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Effects of Diferent Rates of NPK and Blended Fertilizers on Nutrient Uptake and Use Efficiency of Teff [*Eragrostis Tef* (*Zuccagni*) Trotter] in Dedessa District, Southwestern Ethiopia

[1]Fayera Asefa*, [2]Muktar Mohammed and [2]Adugna Debela
[1]Department of Horticulture and Plant Sciences, College Agriculture and Veterinary Medicine Jimma University, Jimma, Ethiopia
[2]Assistant Professor, Department of Natural Resources Management, College of Agriculture and Environmental Science, Haramaya University, Ethiopia; Department of Horticulture and Plant Sciences, College Agriculture and Veterinary Medicine Jimma University, Jimma, Ethiopia
*Corresponding author: E-mail address: fayeraasefa@gmail.com

Abstract
Teff is a major staple food crop in Ethiopia whose yield is constrained by plant lodging, declining soil fertility due to nutrient depletion caused by farming without replenishing nutrients over time, leaching due to inadequate runoff management, removal of crop residue, low level of fertilizer use and unbalanced application of nutrients. Teff is well adapted to highland soils. Yields are low (in average about 1280 kg ha-1) even though fertilization with recommended rate of nitrogen and phosphorus fertilizers is applied. This experiment was conducted with the objective of evaluating different rates of NPK, and Zn and B blended fertilizers on yield, nutrient uptake (N, P, K and Zn) and nutrient use efficiency of teff crops, during 2013 main cropping season in Dedessa District of southwestern Ethiopia. The local variety of Gero was used as a test crop and 14 treatments (11 different rates of NPK, 2 blended fertilizers and unfertilized plot) were used and laid out in randomized complete block design (RCBD) with four replications. Results showed that grain and straw yield; nutrient (N, P, K and Zn) uptake and nutrient use efficiency was varied through all treatments significantly. The maximum yields (grain: 2147.7 kg ha^{-1} and straw: 5852.8 kg ha^{-1}); the highest total nitrogen uptake, phosphorus uptake, potassium uptake and zinc uptake; excellent agronomic efficiency and apparent nutrient recovery were recorded with the application of 200kg ha^{-1} of 14N $21P_2O_5$ $15K_2O$ 6.5S 1.3Zn 0.5B + 23 kg N ha^{-1}. These results should be reflected primary until further work is done, either at several locations or at various seasons, for confirmation. Therefore, taking the findings of the present study in to consideration it may be concluding that farmers can be use 200kg ha^{-1} of 14N $21P_2O_5$ $15K_2O$ 6.5S 1.3Zn 0.5B + 23 kg N ha^{-1} to improve nutrient uptake and fertilizer use efficiency, which are leads to yield increment.
Key words: Teff, zinc and boron blended fertilizer, NPK, yield, nutrient uptake and use efficiency

INTRUDUCTION

Teff [*Eragrostis tef* (*Zuccagni*) Trotter] is one of the most important food cereal crops in Ethiopia, occupying about 22.6% of the cultivated land from the total area of cereals (86.06%) with accounting 16% of the grain production (CSA, 2012). Teff yields are decreasing in many parts of the highlands of Ethiopia (CSA, 2012), which could be the result of plant lodging, a decline in the soil fertility due to high soil erosion and others, and unbalanced chemical fertilizer application. There are several factors have become a common phenomenon that leads to nutrient deficiency in soil as a result cereal production ineffectiveness. To increase production of cereal crops increasing use of appropriate of all essential nutrients are an optional. Fertilizers are an efficient exogenous source of plant nutrients (Akram *et al*., 2007). Since, plant growth and crop production require an adequate supply and balanced amounts of all nutrients (Mengel and Kirkby, 1987) in order to maximize productivity by optimizing the plant nutrient uptake. Consequently, adding micronutrients to NPK fertilizer can be increase fertilizer use efficiency and grain yield for different cereal crops (Malakouti, 2008). The widespread deficiency of nitrogen and phosphorus nutrients is followed by Zn deficiency, which is recording almost 50% of the world soils used for cereal production (Gibbson, 2006). The micronutrient deficiency specifically Zinc 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). For instance, most of cereal crops production in Ethiopia depends on the rain fed. In Ethiopia, nutrient deficiency is one of the vital yield limiting factors at highland areas of the country owing to high soil erosion, intensive cultivation and unbalanced nutrient supply. In this country, a farmers producing the cereal crops using the recommended blanket fertilizer (100 kg Urea ha^{-1} + 100 kg DAP ha^{-1}) as well as other single fertilizers (e.g. TSP and KCl) throughout the years. The essential micronutrients needed for plant growth and productivity did not use and this may be a cause for low cereal crops productivity. The current productivity obtained from the teff through using the recommended blanket fertilizers is very low compared to the potential yield of the crop, in all parts of the country. Consequently, soil productivity and chemical fertilizers that have been practiced in the area, requiring improvements to solve low productivity of the crop. Meaning, it needs nutrient source, which provides the appropriate nutrients to the needs of the crops. Blended fertilizers containing both macronutrients and microelements may possess this characteristic. Therefore, the percent study was initiated with the objective to investigate the effect of different rates of NPK and blended fertilizer on nitrogen, phosphorus, potassium and zinc uptake, and nutrient use efficiency of teff.

MATERIALS AND METHODS

The experiment was conducted at Dedessa District of Illubabor Zone, Southwestern Ethiopia on farmers' field from July - October during the main rain season of 2013. The area lies between 7°50'- 8°10' N and 36°30' - 36°45' E and is located at an altitude of 2260 masl with varying mean annual rainfall of 1800-2200 mm. The mean daily temperature ranges from 13 and 28°C. The soil type of the area is clay loam. The experiment was laid out in a randomized complete block design (RCBD) with four replication. The size of each plot was 5m wide and 10m long (50m^2 area) with 0.5m space between plots. Urea, TSP, KCl, and two blended fertilizers (14N 21P_2O5 15K_2O 6.5S 1.3Zn 0.5B and 23N 23P_2O_5 8.2S 1.2Zn) were used as a treatment source for the experiment. In both blended fertilizer 23 kg N ha^{-1} was added to make up for the shortfall of N fertilizer. Teff local variety Gero at a seed rate of 25 kg ha^{-1} was used and sown in broadcast. Grain and straw yield data were collected following procedures developed for each of the yield. Grain and Straw nutrient uptake were calculated by multiplying nutrient content with the respective straw and grain yield ha^{-1}: $NU = (NC * Y)/100$; where, NU, NC and Y stand for nutrient uptake, nutrient concentration of grain or straw, and grain yield or straw, respectively (Alam *et al.*, 2000). Agronomic and physiological nutrient use efficiency were calculated by using procedures described by Mengel and Kirkby, (1996) as: $[(GnTrt - GoCon)/n]$ for agronomic efficiency and $[(ByTrt - ByCon)/(UnTrt - UnCon)]$ for physiological efficiency; where GnTrt and GoCon stand for grain yield of the treatments fertilized at "n" rates of fertilizer and of unfertilized plots, respectively. ByTrt and ByCon stand for biomass yield (grain + straw) treatments fertilized at "n" rates of fertilizer and of unfertilized plots, respectively. Apparent fertilizer nutrient recovery was calculated as per the procedure described by Pal, (1991); Fageria and Baligar, (2005): $[(UnTrt - UoCon)/n]100$ where, UnTrt stands for nutrient uptake at "n" rate of fertilizers and UoCon stands for nutrient uptake at control or no fertilizer. The collected data were statistically analyzed by ANOVA using SAS vr. 9.2 statistical software. The treatment means were separated using LSD at 5% level of probability.

Table1. Detains of fertilizer treatments used in this experiment

Trt. code	Treatments	
T1	64 kg N + 20 kg P : fertilizer rate recommended by ministry of agriculture (MOA)	
T2	96 kg N + 43 kg P : fertilizer rate recommended by CASCAPE project at study area	
T3	200 kg of 14N 21P_2O_5 15K_2O 6.5S 1.3Zn 0.5B + 23 kg N	
T4	200 kg 23N 23P_2O_5 8.2S 1.2Zn + 23 kg N	
T5	138 kg N [1]+55 kg P +75 kg K	
T6	138 kg N	
T7	55 kg P	138 kg N ha^{-1}, 55 kg P ha^{-1} and 75 kg K ha^{-1} are fertilizer rates predicted for cereal crops production in Ethiopia by using QUEFTS model
T8	75 kg K	
T9	55 kg P + 75 kg K	
T10	138 kg N + 75 kg K	
T11	138 kg N + 55 kg P	69 kg N ha^{-1} and 92 kg N ha^{-1} are nitrogen fertilizer rates recommended for teff production by some researchers in Ethiopia
T12	69 kg N + 55 kg P + 75 kg K	
T13	92 kg N + 55 kg P +75 kg K	
T14	Control	

Where, N: Nitrogen, P: phosphorus, K: potassium, Zn: zinc and B: boron

RESULTS AND DISCUSSION

The analysis of variance showed that the nutrient concentrations and total nutrient uptake (N, P, K, and Zn) in both grain and straw yield at maturity, and nutrient use efficiency were highly significantly ($P < 0.05$) affected by the main effect of different rates of NPK and blended fertilizers (Table 2 and 3). T11 provides the highest nitrogen concentration (23.81 g kg^{-1}) in grains and was increased the minimum nitrogen concentration by 3.39 % over all treatments. Whereas, applying of 14N 21P_2O5 15K_2O 6.5S 1.3Zn 0.5B blended fertilizer increased the minimum of N concentration by about 3.05% over all treatments other than T11. The highest value of phosphorus (4.36 g kg^{-1}) concentration in grains was obtained from application of 14N 21P_2O5 15K_2O 6.5S 1.3Zn 0.5B, while highest zinc concentration (60.00 µg/gdm) was obtained from application of both 14N 21P_2O5 15K_2O 6.5S 1.3Zn 0.5B and 64 kg N ha^{-1} + 20 kg P ha^{-1}. This blended fertilizer also increased the minimum phosphorus and zinc concentration by 0.23% and 20% over all treatments, respectively. However, the higher concentration of potassium in the grain was obtained from T1, followed by T7 and T9 compared with other treatments. This is supported by Siddiqui *et al.,* (2009) who also reported that the incorporation of Zn to NPK fertilizer increase the nutrient content of nitrogen, phosphorus, zinc and boron but no increase potassium concentration, in sunflower plants. Application of 23N 23P_2O_5 8.2S 1.2Zn blend cannot improve the nutrient concentration of N, P and K in straw teff than the treatments. Moreover, the nitrogen, phosphorus and zinc nutrient concentrations in the grain were greater than the nitrogen, phosphorus and zinc nutrient concentrations in straw, whereas the inverse is true for potassium nutrient concentration. The maximum value of total N (134.38 kg ha^{-1}), P (18.36 kg ha^{-1}) and Zn (0.24 kg ha^{-1}) uptake were recorded from application of 14N 21P_2O_5 15K_2O 6.5S 1.3Zn 0.5B blended fertilizer. Thus, this treatment was increased the minimum total nitrogen, phosphorus, potassium and zinc uptake by 16.41%, 11.736%, 0.72% and 15% compared to other treatments, respectively. 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. On other hand, a treatment that accumulates the maximum of N, P, K and Zn nutrients gave the highest yield. Similar to this finding, Assefa (2008) reported that the grain yield at maximum accumulation of nutrient occurs when increasing that nutrient rate does not increase uptake and yield.

Table 2. Effects of rates of NPK and blended fertilizers on nutrient content of grain and straw teff

Treatments code	Grain nutrient concentration				Straw nutrient concentration			
	N (g /kg)	P (g /kg)	K (g/kg)	Zn (µg/gdm)	N (g /kg)	P (g /kg)	K (g/kg)	Zn (µg/gdm)
T1	23.1^{a}	4.33^{ab}	57.80^{a}	60.00^{a}	12.0^{h}	1.43^{g}	21.50^{k}	10.00^{c}
T2	22.3^{ab}	3.93^{d}	51.00^{c}	50.00^{b}	14.8^{f}	1.50^{e}	30.84^{e}	30.00^{a}
T3	22.1^{ab}	4.36^{a}	41.82^{gh}	60.00^{a}	15.2^{e}	1.67^{c}	30.78^{e}	30.00^{a}
T4	22.2^{ab}	3.89^{e}	44.80^{ef}	50.00^{b}	11.2^{i}	1.33^{h}	20.55^{l}	20.00^{b}
T5	21.9^{c}	3.98^{d}	37.06^{k}	40.00^{c}	14.8^{f}	2.52^{b}	30.95^{d}	20.00^{b}
T6	22.2^{ab}	3.35^{k}	36.30^{l}	30.00^{d}	13.6^{g}	2.56^{a}	30.99^{d}	30.00^{a}
T7	22.0^{ab}	4.31^{ab}	56.10^{ab}	50.00^{b}	13.6^{g}	1.09^{i}	27.15^{h}	20.00^{b}
T8	19.3^{e}	3.75^{f}	38.34^{ik}	30.00^{d}	18.4^{b}	1.09^{i}	23.11^{j}	20.00^{b}
T9	21.0^{cd}	4.35^{a}	56.53^{ab}	40.00^{c}	17.2^{c}	0.55^{k}	25.75^{i}	20.00^{b}
T10	20.1^{d}	3.49^{h}	39.36^{i}	40.00^{c}	19.2^{a}	1.02^{j}	28.33^{g}	20.00^{b}
T11	23.6^{a}	4.32^{ab}	46.16^{e}	40.00^{c}	14.8^{f}	1.48^{f}	36.10^{b}	20.00^{b}
T12	22.2^{ab}	4.15^{c}	42.67^{g}	50.00^{b}	10.0^{j}	1.57^{d}	32.86^{c}	30.00^{a}
T13	21.8^{c}	4.13^{c}	50.58^{cd}	40.00^{c}	16.0^{d}	1.50^{e}	37.24^{a}	30.00^{a}
T14	20.2^{d}	3.55^{g}	37.74^{g}	30.00^{d}	12.0^{h}	0.24^{l}	30.52^{f}	20.00^{b}
Mean	21.7	3.97	45.44	43.72	0.80	1.40	29.04	22.86
LSD(0.05)	00.1	0.02	0.6	0.02	0.03	0.01	0.12	0.11
CV (%)	0.47	0.47	1.34	0.15	0.52	0.42	0.29	0.02

Where, N: Nitrogen, P: phosphorus, K: potassium, Zn: zinc and B: boron; Means sharing the same letter do not differ significantly at P ≤0.05 according to the LSD test.

Agronomic efficiency is the amount of additional yield produced for each additional kg of fertilizer applied (Mengel and Kirkby, 2001); whereas apparent recovery efficiency is a measure of the ability of the crop to extract nutrients from the soil. The highest improvement of agronomic efficiency (9.01 kg kg^{-1}) and apparent recovery efficiency (117.5%) were obtained from treatment that received 14N 21P_2O_5 15K_2O 6.5S 1.3Zn 0.5B, followed by 23N 23P_2O_5 8.2S 1.2Zn blended fertilizer (Table 3). This is due to the nutrient uptake increased through application of blended of macronutrients with micronutrients in appropriate form of fertilizer to nutrient deficient soil as a result enhanced the nutrient use efficiency of teff as well as increased its grain productivity. This is because of the effectiveness of Zn functions in plant physiology, including protein and tryptophophan synthesis, carbohydrates metabolism, activated enzyme carbonic anhydrase, synthesis of RNA, ribosome functions (Uchida, 2000). Similar to this finding, Jones *et al.,* (2011) stated matching appropriate essential macronutrients and micronutrients with crop nutrient uptake could optimize nutrient use efficiency and crop yield. Fertilizer use efficiency for different crops increased by the application of suitable micronutrients (Malkouti, 2008). However, the highest physiological nutrient use efficiency (331.82 kg ha^{-1}) was recorded from treatment that received 138 kg N ha^{-1} whereas the lowest of physiological nutrient use efficiency obtained from application of 92 kg N ha^{-1} + 55 kg P ha^{-1} +75 kg K ha^{-1}. In general, improving the nutrient concentration of cereal crops particularly teff in micronutrient deficient soil using a mixture of all essential plant nutrients in adequate and balanced form of fertilizer absolutely enhance the total nutrient (N, P, K and Zn) uptake because of that crop productivity is increased.

Table 3. Effects of rates of NPK and blended fertilizers on total nutrient uptake, AE, ARE and PNE of teff

Treatment code	Grain Yield (Kg/ha)	Straw Yield (Kg/ha)	Total nutrient uptake				Nutrient Use efficiency		
			N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (kg/ha)	AE (kg/kg)	ARE (%)	PNE (kg/kg)
T1	1608.90^{f}	4249.60^{g}	88.23^{ed}	13.06^{h}	142.64^{n}	0.15^{e}	5.96	52.72	132.24
T2	1607.99^{f}	4273.51^{f}	99.08^{d}	12.73^{i}	164.40^{m}	0.20^{c}	4.71	39.44	106.87
T3	2147.70^{a}	5852.80^{a}	134.38^{a}	18.36^{a}	188.91^{k}	0.24^{a}	9.01	117.5	30.03
T4	1922.00^{b}	5196.50^{c}	103.11^{c}	14.67^{e}	227.37^{f}	0.19^{d}	7.71	74.14	62.97
T5	1574.55^{g}	3455.62^{i}	85.68^{e}	14.97^{b}	203.30^{h}	0.11^{h}	2.32	23.92	91.39
T6	1518.20^{h}	3407.46^{j}	80.08^{f}	13.79^{c}	199.95^{hi}	0.17^{c}	4.10	12.79	331.82
T7	1383.90^{j}	3265.32^{k}	74.87^{gh}	9.54^{k}	234.52^{d}	0.14^{f}	7.70	9.99	250.26
T8	958.13^{k}	3152.6^{m}	76.52^{fg}	6.72^{m}	192.02^{ij}	0.08^{n}	0.07	8.84	1025
T9	1471.20^{i}	3236.30^{l}	86.56^{e}	8.18^{l}	230.31^{e}	0.12^{g}	3.99	15.74	241.51
T10	1671.57^{e}	4005.24^{h}	110.43^{b}	9.93^{j}	215.80^{g}	0.16^{d}	3.37	40.73	67.52
T11	1568.64^{g}	4538.11^{e}	104.2^{bc}	13.50^{g}	283.83^{c}	0.17^{c}	3.19	31.44	96.56
T12	1886.10^{c}	5474.16^{b}	96.58^{d}	16.44^{d}	290.85^{b}	0.23^{b}	4.69	77.92	37.78
T13	1728.21^{d}	4703.05^{d}	112.97^{b}	14.19^{f}	306.65^{a}	0.20^{c}	3.49	77.64	33.99
T14	953^{k}	2811.50^{n}	52.94^{i}	4.04^{n}	183.94^{l}	0.09^{i}	0	0	0
Mean	1571.44	4336.96	49.00	49.00	135.42	1.6	-	-	-
LSD(0.05)	9.7654	16.103	0.18	0.18	0.44	0.003	-	-	-
CV (%)	0.43449	0.2596	0.25	0.25	0.22	0.13	-	-	-

Where, N: Nitrogen, P: Phosphorus, K: Potassium, Zn: Zinc, LSD: least significant difference, CV: Covariance, AE: Agronomic efficiency, ARE: apparent recovery efficiency and PNE: Physiological nutrient efficiency. Means sharing the same letter do not differ significantly at P ≤0.05 according to the LSD test.

CONCLUSION

Since its start in the early 1970's, fertilizer use in Ethiopia has focused mainly on the use and application of nitrogen and phosphorous fertilizers in the form of urea and di-ammonium phosphate (DAP) for almost all cultivated crops. Such unbalanced application of plant nutrients may aggravate the depletion of other important nutrient elements in soils such as K, Mg, Ca, S and micronutrients. Some recent reports indicated that nutrients like K, S, Ca, Mg and micronutrients particularly Cu, Mn, B, Mo and Zn are becoming depleted and deficiency symptoms are being observed on major crops in different areas of the country. Moreover, results of this experiment has substantiated the importance of micronutrients (Zn and B) combination with macronutrients NPK fertilizers in improving nutrient concentration, and uptake and enhancing yield of teff. Finally, by virtue of its greater solubility in the soil, total nutrient uptake and fertilizer use efficiency, and the inclusion of micronutrients in its formulation, application of 200 kg of 14N 21P2O5 15K2O 6.5S 1.3Zn 0.5B blended + 23 kg N ha^{-1} fertilizer brought higher yield (2147.7 kg ha^{-1}), compared to NPK fertilizer has been practiced at the study area. Therefore, this blended fertilizer can be recommended for teff production particularly in the study area as well as it greatly benefit farmers where deficiencies of micronutrients in the soil significantly reduce the productivity of the crops.

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