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Evaluating the response of NPSZnB fertilizer on yield and yield components of teff at North western zone of Tigray, Ethiopia

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Teff is one of the major crops grown in central and north western zones of Tigray regional state. However, its productivity is low due to low soil fertility as a result of intensive and long history of cultivation and soil erosion. Therefore, a field experiment was carried out on a farmer's field in Medebay zana and Tahtay koraro districts (Adekemalk and Beles kebelles) during the 2017 and 2018 main cropping seasons to evaluate the response of NPSZnB fertilizers on yield and yield components of teff. The treatments consisted of seven levels of NPSZnB (0, 50, 100, 150, 200, 250 and 300kg ha^{-1}) and control treatment recommended NP (64:46) kgha^{-1}. The experiment was laid out in a RCBD design with three replications. Analysis of the results revealed that, days to 50% heading, plant height, number of productive tillers per plant, straw yield, grain yield and harvest index resulted in significant difference over the control plot at both districts. However, days to 90% physical maturity and head panicle length at Medebay zana district and harvest index at Tahtay koraro have no significant difference within any of their treatments. The highest grain yields (2165.3 and 1996.6 kg ha^{-1}) were obtained in response to the application of 200 and 250 kg ha^{-1}of NPSZnB. It has 56.9 and 55.9% yield increment over control and 7.4 and 11% over the blanket recommendation at Medebay zana and Tahtay koraro districts, respectively. Thus, applications of 200 and 150 kg blended NPSZnB ha^{-1} with N adjusted to 64 kg N ha^{-1} is economically beneficial as compared to the other treatments in Medebay zana and Tahtay koraro districts, respectively because the highest net benefit and the marginal rate of return was above the minimum level (100%).

Keywords: Blended, boron, zink, nitrogen, phosphorus, sulfur, teff and yield.

INTRODUCTION

Teff [*Eragrostis tef* (Zuccagni) Trotter] is one of the most important food cereal crops in Ethiopia, occupying about 24% of the cultivated land from the total area of cereals (85.6%), accounting for 17% of the grain production (CSA, 2017). Teff has got both cultural and economic value for Ethiopian farmers with more than six million

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households' life depending on the production of teff. It is a daily staple food for about 57.20 million people of Ethiopia, and this accounts for more than 64% of the total population of the country (ATA, 2013b). However, the productivity of teff had reduced with time due to factors such as plant lodging, soil fertility decline, high soil erosion, unbalanced chemical fertilizer application, up proper planting method, over planting seed rate and others (Tekulu et al., 2019). There are several factors that have become a common phenomenon which leads to nutrient deficiency in soil resulted in effective cereal production. Nutrient mining due to the application of sub optimal fertilizers fixed with unbalanced nutrients have favored the emergence of multi nutrient deficiency in Ethiopian soils (Tadele et al., 2019) which in part explain fertilizer factor productivity decline and stagnant crop productivity conditions encountered. In Ethiopia, DAP (di-ammonium phosphate) and urea have been the only chemical fertilizers used for crop production with initial understanding that nitrogen and phosphorus are the major limiting nutrients of Ethiopian soils (Fisseha et al., 2020). However, plant growth and crop production require an adequate supply and balanced amounts of all nutrients. To increase production of cereal crops, increase in use of appropriate essential nutrients is an option. Fertilizers are an efficient exogenous source of plant nutrients (ATA, 2014). Among the key strategies that were identified to help increase agricultural production and productivity in Growth and Transformation Plan I (GTP I) period was the soil fertility mapping of the country's agricultural lands. The soil fertility map of Tigray region was completed in the year 2014 and published by Ministry of Agriculture (MOA) and Ethiopian Agricultural Transformation Agency (ATA, 2014) as part of the strategy. The necessity to transform agricultural sector with respect to soil fertility requires application of proper amounts of blended fertilizers for different crops.

Consequently, adding micronutrients and additional macro nutrients to NP fertilizer can increase fertilizer use efficiency and grain yield for different cereal crops (Tewolde et al., 2020). The widespread deficiency of nitrogen, phosphorus and sulfur nutrients is followed by Zn and boron deficiency, which records almost 50% of the world soils used for cereal production (Gibbson, 2006).

The micronutrient deficiency appears to be the most widespread and frequent micronutrient deficiency problem in crops, resulting in severe losses in yield and nutritional quality, particularly areas of cereal production in rain fed production in many parts of the world (Alloway, 2008; Srinivasarao et al., 2009). The soil fertility mapping project in Ethiopia reported the deficiency of K, S, Zn, B and Cu in addition to N and P in major Ethiopian soils and N, P, S, Zn and B particularly in the study area (Ethio SIS, 2014). Balanced fertilizers containing N, P, S, B, Fe and Zn in blend form have been recommended to solve site specific nutrient deficiencies and thereby increase crop production and productivity (ATA, 2014). The major recommended blended fertilizers for Tigray region are NPS, NPSB, NPSZn, NPSZnB, NPSFeZn and NPSFeZnB. Although, new blended fertilizers such as NPSZnB (17% N – 34% P_2O_5 + 7% S + 2.2% Zn + 0.67% B) are currently recommended for the study area (ATA, 2014), the effect of these nutrients on yield, yield components, and overall performance of teff except nitrogen and phosphorus within the blanket recommendation are unknown. Thus, there is a need to develop site specific recommendation with regard to the blended fertilizer rates to increase production and productivity of teff. The amount of N in the blended NPSZnB is small as compared to the requirement of teff that needs supplementation with nitrogen fertilizer in the form of urea. Therefore, this study was conducted to evaluate the response of NPSZnB and N fertilizers rates on yield and yield components of teff and identifying the economically feasible rates.

MATERIALS AND METHODS

Description of the study area

Field experiments were carried out for two consecutive seasons of 2017 and 2018 under rain fed conditions on three selected farmers' fields on each season at Medebay zana (Adekemalk kebelle) and Tahtay koraro (Beles kebelle) districts of northwestern Tigray, northern Ethiopia. The two districts are the basic representatives of the mid-lands of northwestern zone of Tigray regional state. The experimental sites for Medebay zana were extended from 14° 06' 10.608"N to 14° 04' 12.246"N latitude, 38^0 27' 43.75"E to 38^0 25' 36.960"E longitude and an altitude of 1977to1986 m.a.s.l and sites for Tahtay koraro were extended from 14° 04' 36.36"N to 14° 01' 48.7"N latitude, 38° 23' 11.718"E to 38° 22' 29.5"E longitudes and an altitude of 1958 m.a.s.l to 1910 m.a.s.l at about 33 and 10km away from the capital city of northwestern zone (Shire Endaslasie), respectively (Figure 1).

Climate data of the study area

The minimum and maximum monthly average temperatures in the area are 14.59 and 25.61°C, respectively. The average rainfall is around 1002.25 mm for Medebay zana district and the minimum and maximum monthly average temperatures are 10.23 and 28.06°C, respectively (Figure 2 a and b). The average rainfall is around 1037.51 mm for Tahtay koraro district (EMSA, 2018). These areas predominantly lie under semi-arid tropical belt of Ethiopia with a mono-modal and erratic rainfall pattern. The soil type of the study area is characterized as vertisol. The districts are categorized under the semi-arid tropical mid highlands (SA_3) belt of Ethiopia with "Weinadega" agro climatic zone where most of the middle altitude crops such as teff *(Eragrostis tef*), sorghum (*Sorghum bicolor* (L) Moench), fababean (*Vicia faba* L.), chickpea (*Cicer arietinum* L.) and others are commonly grown.

Experimental design, treatment setup and procedures

The experiment was laid out in randomized complete block design (RCBD) with eight treatments, seven levels of NPSZnB and one NP (0, 50, 100, 150, 200, 250, 300 kg NPSZnB ha^{-1} and blanket.

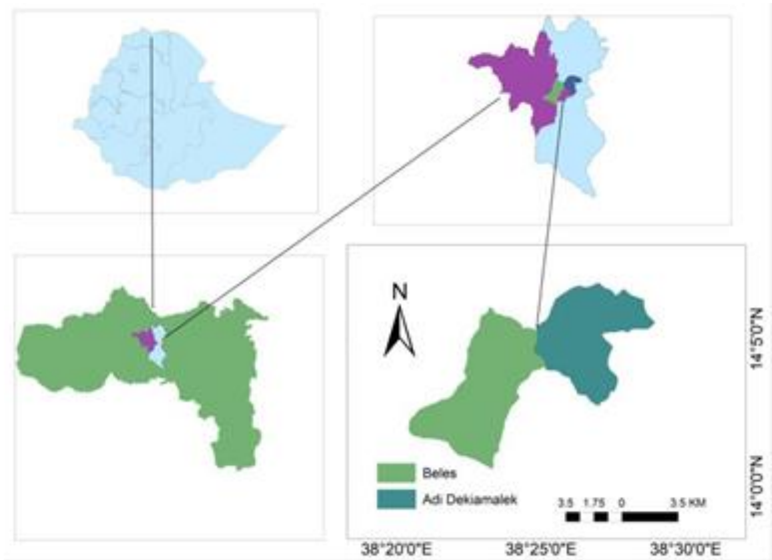

Figure 1. Location map of the study area.
Source: Agricultural office of the district

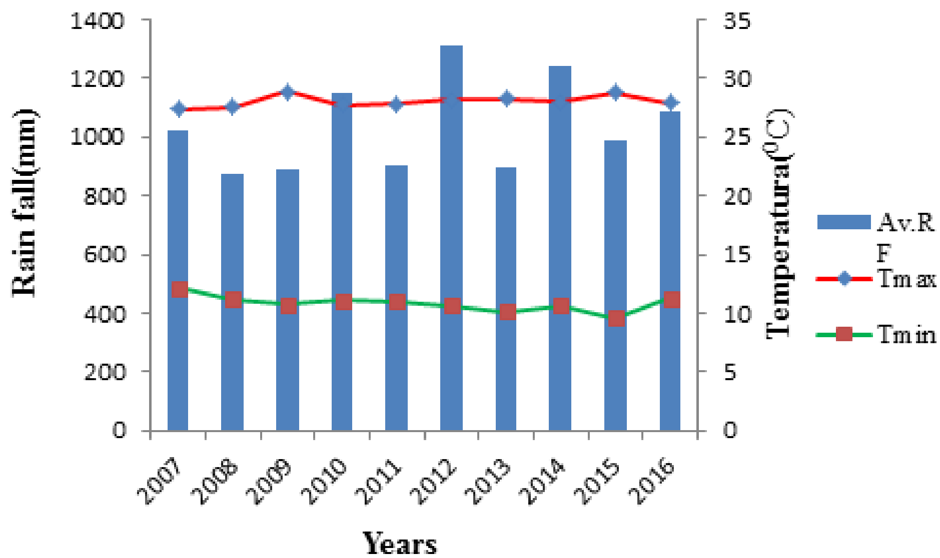

Figure 2. Ten-year annual rainfall, maximum and minimum temperatures recorded Tahtay koraro district.
Source; EMSA (Ethiopian Meteorological Service Agency) Tigray branch (2018).

Recommended NP at rate of 64 kg Nha^{-1} and 46 kg P_2O_5 ha^{-1}). The plot size was 3 x 3 m with three replications. The distance between replication and plots were 1 and 0.5 m respectively. The plots in each replication were represented randomly for each treatment. The seven 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 found in a very low amount in the blended fertilizer it was adjusted to the recommended level; so it was top dressed at two splits (1/3 at 14 days after planting and 2/3 at 45 days after planting) but blended fertilizers was applied at sowing time. The test crop was also planted in rows with 1 x 0.5 x 0.2 m spacing between blocks, plots and row plants respectively. Quncho variety was tested at seed rate of 5kg ha^{-1}. All crop management practices were applied as per the recommendation for the teff crop.

Soil data collection and analysis

Before planting, one representative composite soil sample was taken 0 to 30 cm depth from each farmer's fields using an auger. The collected samples were properly labeled, packed and transported to Shire soil research center. Particle size distribution was determined using the Bouyoucos hydrometer method

(Bouyoucos, 1962). The pH of the soil was measured in the supernatant suspension of a 1:2.5 soil to water ratio using a pH meter (Rhoades, 1982). Electrical conductivity (EC) (1:25 soil to water suspension) was measured according to the method described by Jakson (1967). Organic carbon was determined by the Walkely and Black (1934). Total nitrogen was determined using the Kjeldahl method as described by Bremner and Mulvaney (1982). Available P was determined following the Olsen method (Olsen et al., 1954) using ascorbic acid as reducing agent.

Crop data collection

Agronomic data like days to heading, days to physical maturity, head length plant height, biomass yield, straw yield, grain yield and harvest index were collected.

Data analysis

The collected data were subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using SAS statistical software program (SAS, 2002). Significant difference between and among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez, 1984).

Economic analysis (partial budget analysis)

To assess the costs and benefits associated with the different treatment rates, the partial budget technique of CIMMYT (1988) was applied to economic yield results. 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

Particle size analysis, with sand (14-19%), silt (21-26%) and clay (58-62%), indicates that clay particles dominated the soil and its textural class was categorized as clayey (Table 1). Vertisols are characterized by high clay content with swelling and shrinking characteristics and relatively resistance to erosion (FAO, 2014). In line with this study, Berhanu (1985) reported that Vertisols in Ethiopia generally contain more than 40% clay in their surface horizons. The soil pH of the study area ranging from 6.55 - 7.19 before sowing (Table 1) was found to be slightly acidic to neutral soil (Tekalign, 1991). According to Landon (1991), soils having pH value in the range 5.5 to 7.5 are considered suitable for most agricultural crops. Therefore, the soil pH values recorded in the study area of the present study agrees with these findings. The electrical conductivity was 0.211-0.293dS m^{-1} before sowing indicating a non-saline soil (Marx and Stevens, 1999). Generally, the EC value measured at the study area 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 Landon (1991). There was low available P before sowing (4.06-4.21 ppm) which was rated as very low (Olsen et al., 1954). Therefore area demands high amount of available P from applied NPSZnB fertilizers. The OC and TN in soil before sowing was 0.56-1.129 and 0.047-0.082%, respectively (Table 1). According to the Tekalign (1991) report, 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 (Mohanty et al*.,* 2011). The cation exchange capacity of the soil before sowing was 46-48.4 cmol(+)kg^{-1}. The soil CEC was found to be 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.

Growth parameters

Days to 50% heading and 90% physical maturity

The effects of different blended (NPSZnB) fertilizer rates were highly significant ($P<0.01$) on days to panicle emergence of teff at Medebay zana district and have only a significant difference with the control plot but not in between the fertilized plots at Tahtay koraro area (Table 2). The highest days to 50% panicle emergence (62.67 and 63.06 days, respectively) was recorded for the control plots, while the lowest (54.5 and 56.56 days) was recorded for the highest rates of 200 and 250 kg blended NPSZnB ha^{-1} with N adjusted to 64 kg N ha^{-1} fertilizers at Medebay zana and Tahtay koraro districts, respectively (Table 2). The hastened panicle emergence as a result of the highest rates of NPSZnB could be due to early establishment, rapid growth and development of crop. The application of adjusted N hastened the days to heading possibly because the teff plants were able to take up sufficient N from the soil and also because uptake of N may have enhanced the uptake of other nutrients such as P and S which might speed up growth and development of the crop plant. This result was in agreement with Getahun et al. (2018) who reported that the heading of teff plants was accelerated as NP rate increased from zero to 69 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1} fertilizer applications. On the other hand, there was no significant difference among the treatments to influence 90% physical maturity at Medebay zana district. However, there was significant difference between the fertilized plots and the control plot, despite no statistical difference in between the plots treated with fertilizer at Tahtay koraro district. The highest days to 90% physical maturity (107.22days) was obtained for the control plots, while the lowest (102.39days) was recorded for the blanket recommended NP (64 kg N ha^{-1} and 46 kg $P_2O_5ha^{-1}$) fertilizer (Table 2). The enhanced maturity with the application of blended fertilizer could be due to the

Table 1. Pre- sowing physical and chemical soil characteristics of the study areas.

Soil parameter	Year 1 (2017)					Year 2 (2018)				
	Medebay zana district		Tahtay koraro district			Medebay zana district		Tahtay koraro district		
	Site 1	Site 2	Site 1	Site 2	Site 3	Site 1	Site 2	Site 1	Site 2	Site 3
pH	7.19	6.55	6.71	6.59	7.19	6.85	6.91	6.89	6.99	6.86
EC (dS m^{-1})	0.273	0.211	0.273	0.244	0.283	0.259	0.276	0.289	0.293	0.271
Av.P (ppm)	4.096	4.188	4.06	4.18	4.09	4.08	4.07	4.21	4.16	4.19
OM (%)	1.095	0.982	1.05	1.173	1.301	1.311	1.195	1.982	1.285	1.712
OC (%)	0.624	0.560	0.598	0.668	0.741	0.747	0.681	1.129	0.732	0.975
TN (%)	0.052	0.047	0.050	0.056	0.062	0.062	0.057	0.094	0.061	0.082
CEC(meq100 g^{-1})	47.6	46.5	46	45.1	46.8	48.4	47.7	44.2	45.1	45
Sand (%)	18	14	19	14	16	19	17	15	18	18
Silt (%)	24	24	21	24	26	22	25	25	21	24
Clay (%)	58	62	62	62	58	59	58	60	61	58
Tex. class	clayey	clayey	clayey	clayey	clayey	clayey	clayey	clayey	clayey	clayey

pH= power of hydrogen, EC= electrical conductivity, OC= organic carbon, OM = organic matter, TN= total nitrogen, P_{av}= and CEC= cation exchange capacity.
Source for Analytical results: Shire soil research center (2018)

Table 2. Days to 50% heading and days to 90% physiological maturity of teff as influenced by blended fertilizer (NPSZnB) rate.

Treatments	Medebay zana		Tahtay koraro	
	DH (days)	DPM (days)	DH (days)	DPM (days)
Control (0,0)	62.67[a]	110.17	63.06[a]	107.22[a]
50 NPSZnB kg ha^{-1}	57.50[b]	107.42	58.89[b]	103.33[b]
100 NPSZnB kg ha^{-1}	56.08[cb]	108.08	57.78[b]	103.11[b]
150 NPSZnB kg ha^{-1}	55.33[cb]	107.92	56.89[b]	103.00[b]
200 NPSZnB kg ha^{-1}	54.50[c]	107.00	56.83[b]	102.94[b]
250 NPSZnB kg ha^{-1}	55.25[cb]	107.67	56.56[b]	102.83[b]
300 NPSZnB kg ha^{-1}	54.58[c]	107.33	57.33[b]	102.61[b]
Rec.NP kg ha^{-1}	57.42[b]	107.08	58.56[b]	102.39[b]
Mean	56.67	107.83	58.23	103.43
LSD(P≤0.05)	2.69	NS	3.13	1.71
CV (%)	5.85	6.54	8.16	2.50

Where; DH= Days to 50% Heading, DPM= Days to 90% physiological maturity, LSD= Least Significant Difference, CV= Coefficient of Variance and NS = non-significant; means followed by the same letters are not significantly different (P ≤ 0.05) according to LSD Tests.
Source for Analytical results: Shire soil research center (2018)

presence of balanced fertilizer in the blended fertilizer, as the level of fertilizer increases physical maturity hastened.

The result of present study agrees with the result of Tekulu et al. (2019) reported that as the rate of N increased from 0 to 69 kg N ha^{-1}, days to maturity of teff was significantly delayed.

Plant height and head length

The analysis of variance shows that there were no significant difference among the treatments that received fertilizers, but there was a significant difference (P<0.05) with control plot in plant height in both districts. The highest plant height was observed (127.52 cm at Medebay zana and 119.3 cm at Tahtay koraro), which were obtained from the highest NPSZnB kg ha^{-1} rate and 200kgha^{-1}, respectively; while the shortest plant height (113.52 cm and 78.86 cm) was recorded for the control plot in both districts (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

Table 3. Plant height (cm) and panicle length (cm) of teff as influenced by blended fertilizer (NPSZnB) rate.

Treatments	Medebay zana		Tahtay koraro	
	PH(cm)	HL(cm)	PH(cm)	HL(cm)
Control (0,0)	113.52[b]	46.28	78.86[b]	35.92[b]
50 NPSZnB kg ha^{-1}	124.13[a]	45.97	115.26[a]	47.63[a]
100 NPSZnB kg ha^{-1}	124.93[a]	47.58	118.06[a]	47.42[a]
150 NPSZnB kg ha^{-1}	126.80[a]	47.98	119.06[a]	46.83[a]
200 NPSZnB kg ha^{-1}	128.92[a]	48.10	119.30[a]	47.52[a]
250 NPSZnB kg ha^{-1}	126.68[a]	46.12	117.48[a]	46.51[a]
300 NPSZnB kg ha^{-1}	127.52[a]	47.13	118.21[a]	47.79[a]
Rec.NP kg ha^{-1}	126.43[a]	47.77	115.07[a]	46.96[a]
Mean	124.87	47.12	112.66	47.12
LSD(P≤0.05)	5.90	NS	7.31	2.83
CV (%)	5.82	8.26	9.85	9.36

Where; PH= Plant height, PL= Panicle length, 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.
Source for Analytical results: Shire soil research center (2018)

maximum plant height (112.33 cm) was obtained from the application of the highest rate (69 kg N ha^{-1}); whereas the lowest plant height was obtained from the control plot of the teff crop. 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^{-1}. However in contrast with this finding, increase in the rate of NPSB application from 0 to 150 kg ha^{-1} did not significantly affect the height of teff plants. Whereas, panicle length showed no statistical difference at Medebay zana district, there was no significant difference between the fertilized plots and unfertilized plot at Tahtay koraro district. Accordingly, the plots treated with 300 $kgha^{-1}$ NPSZnB have the highest panicle height (47.79cm) 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^{-1}, while the shortest (31.6 cm) was recorded from the control. Thus, increasing N from 0 to 69 kg N ha^{-1} increased panicle length by about 26.3%, compared to the control.

Yield components and yield

Tillers capacity

The analysis of variance shows that there were no significant difference on total tillers influenced by the treatments at Medebay zana district, but there were statistically significance difference between plots treated with fertilizer and control for Tahtay koraro district. The highest number of total tillers (8.91$plot^{-1}$) was obtained with the application of blended fertilizer 50 kg NPSZnB ha^{-1}, while the lowest number of total tillers (7.6$plot^{-1}$) was obtained from the unfertilized plots (Table 4). The increased total 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 Tekulu et al. (2019), who reported that application of blended fertilizer (69 kg N ha^{-1} + 46 kg P_2O_5 + 22 kg S ha^{-1} + 0.3 kg Zn ha^{-1}) brought significant increase in total tillers (15 tillers per plant) of teff as compared to 5 tillers per plant of unfertilized plot. Productive tillers were significantly affected ($P \leq 0.05$) by the treatments on both districts. The highest number of productive tillers (6.98 $plant^{-1}$ at Medebay zana and 6.77 at Tahtay koraro) was obtained with the application of blended fertilizer 300 and 150 kg NPSZnB ha^{-1} respectively, while the lowest number of productive was obtained from the control plots (Table 4). The highest number of productive tillers might be due to sufficient amount of growth and development of plants owing to the essential elements under blended NPSZnB fertilizer condition. In agreement with the results of this study, Fayera et al. (2014) found that the highest productive tillers of teff (26 tillers per plant) under the application of 200 kg ha^{-1} NPKSZnB blended (14% N, 21% P_2O_5, 15% K_2O, 6.5% S, 1.3% Zn and 0.5% B) + 23 kg N ha^{-1} fertilizer.

Straw yield

As the analysis of variance shows in the table straw yield, there were no significant difference among the fertilized plots but have significant difference with the control

Table 4. Tillers capacity per plant of teff as influenced by NPSZnB fertilizer rate.

Treatment	Medebay zana		Tahtay koraro	
	NT	NET	NT	NET
Control (0,0)	9.42	5.75^{b}	7.60^{b}	4.37^{b}
50 NPSZnB kg ha^{-1}	8.75	6.05^{ba}	8.91^{a}	6.53^{a}
100 NPSZnB kg ha^{-1}	9.67	6.97^{a}	8.60^{ba}	6.39^{a}
150 NPSZnB kg ha^{-1}	9.48	6.63^{ba}	8.72^{ba}	6.77^{a}
200 NPSZnB kg ha^{-1}	9.20	6.47^{ba}	7.92^{ba}	6.12^{a}
250 NPSZnB kg ha^{-1}	9.15	6.63^{ba}	8.43^{ba}	6.61^{a}
300 NPSZnB kg ha^{-1}	9.95	6.98^{a}	8.89^{a}	6.61^{a}
Rec.NP kg ha^{-1}	9.63	6.50^{ba}	8.42^{ba}	6.24^{a}
Mean	9.41	6.50	9.41	6.21
LSD(P≤0.05)	NS	1.01	1.26	0.97
CV (%)	20.31	19.16	22.71	23.66

Where; 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 ≤ 0.05) according to LSD Tests.
Source for Analytical results: Shire soil research center (2018)

Table 5. Grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index (%) of teff as influenced by blended fertilizer (NPSZnB) rate.

Treatments	Medebay zana			Tahtay koraro		
	SY (kgha$^{-1)}$	GY (kgha^{-1})	HI (%)	SY (kgha^{-1})	GY (kgha^{-1})	HI (%)
Control (0,0)	5362^{b}	1433^{b}	21.51^{a}	2531^{b}	881^{b}	27.02
50 NPSZnB kg ha^{-1}	7273^{ba}	1946.6^{ba}	21.14^{a}	5143.6^{a}	1800.9^{a}	25.96
100 NPSZnB kg ha^{-1}	7104^{ba}	1870.6^{ba}	21.11^{a}	5497.4^{a}	1838.8^{a}	24.85
150 NPSZnB kg ha^{-1}	7576^{a}	2039.4^{a}	21.27^{a}	5766.3^{a}	1883.3^{a}	24.60
200 NPSZnB kg ha^{-1}	8187^{a}	2165.3^{a}	21.13^{a}	5733.3^{a}	1795.2^{a}	24.34
250 NPSZnB kg ha^{-1}	7476^{a}	1946.9^{ba}	20.95^{a}	5880.9^{a}	1996.6^{a}	25.37
300 NPSZnB kg ha^{-1}	8422^{a}	1952.2^{ba}	18.26^{b}	5602.0^{a}	1876.6^{a}	25.40
Rec.NP kg ha^{-1}	7407^{a}	2005.3^{a}	21.52^{a}	4946.1^{a}	1777.6^{a}	26.73
Mean	7350.93	1919.90	20.86	5137.53	1731.23	25.53
LSD(P≤0.05)	2026.2	556.51	2.39	1090.3	371.71	NS
CV (%)	33.97	35.72	14.14	32.19	32.57	23.02

Where; Trt= treatment, BY= Biomass Yield, SY = Straw yield, Gy= Grain yield, HI= Harvest index, Variable means followed by the same letters are not significantly different (P ≤ 0.05) according to LSD Tests.
Source for Analytical results: Shire soil research center (2018).

(unfertilized) plot both districts (Medebay zana and Tahtay koraro). The highest straw yield 8422kg ha^{-1} and 5881 kg ha^{-1} was recorded from 300 and 250 kg ha^{-1} of NPSZnB in both districts, respectively. This result showed 36.3 and 67.0% straw yield increment over unfertilized plot and 12.1 and 15.9% over recommended NP for the two districts relatively (Table 5). 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. Tewolde et al. (2020) 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. The application of higher N fertilizer by adjusting to 64kgha^{-1} in the blended fertilizer also improves the straw yield by 36.3 and 67.0% over unfertilized plot (Table 5). This might be due to its enhanced availability, uptake and induction of vigorous vegetative growth with more leaf area resulting in higher photosynthesis and assimilates that resulted in more dry matter accumulation (Brady and Weil, 2002; Tekulu et al., 2019). In agreement with this result, Fenta (2018) found increasing biomass with the increasing rate of nitrogen.

Grain yield

As shown in the analysis of variance, there were no significant difference among the fertilized plots but there was significant difference with the control (unfertilized) plot in all study areas. The highest grain yield (2165kg ha^{-1}) was recorded as a result of 200 kg ha^{-1} of NPSZnB. It has 56.9% yield increment over control and 7.4% over the blanket recommendation at Medebay zana district (Table 5). Tahtay koraro district also shows the same trend; the highest grain yield (1997kg ha^{-1}) was recorded as a result of 250 kg ha^{-1} of NPSZnB (Table 5). It has 55.9% yield increment over control and 11% over the blanket recommendation. The highest grain yield at the highest NPSZnB rates might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to synergetic effect of the nutrients which enhanced yield components and yield (Getahun et al*.,* 2018). In agreement with this result, Jarvan et al. (2012) reported that the addition of 100 kg N ha^{-1} with 10 kg S ha^{-1} to winter wheat gave yield of 5.88 t ha^{-1}, while it gave 5.73 t ha^{-1} when 100 kg N ha^{-1} with 6 kg ha^{-1} S. The highest grain yield (21.65 and 19.67 q ha^{-1}) obtained in both districts in two consecutive research seasons was higher than the national average yield (16.64 q ha^{-1}) (CSA, 2017).

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 no significant difference among any of the treatments in harvest index of teff except with control at Medebay zana; however as the level of the fertilizer increases, the harvest index becomes decreased. Therefore, the highest 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 HI in maize increased when N rate increased.

Partial budget analysis

As indicated in Table 6, the highest net benefit of 60628 Birr ha^{-1} with marginal rate of return (MRR) of 475.7% was obtained in response to application of 200 kg blended NPSZnB ha^{-1} (N was adjusted to 64 kg N ha^{-1}). However, the highest marginal rate of return (711%) was obtained in response to 50kgha^{-1}NPSZnB for Medebay zana district. The same for Tahtay koraro district, the highest net benefit of 53860 Birr ha^{-1} with marginal rate of return (MRR) of 72% , which was below the acceptable MRR (100%) was obtained in response to application of 250 kg blended NPSZnB ha^{-1} and the highest marginal rate of return (1173.3%) was obtained in response to 50kgha^{-1}NPSZnB. However, the plot treated with 150kgha^{-1}NPSZnB had 52710.80 Birrha^{-1} net benefit and MRR of 113.5%, which was still above the acceptable MRR (100%). 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 50 kg ha^{-1} NPSZnB 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 in an additional 50 kg ha^{-1} NPSZnB. 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 200 and 150 kg blended NPSZnB ha^{-1} with N adjusted to 64 kg N ha^{-1} is economically beneficial as compared to the other treatments in Medebay zana and Tahtay koraro districts respectively because the highest net benefit and the marginal rate of return was above the minimum level (100%).

CONCLUSION AND RECOMMENDATION

The major teff agronomic parameters can be improved by using the blended NPSZnB fertilizer as compared to the blanket recommended NP fertilizer rates. The days to heading, plant height, number of productive tillers per plant, straw yield, grain yield and harvest index showed a significant difference over the control plot at both districts. But days to 90% physical maturity and head length (panicle length) at Medebay zana district and harvest index at Tahtay koraro have no significant difference within any of their treatments. Even if there were no significant difference among the fertilized plots in most parameters, the plots treated with higher level of blended fertilizer resulted in improved yield over the blanket recommended NP fertilizer. Generally, this study revealed that the potential advantages of blended fertilizer rates (NPSZnB) over the blanket NP fertilizer recommendation for teff production grown on vertisols in two year experimentation on both districts. There is a positive correlation between straw yield and plant height, panicle length per plant and number of tillers per plant; and between grain yield and plant height, panicle length per plant, number of tillers per plant in all the study sites. The partial budget analysis revealed that applications of 200 kgha^{-1} NPSZnB with N adjusted to 64 kgha^{-1} with benefit of 60628 Birr ha^{-1} and MRR of 475.7% was

Table 6. Partial budget analysis of the experiment.

Treatments	Grain yield GY (kgha^{-1})	AY (10% less) (kg ha^{-1})	TR [Grain yield*23.8] (1)	Straw yield SY (kg ha^{-1})	AY (10% less) (kg ha^{-1})	(TR) [Grain yield*3.1](2)	GR Sum (1+2)	Costs FC [Birr]	TaAC [Birr]	TVC [Birr]	NR [TR-TVC]	MRR (ratio) [(Rt2-Rt1)/(Ct2-Ct1)	MRR (%)
Medebay zana district													
Control (0,0)	1432.9	1289.61	30692.72	5362	4825.8	5159.6	35852.32	0	0	0	35852.32	0.000	0.0
50NPSZnB	1946.6	1751.94	41696.17	7273	6545.7	11351.6	53047.77	1980.25	140	2120.25	50927.52	7.110	711.0
100NPSZnB	1870.6	1683.54	40068.25	7104	6393.6	16402.4	56470.65	2708.85	210	2918.85	53551.8	3.286	328.6
Rec.NP(100:100)	2005.3	1804.77	42953.53	7407	6666.3	11995.1	54948.63	2918.75	210	3128.75	51819.88	D	D
150NPSZnB	2039.4	1835.46	43683.95	7576	6818.4	16862.8	60546.75	3437.45	280	3717.45	56829.3	4.104	410.4
200NPSZnB	2165.3	1948.77	46380.73	8187	7368.3	18763.7	65144.43	4166.05	350	4516.05	60628.38	4.757	475.7
250NPSZnB	1946.9	1752.21	41702.6	7476	6728.4	21288.6	62991.2	4894.65	420	5314.65	57676.55	D	D
300NPSZnB	1952.2	1756.98	41816.12	8422	7579.8	21855.9	63672.02	5623.25	490	6113.25	57558.77	D	D
Tahtay koraro district													
Control (0,0)	880.9	792.81	18868.88	2530.7	2277.63	7060.65	25929.53	0	0	0	25929.5	0	0.0
50NPSZnB	1800.9	1620.81	38575.28	5143.6	4629.24	14350.6	52925.92	1980.25	140	2120.25	50805.7	11.73	1173.3
100NPSZnB	1838.8	1654.92	39387.1	5497.4	4947.66	15337.7	54724.84	2708.85	210	2918.85	51806	1.25	125.3
Rec.NP(100:100)	1777.6	1599.84	38076.19	4946.1	4451.49	13799.6	51875.81	2918.75	210	3128.75	48747.1	D	D
150NPSZnB	1883.3	1694.97	40340.29	5766.3	5189.67	16088	56428.26	3437.45	280	3717.45	52710.8	1.13	113.3
200NPSZnB	1795.2	1615.68	38453.18	5733.3	5159.97	15995.9	54449.09	4166.05	350	4516.05	49933	D	D
250NPSZnB	1996.6	1796.94	42767.17	5880.9	5292.81	16407.7	59174.88	4894.65	420	5314.65	53860.2	0.72	72.0
300NPSZnB	1876.6	1688.94	40196.77	5602	5041.8	15629.6	55826.35	5623.25	490	6113.25	49713.1	D	D

GY= grain yield, AY= adjusted yield, TR= total revenue, SY= straw yield, GR= gross revenue, FC= fertilizer cost, TaAC= total and application cost, TVC=total variable cost, NR= net revenue and MRR= marginal rate of return.
Source for Analytical results: Shire soil research center (2018).

economically feasible rate for Medebay zana district (Adekemalk kebelle). Similarly, for Tahtay koraro area (Beles kebelle), application of 150kgha^{-1}NPSZnB with N adjusted to 64 kgha^{-1} have thebest economic benefit of 50806 Birr ha^{-1} and MRR of 113.5%. Therefore, it can be recommended that applications of 200 kgha^{-1}and 150kgha^{-1} blended NPSZnB fertilizer with N adjusted to 64 kgha^{-1} for Medebay zana and Tahtay koraro areas respectively, can produce good teff yield. Other areas with similar agro-ecological conditions and similar soil type also can use those rates as benchmark for farther studies.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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