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Response of Tef [*Eragrostis tef (Zuccagni) Trotter*] to Nitrogen and NPS-B Blended Fertilizers on Andisols of Southern Ethiopia

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Abstract

Inorganic fertilizers are important tools to overcome soil fertility problems and are also responsible for a large part of the food production increases. The study was aimed to determine the optimum level of NPS-B by supplementing N from urea rates for maximum yield of tef production and to determine the economically optimum level of NPS-B by supplementing N from urea fertilizer. The treatments were: (100 kg ha^{-1} NPSB + 100 kg ha^{-1} Urea), (150 kg ha^{-1} NPSB + 100 kg ha^{-1} Urea), (200 kg ha^{-1} NPSB + 100 kg ha^{-1} Urea), (150 kg ha^{-1} NPSB + 200 kg ha^{-1} Urea), (150 kg ha^{-1} NPSB + 200 kg ha^{-1} Urea), (150 kg ha^{-1} NPSB + 200 kg ha^{-1} Urea), (200 kg ha^{-1} NPSB + 200 kg ha^{-1} Urea), (250 kg ha^{-1} NPBS + 200 kg ha^{-1} Urea), (100 kg ha^{-1} NPSB + 300 kg ha^{-1} Urea), (150 kg ha^{-1} NPSB + 300 kg ha^{-1} Urea), (200 kg ha^{-1} NPSB + 300 kg ha^{-1} Urea), (250 kg ha^{-1} NPSB + 300 kg ha^{-1} Urea), control and R-NP (60N 35 P_2O_5). The treatments were arranged in a randomized complete block design and replicated three times. The maximum biomass yield (13.2 tone ha^{-1}), grain yield (2.6 tone ha^{-1}) was obtained from the application of 200 kg ha^{-1} of NPS-B blended fertilizer with 100 kg ha^{-1} Urea. The economic analysis revealed that the highest net benefit of 93885.9 ETB ha^{-1} with a marginal rate of return (MRR%) of 143.8% was obtained in response to the application of 200 kg ha^{-1} of NPS-B blended with 100 kg ha^{-1} of Urea. However, the lowest net benefit was obtained from an unfertilized or control plot. Therefore, applications of 200 kg ha-1 NPSB of blended plus 100 kg ha-1 of urea are economically advisable for farmers in the Halaba districts southern, Ethiopia and areas with similar agro-ecological and soil types for better tef production.

Keywords

Grain yield, Nitrogen, NPS-B blended fertilizers, Tef

1. Introduction

Teff (*Eragrostis tef* /Zucc. / Trotter) is a versatile cereal crop concerning adaptation for the diverse agro-climatic and soil conditions. For this reason, about 2.8 million hectares of land are cultivated annually, covering more than 28% of the total area annually under cereals in Ethiopia. However, its grain yield productivity level is generally low and equal to 1.15 Mg ha^{-1} [1]. Nitrogen and phosphorus nutrients are the major tef yield-limiting factors, the unbalanced and un-optimal fertilization of Ethiopian soils by applications of only DAP and urea (N and P containing fertilizers) for a long period has led to severe nutrient mining of the agricultural soils, particularly when the entire crop biomass (grain and stover) is removed from the land. Such low levels of tef yield are widely believed to be due to low soil fertility caused by low and unbalanced fertilizer application [2].

On the other hand, continuous application of DAP (Di-Ammonium Phosphate: 18-6% N-P2O5) containing only nitrogen (N) and phosphorus (P) without due consideration of other nutrients is known to cause depletion of secondary and micronutrients [2]. Recently, the agricultural extension program has promoted a blanket recommendation of 100 kg DAP and 100 kg urea/ha for all cereal crops and soil types but the actual application rate is 65 kg DAP and 45 kg urea/ha [2]. The low and unbalanced fertilizers application together with poor soil fertility management is presented as the major cause for low agricultural productivity in Ethiopia [3]. Under such conditions, the application of multi-nutrient blended fertilizers is acknowledged for being able to enhance the productivity and nutrient use efficiency of crops [2].

Recently, according to the soil fertility map Ethiopia soil analysis data revealed that the deficiencies of most of the nutrients such as nitrogen (86%), phosphorus (99%), sulfur (92%), born (65%), zinc (53%), potassium (7%), copper, manganese, and iron were widespread in Ethiopian soils [4]. Similarly, Asgelil et al. [5] found that the soil analyses and site-specific studies also indicated that elements such as K, S, Ca, Mg, and micronutrients (Cu, Mn, B, Mo, and Zn) were becoming depleted and deficiency symptoms were observed in major crops in different parts of the country. Inorganic fertilizers have been an important tool to overcome soil fertility problems and are also responsible for a large part of the food production increases.

The drive for higher agricultural production without balanced use of fertilizers created problems of soil fertility exhaustion and plant nutrient imbalances not only of major but also of secondary macronutrient and micronutrients. Similarly [6, 7] stated that the deficiencies of secondary macronutrients and micronutrients will arise if they are not replenished timely under intensive agriculture. Consequently, to overcome this problem, multi-nutrient balanced fertilizers containing N, P, K, S, B, and Zn in blended form have been issued to ameliorate site-specific nutrient deficiencies and thereby increase crop production and productivity.

Having considered the problems outlined above, the Ethiopian government has been promoting the use of multi-nutrient blend fertilizers since 2015. The promotion of blend fertilizer follows from the results of the soil fertility survey and preparation of the regional nutrient deficiency atlas of the country under the Ethiopian Soil Information System project [4]. To supply sulfur and Boron commercial fertilizer, DAP is replaced by NPSB. Since the composition of newly introduced fertilizer differs from that of familiar fertilizer (DAP), the appropriate rate is not determined, and insufficient information for Tef production in the study area. Therefore, this research aimed to determine the optimum level of NPS-B by supplementing N from urea for maximum yield of tef production and to determine the economically optimum level of NPS-B by supplementing N from urea fertilizer at Halaba district, Southern Ethiopia.

2. Methods

2.1. Description of the Experimental Area

The study was conducted during the 2019-2020 cropping season in the Halaba districts of Southern Ethiopia. The geographic locations of the experimental sites in Halaba (7°24'53.87" N and 38°6'55.54" E at an altitude of 1790 *m. a. s. l.*). The major crops are grown in the area where maize, wheat, sorghum, barley, tef, and pepper. The dominant soil type in the study area in Andisols.

2.2. Experimental set-up and procedure

The experimental sites were prepared for sowing using standard cultivation practices and were plowed using oxen-drawn implements. The experiment was laid out in randomized complete block design with three replicates for each treatment and detail of the treatments (Table 1). The blended and phosphorus-containing fertilizers from NPSB and triple superphosphate (TSP), respectively were basally applied once at sowing to minimize losses and increase use efficiency. Tef (*Quncho DZ-Cr-387 variety*) was used. The nitrogen fertilizer from Urea was applied in the row two times; half at sowing and the other half during the maximum growth; between the third and fourth weeks of sowing, and at the full tillering stage. All other agronomic management practices were applied as per recommendation. The necessary data were collected at the right time and crop growth stage.

2.3. Crop, Soil Data Sampling, and Analysis

The crop yield and yield components collected included several effective tillers, days to 50% flowering, days to panicle emergence, days to maturity, plant height, panicle length, grain yield, biomass yield, and seed weight. Representative composite surface soil samples were collected from 0-20cm depth at each experimental unit just before sowing. After manual homogenization, the samples were ground to pass a 2 mm sieve. Soil particle size distribution was determined by the Boycouos hydrometric method [8]; pH of the soils was measured in water suspension in a 1:2.5 (soil: water ratio) [8]; organic carbon was determined using the wet oxidation method [9]; total nitrogen was determined using

Kjeldahl digestion with concentrated H_2SO_4 and $K_2SO_4^-$ catalyst mixture [10] available P was determined using the Olsen method [11]; total sulfur in soil extracts was done using Turbidimetric method. The cation exchange capacity was determined after extracting the soil samples by ammonium acetate method (1N NH_4OAc) at pH 7.0 [12] Exchangeable acidity (EA) Al^{+3} and H^+ were determined from a neutral 1N KCl extracted solution through titration with a standard NaOH solution [13].

Table 1. Detail of treatment set up and nutrient levels

No	Urea (kg ha^{-1})	NPS-B (kg ha^{-1})	Nutrient level (kg ha^{-1})			
			N	P_2O_5	S	B
1	Control		0	0	0	0
2	*Rec-N and P*		60	35	0	0
3	100	100	64.1	36.1	6.7	0.71
4	100	150	73.15	54.15	10.05	1.065
5	100	200	82.2	72.2	13.4	1.42
6	100	250	91.25	90.25	16.75	1.775
7	200	100	110.1	36.1	6.7	0.71
8	200	150	119.15	54.15	10.05	1.065
9	200	200	128.2	72.2	13.4	1.42
10	200	250	137.25	90.25	16.75	1.775
11	300	100	156.1	36.1	6.7	0.71
12	300	150	165.15	54.15	10.05	1.065
13	300	200	174.2	72.2	13.4	1.42
14	300	250	183.25	90.25	16.75	1.775

The nutrients level of in 100 kg of NPS-B were (18.1 N – 36.1 P_2O_5 – 0.0 K_2O + 6.7 S + 0.0 Zn + 0.71 B)

2.4. Economic Analysis

Economic analysis was performed to investigate the economic feasibility of the treatments. Partial budget and marginal analyses were used. Current prices of tef, urea, TSP, and NPS-B fertilizer were used for the analysis. The potential response of crops towards the added fertilizer and price of fertilizers during planting ultimately determine the economic feasibility of fertilizer application [14]. The market cost of tef was 42.00 Eth-birr kg^{-1}. The prices for blended fertilizers NPSB, TSP, and Urea were 20.50, 20.50, and 18.25 Eth-birr kg^{-1}, respectively. The cost of other production practices like seed and weeding was assumed to remain the same or insignificant among the treatments.

Analysis of the marginal rate of return (MRR) was carried out for non-dominated treatments, and the MRRs were compared to a minimum acceptable rate of return (MARR) of 100% to select the optimum treatment [14]. The net benefit per hectare for each treatment is the difference between the gross benefit and the total variable costs. The average yield was adjusted downward by 10% to reflect the difference between the experimental field and the expected yield at farmers' fields and with farmer's practices from the same treatments [14].

2.5. Statistical Analysis

Data from the field and laboratory were tested for normality, before being subjected to analysis of variance (ANOVA) using SAS software program version 9.4 [15]. The significant difference among treatment means was evaluated using the least significant difference at ($p \leq 0.05$).

3. Results

3.1. Physicochemical properties of the Soil

The soil particle size distributions of the experimental site were 63.1%, 21.3%, and 15.3% sand, silt, and clay, respectively. Thus, the soil textural class of the soil was sandy loam [16]. The pH value of the soil was 6.5 (*1:2.5 soil: water*). The soil pH has a vital role in determining several chemical reactions in influencing plant growth by affecting the activity of soil microorganisms and altering the solubility and availability of most of the essential plant nutrients, particularly the micronutrients such as Fe, Zn, B, Cu, and, Mn [17]. The available P content of the soil was 11.2 (ppm). According to Olsen et al. [14], the status of available P of both sites categorized under medium level (Table 2). The organic carbon and total nitrogen content of the experimental soil were (1.5%) and (0.12%) respectively. According to Tekalign [18], rating of organic carbon and total nitrogen content of the experimental site soil under moderate to medium. Total sulfur (S) (2.8) and statuses of the soil found were d under the low category [18, 19] (Table 2). Whereas, the cation exchange capacity of soil sites, 12.8 meq 100g sample^{-1}, respectively, London, [20], Hazelton and Murphy, [21] were found at medium status (Table 2).

Table 2. Physio-chemical properties of the soil

Parameters	Value	Rating	Reference
Sand (%)	63.1		-
Silt (%)	21.6		
Clay (%)	15.3		
Textural class	Sandy Loam		[16]
pH (1:2.5 soil: water)	6.1		
Available P (mg kg^{-1})	11.2	Medium	[11]
Sulfur (mg kg^{-1})	2.8	Low	[19]
Total nitrogen (%)	0.12	Low	[18]
Organic carbon (%)	1.5	Low	[18]
Cation exchange capacity (cmol (+) kg^{-1})	12.8	Moderate	[20, 21]

3.2. Effects of NPS-B blended fertilizers and Urea on Yield and Yield Components of Tef

Application of NPSB blended fertilizers and Urea were highly significantly (p<0.01) influence yield and yield components of tef. The pooled mean analysis revealed that the tallest plant height (100.9 cm) was obtained from the application of 250 kg ha^{-1} NPSB with 300 kg ha^{-1} Urea. The longest spike length (36.9cm) was obtained from the application of 200 kg ha^{-1} NPSB with 300 kg ha^{-1} Urea. And the maximum number of tillers per m^2 (385) was obtained from the application of 200 kg ha^{-1} NPSB with 100 kg ha^{-1} Urea. However, the minimum tef yield components were obtained from unfertilized or control plots.

This significant increment of tef yield components may be attributed to the fact that N usually favors vegetative growth of teff, resulting in higher stature of plants while P is the main element involved in energy transfer for cellular metabolism in addition to its structural role and Sulphur enhanced the formation of chlorophyll and encouraged vegetative growth [22]. Similarly, an adequate supply of phosphorus increases tiller emergence, especially secondary tillers, and their survival, it helps in increasing the biomass yield through proper regulation of carbohydrates translocation [23]. An ample supply of boron facilitates photosynthetic activities and leaf expansion that leads to improved plant growth [24]. This might be due to plants grown on plots treated with a higher rate of N for their vegetative growth, higher P phosphorus for their good root development, higher level of S for a high number of tillers, and B for its higher cell division; it also contributed to increasing the total number of tillers per plant and influenced the straw yield [25]. The current findings were in line with [29, 29] were reported that the contained application of blended fertilizer with urea provides significantly higher yield components on tef.

The combined year's analysis revealed that application of NPSB blended fertilizer with N from urea was highly (*p<0.01*) significantly influence the biomass and grain yield (Table 5). The maximum biomass yield (12.9 tone ha^{-1}), grain yield (2.5 tone ha^{-1}) was obtained from the application of 200 kg ha^{-1} NPSB blended fertilizer with 100 kg ha^{-1} Urea (Figure 5). The total grain yields obtained at 200 kg ha^{-1} NPSB blended with 100 kg ha^{-1} Urea rates of fertilizers exceeded yield produced by 137.1% and 70.2%, unfertilized or control and recommended NP fertilize respectively.

Tef yields were consistently increased across blended NPS-B fertilizer and N from urea. This might be due to better crop growth rate, leaf area index, and accumulation of photo-assimilate due to maximum days to maturity by the crop, which ultimately produced more biomass and grain yields. Fageria et al. [25] also indicated that the application of S enhanced the photosynthetic assimilation of N in crops. Hence, the application of N and S increased the net photosynthetic rate which in turn increased the dry matter as 90% of dry weight is considered to be derived from products formed during photosynthesis. This result in conformity with this finding of different scholars [26, 27, 28, 29, 30] were reported that the application of different blended fertilizers with a combination of N from urea was increased biomass, grain of tef.

Table 3. Mean values of yield and yield components of tef as influenced by nitrogen and NPS-B blended fertilizer during 2019 cropping season

Treatments (kg ha^{-1}) Urea	NPSB	PH (cm)	SL (cm)	NT (m^2)	BM (t ha^{-1})	GY (t ha^{-1})
Control		62.1^{b}	13.7^{b}	75^{e}	6.2.0^{e}	0.6^{h}
RNP		99.1^{a}	33.5^{a}	354^{ab}	13.1^{ab}	2.2^{b}
100	100	90.0^{a}	32.4^{a}	219^{d}	9.4^{d}	1.3^{gh}
100	150	95.7^{a}	33.9^{a}	277^{bcd}	11.7^{bc}	2.0^{cdd}
100	200	100.8^{a}	32.1^{a}	385^{a}	13.5^{a}	2.8^{a}
100	250	100.3^{a}	34.3^{a}	324^{abc}	12.4^{ab}	2.0^{bc}
200	100	93.5^{a}	35.3^{a}	318^{abc}	10.8^{bcd}	1.9^{bcd}
200	150	100.0^{a}	34.2^{a}	275^{bcd}	12.2^{abc}	1.9^{bcd}
200	200	92.0^{a}	28.5^{a}	241^{cd}	9.8^{cd}	1.7^{cde}
200	250	100.0^{a}	34.5^{a}	248^{cd}	12.7^{ab}	2.0^{bc}
300	100	99.1^{a}	33.1^{a}	343^{ab}	12.3^{abc}	1.8^{bc}
300	150	97.8^{a}	32.2^{a}	315^{abc}	12.6^{ab}	1.6^{cde}
300	200	103.0^{a}	36.9^{a}	308^{abcd}	13.0^{ab}	2.2
300	250	100.3^{a}	33.0^{a}	296^{abcd}	12.1^{abcd}	1..1^{g}
CV		9.2	21.4	19.1	13.1	9.1
LSD@ ≤0.05		14.7*	14.7**	91.2**	2692.2**	271.6**

Means with the same letter along the column are not significantly different at $p \leq 0.05$, where; PH -plant height, SL-Spike length, NT-number of tillers, BM-biomass, GY-grain yield, R-NP=recommended rate of nitrogen and phosphorous

Table 4. Mean values of yield and yield components of tef as influenced by nitrogen and NPS-B blended fertilizer during 2019 cropping season

Treatments (kg ha^{-1}) Urea	NPSB	PH (cm)	SL (cm)	NT (m^2)	BM (t ha^{-1})	GY (t ha^{-1})
Control		54.9^{f}	14.9^{e}	99^{e}	5.6^{d}	0.3^{f}
RNP		95.2^{abc}	25.0^{abc}	256^{abc}	11.5^{abc}	1.7^{bcd}
100	100	82.8^{e}	16.2^{de}	154^{ef}	9.0^{bc}	1.1^{e}
100	150	88.5^{bcde}	24.4^{abc}	279^{ab}	11.4^{abc}	1.7^{bcd}
100	200	96.9^{ab}	29.2^{a}	321^{a}	12.9^{a}	2.5^{a}
100	250	96.4^{ab}	24.8^{abc}	226^{bcde}	12.8^{a}	1.9^{b}
200	100	86.3^{cde}	25.8^{abc}	220^{bcde}	10.2^{abc}	1.6^{bcd}
200	150	96.1^{ab}	24.7^{abc}	244.0^{bcd}	11.9^{ab}	1.6^{bcd}
200	200	84.8^{de}	20.7^{cd}	177de	8.6^{cd}	1.5^{cde}
200	250	92.8^{bcd}	25.0^{abc}	250^{abcd}	12.7^{a}	1.7^{bcd}
300	100	91.9	23.6^{bc}	245^{bcd}	11.7^{abc}	1.5^{cde}
300	150	93.9^{abcd}	22.7^{bc}	217^{bcde}	12.1^{ab}	1.3^{de}
300	200	95.8^{ab}	27.4^{ab}	210^{bcde}	12.5^{a}	1.7^{bc}
300	250	103.1^{a}	23.5^{bc}	198^{cde}	11.5^{abc}	0.6^{f}
CV		6.3	13.9	20.1	17.1	16.6
LSD@ ≤0.05		9.4*	5.9**	74.5**	3168.3**	412.9**

Means with the same letter along the column are not significantly different at $p \leq 0.05$, where; PH -plant height, SL-Spike length, NT-number of tillers, BM-biomass, GY-grain yield, R-NP=recommended rate of nitrogen and phosphorous

Table 5. Pooled mean values of yield and yield components of tef as influenced by nitrogen and NPS-B blended fertilizer during 2019-2020 cropping season

Treatments ($kg\ ha^{-1}$) Urea	NPSB	PH (cm)	SL (cm)	NT (m^2)	BM ($t\ ha^{-1}$)	GY ($t\ ha^{-1}$)
Control		58.5^{e}	14.3^{d}	87^{f}	5.9^{d}	0.5^{i}
R-NP		97.1^{abc}	29.3^{abc}	305^{ab}	12.3^{ab}	1.91^{bc}
100	100	86.4^{e}	24.3^{c}	187^{e}	9.3^{c}	1.2^{g}
100	150	92.1^{bcde}	29.1^{abc}	278^{bc}	11.5^{ab}	1.8^{bcde}
100	200	98.8^{ab}	30.7^{ab}	353^{a}	13.2^{a}	2.6^{a}
100	250	98.3^{abc}	29.6^{abc}	275^{bc}	12.6^{a}	2.0^{b}
200	100	89.9^{e}	30.5^{abc}	269^{bc}	10.5^{bc}	1.8^{bcde}
200	150	98.0^{abc}	29.5^{abc}	259^{bcd}	12.1^{ab}	1.7^{cde}
200	200	88.4^{cde}	24.6^{bc}	209^{de}	9.2^{c}	1.6^{ef}
200	250	96.4^{abcd}	29.8^{abc}	249^{bcd}	12.7^{a}	1.8^{bcde}
300	100	95.5^{bcde}	28.4^{abc}	294^{bc}	12.1^{ab}	1.7^{def}
300	150	95.9^{abcd}	27.5^{abc}	266^{bc}	12.3^{ab}	1.5^{f}
300	200	99.4^{ab}	32.2^{a}	259^{bcd}	12.7^{a}	1.9^{bcde}
300	250	101.7^{a}	28.3^{abc}	247^{cd}	11.9^{ab}	0.8^{h}
CV		8.1	19.7	19.3	15.3	12.6
LSD@<0.05		8.6*	6.3*	56.7*	1999.2**	237.5**

Means with the same letter along the column are not significantly different at ≤ 0.05, where; PH -plant height, SL-Spike length, NT-number of tillers, BM-biomass, GY-grain yield, R-NP=recommended rate of nitrogen and phosphorous

3.3. Economic Analysis

As indicated in Table 6, the highest net benefit of 93885.9 ETB ha^{-1} with a marginal rate of return (MRR%) of 143.8% was obtained in response to the application of 200 kg ha^{-1} of blended NPSB with 100 kg ha^{-1} of Urea. However, the lowest net benefit was obtained from the unfertilized or control plot (Table 6). Thus, applications of 200 kg ha^{-1} NPSB of blended plus 100 kg ha^{-1} of urea is economically advisable for farmers in the study area for better tef production; 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%).

Table 6. Nitrogen and NPS-B blended fertilizer effects on partial budget and marginal rate of return analysis for tef production

Treatments	GY ($t\ ha^{-1}$)	GB	TVC	NBC	MRR%
1	0.5	17694.2	0.0	17694.2	
2 (*R-NP*)	1.91	73184.6	3643.5	69541.1	14.2
3	1.2	45552.8	3875.0	41677.8	d
4	1.8	68350.0	4900.0	63450.0	21.2
7	1.8	67223.5	5700.0	61523.5	d
5	2.6	99810.9	5925.0	93885.9	143.8
8	1.7	65435.6	6725.0	58710.6	d
6	1.8	74862.9	6950.0	67912.9	40.9
11	1.7	63383.0	7525.0	55858.0	d
9	1.4	60778.6	7750.0	53028.6	d
12	1.5	56352.2	8550.0	47802.2	d
10	1.8	69245.8	8775.0	60470.8	56.3
13	1.9	70213.5	9575.0	60638.5	0.2
14	0.8	29899.8	10600.0	19299.8	d

R-NP=recommended rate of nitrogen and phosphorous, GY=grain yield, TCV = Total cost that varies; NBC = Net benefit-cost, GB=Growth benefit, Marginal rate of return; d=Dominance.

4. Conclusion and Recommendation

The result of the current study indicated that balanced and adequate soil nutrient management is one important practice for increasing tef yield component and yield. The result of the economic analysis showed that the combined application of 200 kg ha^{-1} of NPSB and 100 kg ha^{-1} of Urea gave economic benefit. Therefore, it could be concluded that the application of 200 kg ha^{-1} of NPSB with supplement 100 kg ha^{-1} of Urea fertilizer combinations was producing economically profitable tef production in the area.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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