)
10	P_{av} (mg kg^{-1})	4.17	Very low	Olsen *et al*. (1954)
11	S_{ext} (mg kg^{-1})	4.28	Low	Hazelton and Murphy (2007)
12	B_{ext} (mg kg^{-1})	0.319	Low	Berger and Truog (1939)
13	CEC cmol (+)kg^{-1}	56.4	Very high	Landon (1991)

BD= bulk density, ph= power of hydrogen, EC= electrical conductivity, OC= organic carbon, TN= total nitrogen, P_{av}= available phosphorus, S_{ext}= extractable sulfur, B_{ext}= extractable boron and CEC= cation exchange capacity.
Source: Tigray agricultural research institute; shire soil research center

Table 2. Grain and straw yield of teff as influenced by NPSB.

Treatments (NPSB-N kg ha^{-1})	GY (kg ha^{-1})	SY (kg ha^{-1})
0-0	1051^{e}	1550^{f}
Rec. NP (46-46)	1868^{c}	4299^{d}
25-46	1339^{d}	3329^{d}
50-46	1632^{c}	4069^{d}
100-46	2288^{b}	5879^{c}
150-46	2356^{b}	6044^{c}
200-46	2485^{b}	6559^{c}
250-46	2803^{a}	7730^{a}
300-46	2393^{b}	7634^{a}
$LSD_{(0.05)}$	247	439
P-value	<.0001	<.0001
CV (%)	4.27	2.93

GY= grain yield, SY= straw yield, LI = Lodging index, HI = harvest index, variable means followed by the same letters are not significantly different (*p≤0.05*) according to LSD tests.
Source: Tigray agricultural research institute; shire soil research center

Effects of NPSB fertilizer rates on teff yield and yield components

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 kg ha^{-1}) was obtained as a result of 250 kg ha^{-1} of NPSB, whereas the lowest yield (1051 kg ha^{-1}) was from the control plot (Table 2).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 q ha^{-1}) weighed down the national average yield (16.64 q ha^{-1}) (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 2) and higher panicle length (Appendix Table 3) obtained at the plot treated with 250 kg NPSB ha^{-1} might have contributed more to the cumulative effect towards enhanced yield.

The response of teff for blended fertilizer rates didn't show consistent variation among treatments but it indicated the importance of the macro and micro nutrients. In line with this study, Lemlem et al. (2015) reported that application of blended fertilizer and urea significantly increased the N, P, K, Zn, Mg and S concentration of teff grains and increased grain yield in Regosols and Vertisols.

The increased grain yield might be due to effect of balanced nutrients on improving crops agronomic performance whereby enhanced nutrient use efficiency (Feyera 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 (Getahun et al., 2018).

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^{-1} (Table 2), 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_2O_5 kg ha^{-1}). Increasing the rates of blended fertilizer rates from 0 kg ha^{-1} to 250 kg ha^{-1} 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 and contributed to increasing the total number of tillers per plant and influence the straw yield (Fageria et al., 2011).
The plots treated with blend fertilizer scored higher straw yield was 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.

Nutrient uptake and protein content

Grain, straw and total nutrient uptake

Nitrogen uptake: The grain and straw N contents and their uptakes were affected by the application of different rates of NPSB fertilizer. Both the grain and straw N contents increased with each successive addition of N fertilizer within the blended fertilizer (NPSB) but beyond 250 kg ha^{-1} starts to fall down (Figure 3). Accordingly, the highest grain (73.78 kg ha^{-1}), straw (131.77 kg ha^{-1}) and total (205.51 kg ha^{-1}) uptake of teff was obtained at the rate of 250 kg NPSB ha^{-1}, while the least was obtained from the control plot (Appendix Table 1).

The grain N, straw N and total N uptakes of teff were increased by 38.11%, 37.02%, and 37.40%, respectively relative to the recommended NP fertilizer. While relative to the control plot N grain N, straw N and total N uptakes of teff were increased by 84.32%, 88.12%, and 86.75% in response to 250 kg NPSB ha^{-1} (Appendix Table 1). Figure 3 clearly showed the positive effects of N on teff grain and straw yields and the improvement of grain and straw N contents by application of NPSB fertilizer until 250 kg NPSB ha^{-1}. The results indicated that grain; straw and total N uptake of the fertilizer N was significantly enhanced by the application of NPSB than blanket recommended NP fertilizer.

Moreover, the results are in line with the findings of Sheoran et al. (2015), who reported that combined use of nutrients gave superior N grain uptake than their individual use. An increase in nutrients uptake could be due to supply of balanced nutrient and well-developed root system supported by better absorption of water and nutrient (Devi et al., 2011; Singh et al., 2011).

Phosphorus uptake

There were higher significance differences between the levels of the treatment to influenced grain, straw and total P uptake. The results (Appendix Table 2) showed that the highest total P uptake (18.48 kg P ha^{-1}) was obtained from the plots treated with 250 kg NPSB ha^{-1}. This result clearly indicates the need of N and other nutrients application in the form of balanced/blended fertilization to boot P uptake by the plants. The highest P uptake by grain (8.04 kg ha^{-1}), straw (11.05 kg ha^{-1}) and total (19.09 kg ha^{-1}) were obtained from 250 kg NPSB ha^{-1}, respectively (Appendix Table 2). This is due to the application of combination of macronutrients with micronutrients in balanced form of fertilizer to nutrient deficient soil, improves the nutrient concentration and uptake as a result yield is increased.

The uptake of P in the grain, straw and total were high in the plots which receive higher blended fertilizers up to 250 kg NPSB ha^{-1} (Figure 4); however it starts to fall beyond this level. At study site application of blended fertilizers under balanced fertilization has improved grain and straw P contents by 65.1% and 74.93%, respectively over the plot receiving no fertilizer and the plot treated with the blanket recommendation (Appendix Table 3). These results are in agreement with the findings of Feyera et al. (2014), who reported that micronutrients (B) combination with macronutrients NPS fertilizers in improving nutrient concentration, uptake and enhancing yield of teff.

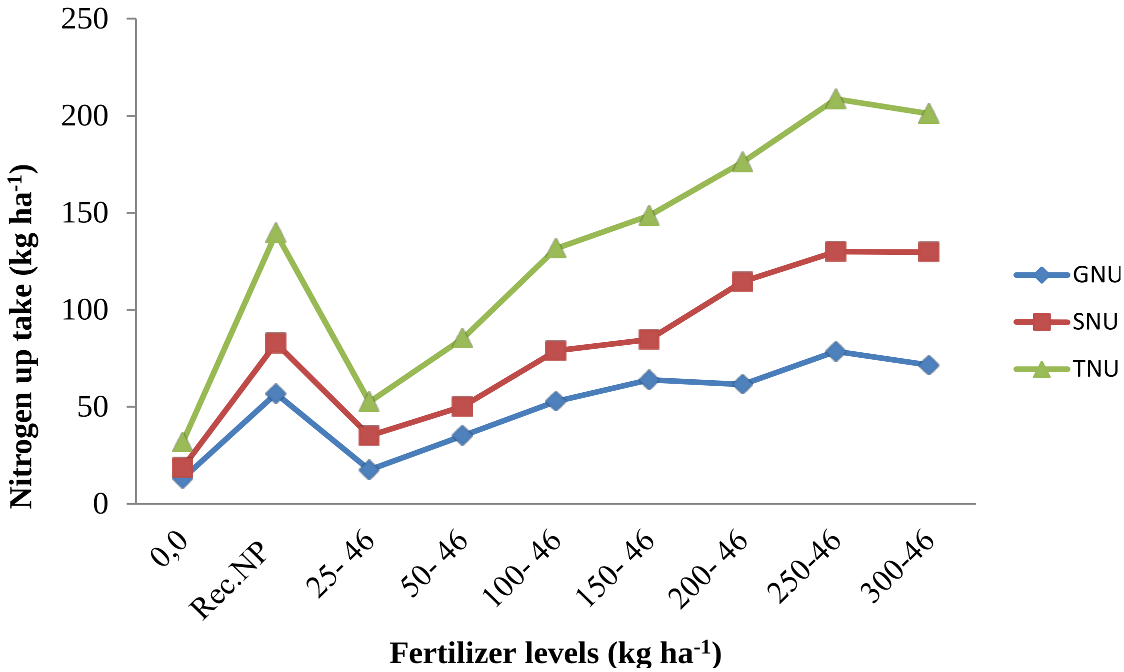

Figure 3. Grain, straw and total nitrogen uptake under blended fertilization.
Source: Tigray agricultural research institute; Mekelle soil research center

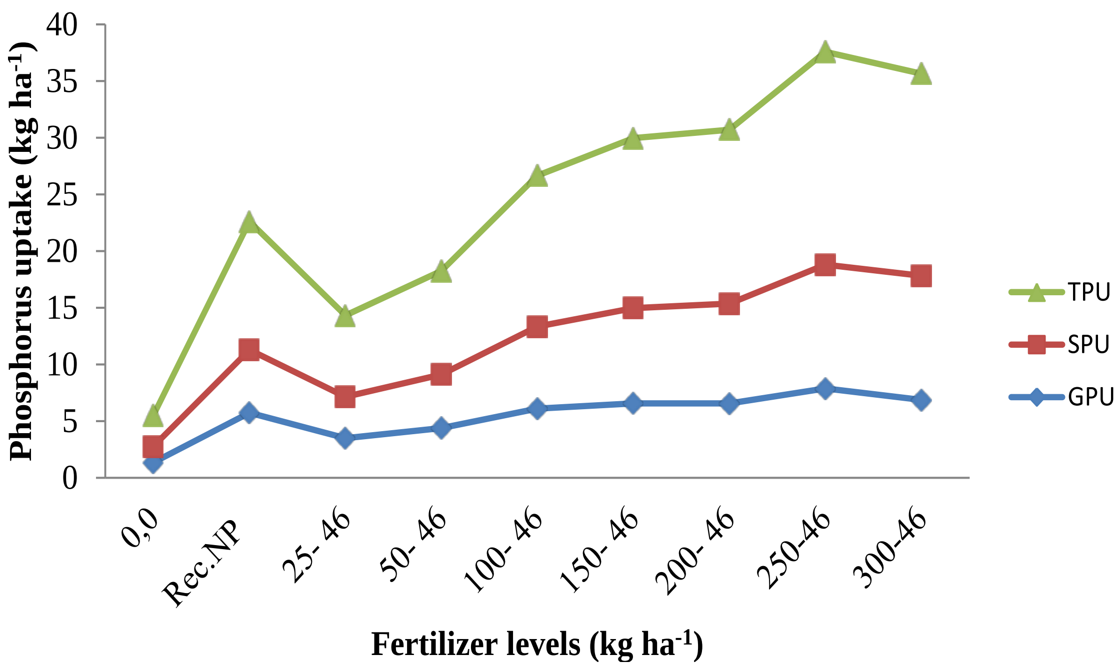

Figure 4. Grain, straw and total uptake of phosphorus under blended fertilization.
Source for analytical results: Tigray agricultural research institute; Mekelle soil research center

Sulfur uptake

The result presented in Appendix Table 3 indicated that S uptake by grain and straw was highly affected by various levels of NPSB. Increasing trend in S uptakes was observed up to 200 kg NPSB ha^{-1} and the decreasing trend of nutrients uptake was observed in the two higher application rate of NPSB (Figure 5). The plot treated by

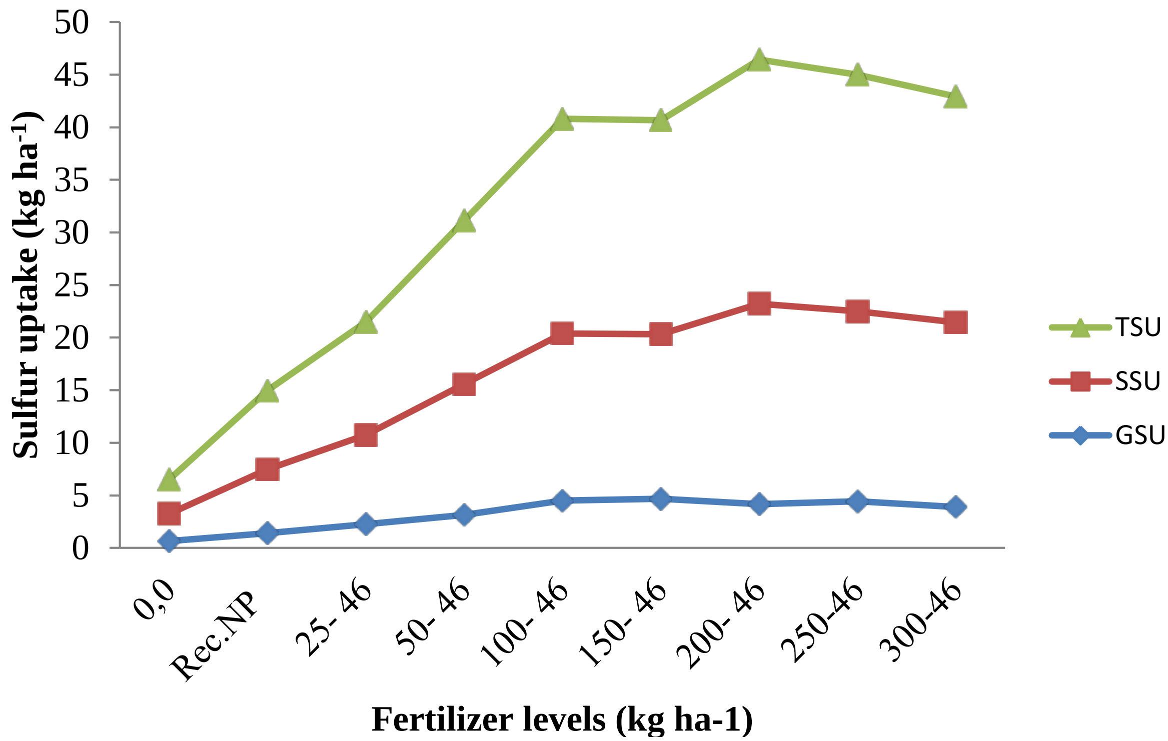

Figure 5. Grain, straw and total uptake of sulfur under blended fertilization.
Source for analytical results: Tigray agricultural research institute; Mekelle soil research center

blanket recommended NP fertilizer score lower uptake than 25 and 50 kg NPSB ha^{-1}.

The application of 200 kg NPSB ha^{-1} gave highest S uptake by grain, straw and total uptake (4.56, 18.32 and 23.14 kg ha^{-1}, respectively), while the lowest uptake of S by grain, straw and total uptake (0.59, 2.16 and 2.75 kg ha^{-1}, respectively) was control. The increase in S uptake by grain seed and straw yield which ultimately increasing the S uptake by teff. This study is in line with the findings of Ramswaroop et al. (2017), who reported that nutrient content and uptake in grain and straw were influenced by sulfur application. Moreover, it is a key ingredient in the formation of chlorophyll and required to synthesis of S containing amino acids such as cystine, cysteine and methionine etc. and building block of protein which might have resulted in enhanced growth and development of plant and ultimately resulted in higher uptake of N, P, K and S (Shah et al., 2013).

Grain protein content

Grain protein content of teff was affected by N application rates within the NPSB blended fertilizer. The highest and lowest grain protein contents were recorded for grain harvested from plots treated with 250 kg NPSB ha^{-1} (16.77%) in the form of blend and 0 kg NPSB ha^{-1} (1.64%), respectively (Figure 6). In general, grain protein content showed increasing trend with N rates within NPSB but it started to decrease beyond the 250 kg NPSB ha^{-1} (Figure 6).

The result is in line with Sofonyas et al. (2018) and Bereket et al. (2014), who reported that grain protein content is increased with increasing application of N to bread wheat.

Conclusion

Therefore, application of blended fertilizer has brought a significant effect in the teff yield and yield components. Similarly, NPS concentration, N uptake, P uptake, S uptake and grain protein content had been highly significantly ($P<0.001$) affected by the levels of NPSB. Generally, grain yield, NPS uptake and grain protein content showed increased trend until the level of 250 kg NPSB ha^{-1}, but it starts to fall beyond that level. There is a positive correlation between NPS concentration and their uptake, grain and/or straw yield and NPS uptake and between N grain concentration and grain protein content on the experimental area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

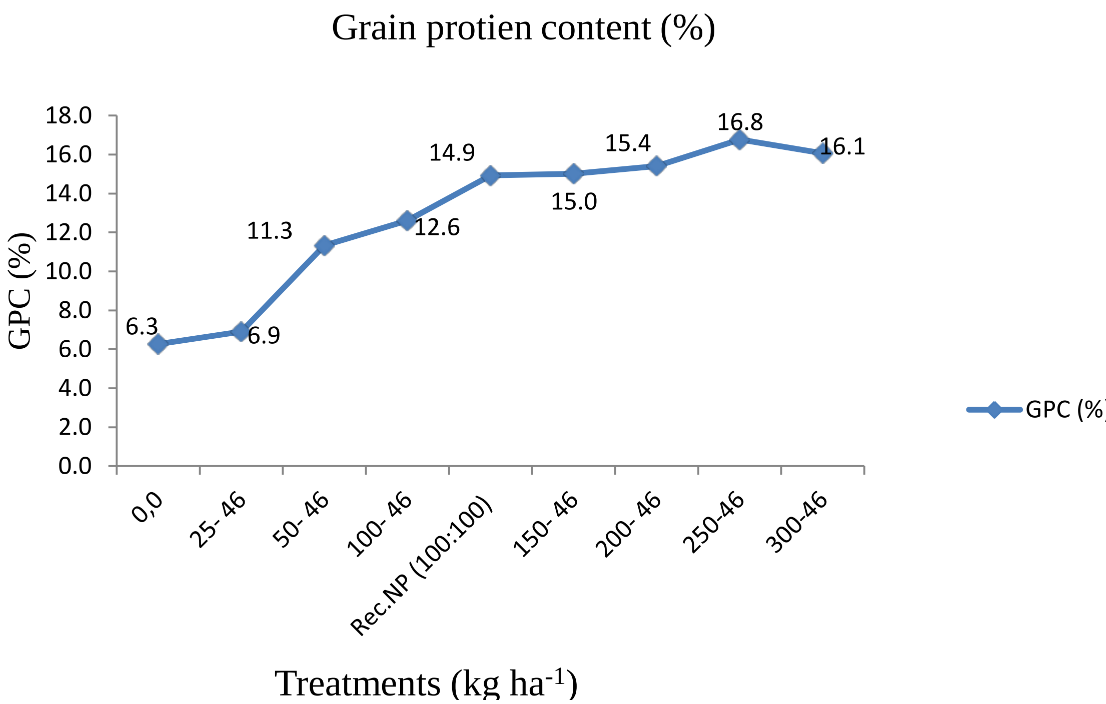

Figure 6. Grain protein content as affected by the rate of N within the blended fertilizer.
NB: GPC (%) = Grain protein content in percentage.
Source for analytical results: Tigray agricultural research institute; Mekelle soil research center

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APPENDIXES

Appendix Table 1. Grain, straw and total nitrogen uptake of teff as influenced by NPSB levels.

Treatments (NPSB-N kg ha^{-1})	Nitrogen (kg ha^{-1})		
	GNU	**SNU**	**TNU**
0-0	11.57^{e}	15.66^{e}	27.23^{g}
Rec. NP (46-46)	45.66^{c}	82.99^{c}	128.64^{d}
25-46	16.23^{e}	33.65d^{e}	49.88^{f}
50-46	31.36^{d}	50.05^{d}	81.41^{e}
100-46	50.61^{cb}	78.71^{c}	129.32^{d}
150-46	62.15^{ba}	84.69^{c}	146.83^{c}
200-46	67.16^{a}	111.70^{b}	178.86^{b}
250-46	73.78^{a}	131.77^{a}	205.51^{a}
300-46	67.47^{a}	126.26b^{a}	193.74^{ba}
$LSD_{(0.05)}$	12.66	18.29	17.51
P-value	<.0001	<.0001	<.0001
CV (%)	9.35	8.04	4.82

GNU= grain N uptake, SNU= straw N uptake, TNU = Total N uptake, variable means followed by the same letters are not significantly different (*p≤0.05*) according to LSD tests
Source for analytical results: Tigray agricultural research institute; Mekelle soil research center

Appendix Table 2. Grain, straw and total phosphorus uptake of teff as influenced by NPSB levels.

Treatments (NPSB-N kg ha^{-1})	Phosphorus uptake (kg ha^{-1})		
	GPU	**SPU**	**TPU**
0-0	1.20^{e}	1.18^{e}	2.38^{f}
Rec. NP (46-46)	4.41^{dc}	5.51^{cd}	9.92^{de}
25-46	3.23^{ed}	4.74^{d}	7.97^{e}
50-46	3.54^{ed}	4.71^{d}	8.24^{e}
100-46	5.96^{bac}	7.20^{cb}	13.16^{dc}
150-46	5.59^{bdc}	7.79^{b}	13.38^{c}
200-46	7.20^{ba}	8.59^{b}	15.80^{bc}
250-46	8.04^{a}	11.05^{a}	19.09^{a}
300-46	6.48^{bac}	10.43^{a}	16.92^{ba}
$LSD_{(0.05)}$	2.37	1.79	3.25
P-value	<.0001	<.0001	<.0001
CV (%)	16.31	9.21	9.57

GPU= grain P uptake, SPU= straw P uptake, TPU = Total N uptake, variable means followed by the same letters are not significantly different (*p≤0.05*) according to LSD tests.
Source for analytical results: Tigray agricultural research institute; Mekelle soil research center

Appendix Table 3. Grain, straw and total sulfur uptake of teff as influenced by NPSB levels.

Treatments (NPSB-N kg ha^{-1})	Sulfur uptake (kg ha^{-1})		
	GSU	**SSU**	**TSU**
0-0	0.59^{e}	2.16^{d}	2.75^{d}
Rec. NP (46-46)	1.22^{de}	7.47^{c}	8.68^{c}
25-46	2.11^{dc}	8.14^{c}	10.25^{c}
50-46	3.15^{bc}	12.41^{b}	15.56^{b}
100-46	3.84^{ba}	17.22^{a}	21.06^{a}
150-46	4.54^{a}	15.64^{ba}	20.18^{a}
200-46	4.56^{a}	18.58^{a}	23.14^{a}
250-46	3.75^{ba}	18.32^{a}	22.07^{a}
300-46	3.66^{ba}	17.61^{a}	21.27^{a}
$LSD_{(0.05)}$	1.35	3.71	3.56
P-value	<.0001	<.0001	<.0001
CV (%)	15.53	9.92	7.73

GSU= grain S uptake, SSU= straw S uptake, TSU = Total S uptake, variable means followed by the same letters are not significantly different ($p \leq 0.05$) according to LSD tests.
Source for analytical results: Tigray agricultural research institute; Mekelle soil research center