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Response of tef (*Eragrostistef*) to foliar application of micronutrients in Central Rift Valley of Ethiopia

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The present study was carried out to investigate effect of foliar application of micronutrients on yield and yield components of tef(*Eragrostistef*) Gemechis variety, in three districts; Boset, Adama and Dodota during 2014-2015. The trial was laid out in a randomized complete block design in three replicates. Seven treatments comprising chelates of four micronutrients viz., Copper (Cu), Zinc (Zn), Iron (Fe), and Manganese (Mn) separately, combination of these chelate micronutrients, with NPK (nitrogen, phosphorus and potassium), NP (nitrogen and phosphorus) and NPK were evaluated. The chelated blended type fertilizers were foliar applied at rate of 1.12 kg ha^{-1} in 600L of water with recommended rates of NPK (41N, 46 P_2O_5 and 60 K_2O). The result revealed that at Melkassa and Adulala significantly high ($p< 0.05$) tef yield 1350 $kgha^{-1}$ and 1991.7 $kgha^{-1}$ were obtained by the application of Cu respectively. At Dodota significantly high ($p< 0.05$) tef yield 1920.8 $kgha^{-1}$ was obtained by the application of Mn. At Wolenchiti plant height and panicle length significantly affected by the application of Zn and Mn however, the grain yield and biomass yield was not significantly affected by the foliar application of micronutrients. Partial budget analysis was also carried out to identify the rewarding treatment for economic production of tef, at Melkassa the application of NPK with or without micronutrients have no meaningful economic advantage over the recommended NP fertilizers. At Adulala and Dodota, the highest net benefit 26,757 and 25,736.5 $ETBha^{-1}$ were obtained respectively with high Marginal Rate of Return (MRR) greater than 100% by the application of NPK with micronutrients.

Key words:chelates, foliar spray, Micronutrient, tef variety (Gemechis), net benefit, Ethiopia

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INTRODUCTION

Cereals are the major food crops in Ethiopia both in terms of the area they covered and total production. Out of the total grain crop area, 79.38% was under cereals. Tef, maize, sorghum and wheat took up 24.31%, 16.08%, 13.52 % and 12.94% of the grain crop area, respectively (CSA, 2014). However, tef was the first in its area coverage, its average grain yield was 1,465 $kgha^{-1}$.

Fertilizer use in Ethiopia has focused mainly on the use and application of nitrogen and phosphorous fertilizers in the form of di-ammonium phosphate (DAP) and urea for almost all cultivated crops for both market and food security purposes for the last several years. When micronutrients are not applied in combination with common fertilizers, fertilizing soils with macronutrients are likely to encourage disparity between these nutrient groups and individual nutrients. Nearly 50% of the soils cultivated for cereal production Worldwide have low levels of plant-available zinc (Zn) (Graham and Welch, 1996). Iron (Fe) deficiency is often seen in high pH and calcareous soils in arid regions. Soils that have high bicarbonate levels may enhance Fe deficiency, also Zn and manganese (Mn) availability decrease with increasing soil pH as described by Havlin et al. (2005). It has been reported that, in spite of favorable developments in the use of nitrogen and phosphorus fertilizers to increase crop production, two to six times more of the micronutrients are being removed annually through crop harvest from the soil than are applied to it (Katyal and Randhawa, 1983). This is particularly true in countries like Ethiopia where there is no micronutrient application in the form of chemical fertilizer or organic amendments.

Micronutrient deficiencies are more widely recognized in tropical soils than before (Asgelil *et al*., 2007). Since the availability of micronutrients is influenced by soil reaction, an important strategy for increasing micronutrient concentration in grains is fertilization with soil or foliar application (Cakmak 2002).

Responses to application of micronutrients were reported elsewhere. In Australia, it was found that Zn-deficient wheat plants were more susceptible to takeall infection than Zn-adequate plants (Brennan, 1992). An interesting research result in Turkey indicated that grain yield from seeds of bread wheat with high zinc content was significantly higher than seeds of low zinc content, indicating the importance of Zn for grain yield increase (Yilmaz *et al*.,1997). A 2-years experiment results in southeast Iran showed that foliar application of Zn, Fe and Mn on wheat crop increased the concentration of the respective micronutrients in wheat grain (Pahlavan-Rad and Pessarakli, 2009). Korzeniowska and Stanisławska-Glubiak (2011) also depicted 20% wheat grain yield was increased by foliar application of copper sulfate.

However, the study on the effect of micronutrients on crop yield in Ethiopia is scanty. Therefore, this study was initiated to evaluate the response of tef to some micronutrients in tef grower Districts of central Rift Valley of Ethiopia.

OBJECTIVE

To determine the response of tef yield and yield components to micronutrient (Zinc, Copper, Manganese, Iron) foliar applicationsunder CRV soil types.

MATERIALS AND METHODS

Area description

The study was conducted on farmers' field in three Districts namely, at Boset (Welenchiti), Adama (Adulala and Melkassa), Dodota (Dera) on- station and (Figure 1) from 2014-2015 in two consecutive cropping seasons Ababa. In Wolenchit, (add in before "Wolenchiti"), situated some 120 km away from Addis in Boset District, two trials (one on-farm and one at sub-station) were conducted. Geographically the sub-station was located at latitude of 8.668395 North and longitude of 39.444081 East at the elevation of 1441masl. Adulala and Melkassa are situated some 100 and 107 km away from Addis Ababa, respectively at Adama District on the way to Assela town. One on-farm and one on-station trials were conducted. The experiment conducted at Adulala was at latitude of 8.473193 North and longitude of 39.300586 East at the altitude of 1650 masl, and Melkassa(MARC) was located at 8.418250 North, 39.321473 East with altitude of 1550masl. Derais situated some 117 km away from Addis Ababa at Dodota District. Only one on-farm trial was conducted. The geographical location of on-farm field of Dera was 8.291515 North and 39.314331 East altitude of 1710 masl. The annual rainfall, the maximum and minimum temperature of the study areasand map of the locations are indicated in Table 1.

METHODS

Treatment arrangement and preparation of Spray Solutions

The gross experimental plot size was 5m by 5m from which 3m by 3m was harvestable area. All agronomic practices, macro-nutrient fertilizer application, and other crop management practices were as per recommended for specific area and test crop. A recommended seed rate 25 kg ha^{-1} of tef variety Gemechis was planted in broadcast. The detail treatment plan for the application and appropriate treatment application period (crop development stage) were as indicated in Table 2. The treatments were arranged in randomized complete block design (RCBD) with three replications. Application of micronutrients were based on the product formulation andrecommendation.

A full basal dose of 18kg N ha^{-1} from DAP, 46 kg P_2O_5 ha^{-1} from DAP agronomic recommendation of Tef, additionally 60 kg K_2O ha^{-1} from murate of potash (KCl) was applied as one application and 25kg N $ha^{-1}$from urea was top-dressed after two weeks in broadcast. Four micronutrients (copper, zinc, iron, manganese and mixture of all) at a single rate alone in the form of blended type were applied at the following two stages:

i. After 21 days of emergence.
ii. Before panicle initiation.

Cu chelate (14% Cu), Zn chelate (14% Zn), Mn chelate

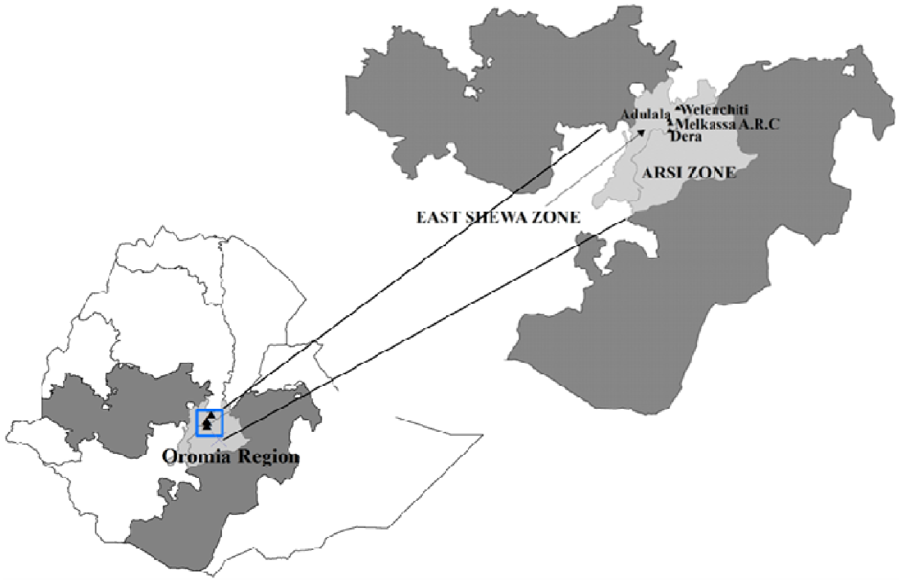

Figure 1. Study area location map

Table 1. Rainfall and temperature data of the testing or near the testing sites during the study period

Location	Year	Rainfall (mm)	Maximum temperature (°C)	Minimum temperature (°C)
Wolenchiti	2014	797.8	30.6	15.0
	2015	621.0	31.5	15.4
Melkassa/Adulala/Dera[1]	2014	791.5	29.3	15.1
	2015	483.3	30.3	14.9

[1] The rainfall and temperatures data were from the weather station at MARC. Both Adulala and Dera are located within about 7-10 kms from this weather station**.**

(13% Mn), Fe chelate (13.2% Fe) at the rate of 1.12 kg $ha^{-1}$and mixture of all of these (Cu+Zn+Fe+Mn) at half of the product recommendation to avoid high concentration injury. The volume of water (1.5 Liters per plot) was estimated by calibrating the average volume of water required to wet completely the tef plant of each plot. The spray solution was prepared for each micronutrient in five well labeled 2 liters polyethylene manual sprayers at the rate of 1.12kg ha^{-1} in 600 liters of water according to the product recommendations 1kg of the product mixed with 500L water. Water without micronutrient was also applied to all the control plots to avoid the wetting effect difference of the tef plots due to spray. Detail of treatment combinations are given in Table 2.

Sample collection

Composite soil samples were collected from 0-15 cm depth before planting from all experimental sites using auger. Soil sub-samples of each experimental sites were mixed in plastic bags to make one composite sample per trial site that makes a total of four composite samples.

Thirty to fifty above ground whole plant samples were collected from both treated and untreated plots at panicle initiationas indicated by Mills & Jones (1996) for wheat. The samples were kept in paper bag, and were well managed, labeled and then transported to MARC soil laboratory.

Analytical methods

The soil samples were air-dried, crushed with mortar and pestle, passed through 2 mm wire sieve for various physico-chemical parameters analysis.

The air-dried whole plant Tef samples were ground to pass a 2 mm sieve. To avoid contamination, the samples were stored in plastic bags. The samples were again oven dried at 75 °C for 24 hours until it maintained constant weight and cooled in desiccators for 2 hour. Then,5g of each samples weighed were ashed by muffle, raising the temperature slowly up to 450°C (about 2.5h) and maintaining this temperature

Table 2. Treatment setup.

Treatment No	Treatments	Other Fertilizers ha^{-1}	Zn	Cu	Fe	Mn
		kg/ha	kg ha^{-1} in 600 L of water			
1	Zn_0, Cu_0, Fe_0, Mn_0, $(Zn+Cu+Fe+Mn)_0$	41N, 46 P_2O	--	--	--	--
2	Zn_0, Cu_0, Fe_0, Mn_0, $(Zn+Cu+Fe+Mn)_0$	41N, 46 P_2O_5,60K_2O	--	--	--	--
3	Zn_0, Cu_1, Fe_0, Mn_0, $(Zn+Cu+Fe+Mn)_0$	41N, 46 P_2O_5,60K_2O	--	1.12	--	--
4	Zn_1, Cu_0, Fe_0, Mn_0, $(Zn+Cu+Fe+Mn)_0$	41N, 46 P_2O_5,60K_2O	1.12	--	--	--
5	Zn_0, Cu_0, Fe_1, Mn_0, $(Zn+Cu+Fe+Mn)_0$	41N, 46 P_2O_5,60K_2O	--	--	1.12	--
6	Zn_0, Cu_0, Fe_0, Mn_1, $(Zn+Cu+Fe+Mn)_0$	41N, 46 P_2O_5,60K_2O	--	--	--	1.12
7	Zn_0, Cu_0, Fe_0, Mn_0, $(Zn+Cu+Fe+Mn)_1$	41N, 46 P_2O_5,60K_2O	0.56	0.56	0.56	0.56

overnight. The ash samples were moistened with a few drops of water and covered with a glass for the determination of Cu, Fe, Mn, and Zn.

Soil texture, bulk density, pH, EC, organic carbon, total nitrogen, and available phosphorus were determined at MARC soil laboratory. Other chemical parameters including soil exchangeable cations (K, Na, Ca, Mg), Cation exchange capacity (CEC), and Zinc (Zn), Copper (Cu), Iron (Fe) and Manganese (Mn) in both soil and plant samples were determined at Debrezeyit Agricultural Research Center soil laboratory.

Particle size distribution of the soil samples was determined by hydrometer method (Bouyoucos, 1962). Soil bulk density was determined on the undisturbed core sampling method after drying the soil samples in an oven at 105°C to constant weights (Blake and Hartge, 1986). Potentiometric method using a glass calomel combination electrode was used to measure pH of the soils in water suspension in a 1:2.5 (soil: water ratio) (Van Reeuwijk, 1992). Electrical conductivity (EC) was measured using a conductivity meter from the same soil water suspension extract. The Walkley and Black (1934) wet digestion method was used to determine soil organic carbon (OC) content. Total nitrogen content of the soil was determined by wet-oxidation procedure of the Kjeldahl method (Bremner and Mulvaney, 1982). Available P was determined using the standard Olsen *et al.* (1954) extraction methods. The absorbance of available P extracted was measured using spectrophotometer after colour development.

Exchangeable cations (Ca, Mg, K and Na) were determined after extracting the soil samples by 1N neutral ammonium acetate (1N NH_4OAc) solution adjusted to a pH 7.0. Exchangeable Ca and Mg in the extract were measured by atomic absorption spectrophotometer (AAS) whilst K and Na were determined using flame photometer from the same extract (Okalebo et al., 2002). Cation exchange capacity of the soils was determined from the ammonium acetate saturated samples through distillation and measurement of ammonium using the modified Kjeldhal procedure as described by Okalebo et al. (2002). Micronutrients (Fe, Mn, Zn, Cu) in both soil and plant samples were extracted by Di-ethyl Tri-amine Penta-acetic acid (DTPA) as described by Tan (1996) and all these micronutrients were measured by AAS.

Data Analysis and Interpretation

Standard values reported by Mills &Jones(1996), for wheat were used as leaf analysis result guide for diagnosing nutrient status of tef, and standard values reported by Clements and McGowen (1994), Bruce and Rayment (1982),Charman and Roper (2007),FAO (2006), Hazelton and Murphy (2007) and Jones andBenton(2003) were used as soil analysis result guide for diagnosing nutrient status of the soil in the test sites.

The collected data were subjected to statistical analysis. Analysis of variance (ANOVA) using SAS9.0 software program, SAS (2003). When significant differences between treatment means were evident from ANOVA, mean separation was computed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez, 1984).

Economic analysis was performed for all locations having statistical significance differences observed among the mean grain yieldsover years, to investigate the economic feasibility of the treatments. Partial budget, dominance and marginal analyses were used. The average yields were adjusted downwards to reflect the difference between the experimental plot yield and the yield farmers expect from the same treatment. The average open market price (ETB kg^{-1}) for tef (16.00) and the official prices of each fertilizers of TSP (17.00), Urea (14.00), potassium chloride (15.00) and the estimated micronutrient fertilizer price (92.00 ETB kg^{-1}) were used for analysis. For a treatment to be considered as worthwhile option to farmers, the minimum acceptable rate of return (MARR) was 100% (CIMMYT, 1988), which is suggested to berealistic.

Table 3. Soil analysis results for 0-15 cm surface soil

Location	Units	Dera	Wolenchiti	Adulala	Melkassa	Status	References
Sand	%	71	63	66	49		
Clay		11	14	8	19		
Silt		18	23	26	32		
T. Class		SL	SL	SL	SCL		
BD	g cm^{-3}	1.18	1.19	1.21	1.12		
pH		8.3	7.6	7.8	7.5		
EC	dS m^{-1}	0.6	0.5	0.2	0.9		
AP	mg kg^{-1}	10.7	14.3	12.6	15.3	low	Clements and McGowen (1994).
TN	%	0.1	0.2	0.1	0.2	low	Bruce and Rayment (1982).
OC		1.6	2.8	1.8	1.1	Low-high	Charman and Roper (2007).
Exch. Na	Cmol (+) kg^{-1}	1.2	1.5	0.2	0.5	low	FAO (2006)
Exch. K		2.6	2.0	3.8	3.0	high	FAO (2006)
Exch. Ca		24.5	18.8	14.4	14.0	high	FAO (2006)
Exch. Mg		4.9	3.2	2.4	3.4	High-v.high	FAO (2006)
CEC		44.1	39.8	21.6	33.0	High-v.high	Hazelton and Murphy (2007)
Cu	mgkg^{-1}	0.5	0.4	0.3	0.7	Low-high	Jones and Benton (2003)
Fe		3.3	1.7	2.3	6.1	Low-high	Jones and Benton (2003)
Mn		16.3	7.4	6.3	12.4	V. high	Jones and Benton (2003)
Zn		2.3	0.1	0.1	0.7	Low-high	Jones and Benton (2003)

RESULT AND DISCUSSION

Soil analysis result

The soil test result as indicated in Table 3 showed that the soils of all experimental sites were sand dominated light in its density, this showed that they have low moisture retention capacity, good aeration and root respiration. The soil reaction indicated that the soil of experimental sites were from slightly to moderately alkaline in reaction, this revealed that the soil of the experimental sites have some fixation problem of nutrients specially phosphorus and most micronutrients,due to this micronutrients were deficient, these is supported experimentally by the soil analysis results (Table 3) and the standards given by Clements and McGowen (1994) and Jones and Benton (2003)

The EC of the experimental sites were low, this indicated that there was no salinity problem in the experimental sites. Other soil parameters like total N, available P, in the experimental sites were inadequate level to grow plants,Organic carbon (OC) content was from low to high, Exchangeable bases except sodium were high as the standards given by Bruce and Rayment (1982), FAO (2006) and Charman and Roper (2007).

Plant analysis result

Whole plant tef sample analysis results of micro nutrients with their status is indicated in Table 4. The analysis result revealed that, at MARC the copper concentration in tef plant dry matter (DM) except in copper treated plot wasbelow 0.1ppm. Iron and manganese were in adequate level before and after foliar spray of these nutrients. However, in zinc treated plot, zinc concentration was improved than in another treatments according to the standard given by Mills and Jones,1996.

Table 4. Plant analysis results in mg kg^{-1}DM and its status

Location	Treatments	NP	NPK	NPK+Cu	NPK+Zn	NPK+Fe	NPK+Mn	NPK+Cu+Zn+Fe +Mn	Mills & Jones, 1996
Melkassa	**Cu**	trace	trace	**6.1**	trace	trace	trace	trace	medium
	Fe	23.1	76.8	56.1	62.3	**145**	111.9	52.3	medium
	Mn	25.1	27.6	28.1	30.2	29.6	**65.2**	32.2	Medium
	Zn	15.2	16.1	14.0	**21.7**	14.5	15.32	17.9	low
Wolenchiti	**Cu**	trace	trace	**5.4**	trace	trace	trace	trace	low
	Fe	39.3	34.45	40.65	56.0	**165.05**	118.1	148.2	medium
	Mn	40.95	42.05	65.3	65.7	68.25	**74.0**	66.65	medium
	Zn	19.9	20.2	20.7	**25.0**	25.87	25.46	24.25	low
Adulala	**Cu**	trace	3.1	**6.7**	2.8	1.5	1.3	3.4	medium
	Fe	81.9	64.3	62.1	83.4	**185.9**	88.0	158.5	medium
	Mn	50.7	56.5	49.7	43.3	52.3	**78.4**	69.7	medium
	Zn	28.5	27.9	29.2	**36.8**	27.8	29.0	26.3	medium
Dodota	**Cu**	trace	trace	**4.2**	trace	trace	trace	trace	low
	Fe	74.1	81.6	73.4	77.6	**97.5**	71.9	87.4	medium
	Mn	46.5	42.0	56.7	89.4	65	**99.9**	55.8	medium
	Zn	26.08	25.52	26.3	**25.71**	24.2	25.3	23.75	low

NB: the micronutrient contents compared to the standards are in bold.

At Wolenchiti the copper concentration except copper treated plot were too small, below 0.1ppm. Other micronutrients were in adequate level,all treatment plots which received micronutrients foliar spray improved the concentration of these nutrients as compared with the standard given by Mills and Jones,1996.

The tef whole plant sample analysis at Adulala revealed that except copper other micronutrients were adequate enough however, the foliar application of these nutrients improved their concentration in the treatment plots with these nutrients. The foliar spray of copper improved the copper concentration in the tef tissue as shown in Table 4.

At Dodota the plant tissue micronutrients content was influenced by the foliar application of these nutrients as shown in Table 4. Foliar spray of copper increased the concentration of copper though, not in adequate amount as compared tothe standards given by Mills and Jones, (1996)

Yield parameters

The combined analysis over years indicated in Table 5 showed that tef grain yield was significantly influenced ($p<0.05$) by the foliar application of copper at Melkassaand Adulala as compared to the NPK control. The grain yield of tefwas increased by 15.7% at Melkassa and 10.65 % at Adulala due to application of Cu. This result is in line to Kumar et al. (2009) finding that showed wheat grain yield increase by the application of Cu at Pakistan. However, other yield parameters of tef were not significantly affected by the treatment factors at Melkassa. High biomass yield and low grain yield at Melkassa was probably due to the high rainfall of the season (Table 1) that caused lodging and low rainfall caused early cease of the grain feeling of tef.

As indicated in Table 5,at Adulala the plant height and biomass yield of tef were significantly increased by the application of NP, NPK and most micronutrients. All potassium with micronutrients treated plots weresignificantly superior to the NP treated plot, the application of grain and micronutrients were increased the tef yield.

At Wolenchiti the analysis of variance (at $p<0.05$ level) revealed that plant height and panicle length were significantly influenced by the application of zinc,

Table 5. Mean tef plant height and panicle length (cm),grain yield and biomass (kg ha^{-1}) as influenced by the foliar application of micronutrients at MARC and Adulala.

	Melkassa				Adulala			
Treat	PH	PL	GY	BM	PH	PL	GY	BM
Rec.NP	106.5	38.8	1166.7^{c}	7750.0	95.3^{ab}	32.6	1436.7^{b}	4683.3^{ab}
Rec.NPK	108.0	39.5	1200.0^{bc}	8916.7	92.1^{b}	33.6	1800.0^{a}	4366.7^{ab}
Rec.NPK+Cu	108.4	42.5	1350.0^{a}	6833.3	99.2^{ab}	33.7	1991.7^{a}	5433.3^{a}
Rec. NPK+Zn	108.9	41.8	1333.3^{ab}	8833.3	93.6^{ab}	32.8	1826.7^{a}	5066.7^{a}
Rec.NPK+Fe	103.1	43.4	1266.7^{abc}	9250.0	100.0^{a}	32.3	1753.3^{a}	4766.7^{ab}
Rec.NPK+Mn	109.3	42.6	1300.0^{abc}	8666.7	92.1^{b}	32.8	1805.0^{a}	3433.3^{b}
Rec.NPK+Zn+Cu+Fe+Mn	106.6	43.0	1250.0^{abc}	8166.7	96.4^{ab}	32.6	1738.3^{a}	4516.7^{ab}
CV(%)	7.75	11.86	9.98	26.54	6.47	6.62	13.85	26.14
$LSD_{<0.05}$	ns	ns	148.3	ns	7.25	ns	286.8	1412.4

BM= biomass yield, GY= grain yield, PH= plant height and PL= panicle length

Table 6. Mean tef plant height and panicle length (cm), grain yield and biomass (kg ha^{-1}) as influenced by the foliar application of micronutrients at Wolenchiti and Dodota.

	Wolenchti				Dodota			
Treatment	PH	PL	GY	BM	PH	PL	GY	BM
Rec.NP	99.83^{b}	35.97^{b}	1646.7	9100	74.27^{b}	23.33^{b}	1106.1^{b}	3052.30
Rec.NPK	104.83^{ab}	38.33^{ab}	1640	9200	81.07^{a}	28.67^{a}	1274.8^{b}	3715.30
Rec.NPK+Cu	108.17^{ab}	39.0^{ab}	1936.7	8333	79.53^{ab}	28.00^{ab}	1577.6^{ab}	3912.60
Rec. NPK+Zn	114.5^{a}	39.17^{ab}	1780	8800	79.67^{ab}	29.87^{a}	1511.4^{ab}	3100.90
Rec.NPK+Fe	101.33^{b}	37.27^{ab}	1696.7	10200	77.53^{ab}	27.8^{ab}	1179.6^{b}	3509.80
Rec.NPK+Mn	112.83^{a}	39.83^{a}	1773.3	9133	81.93^{a}	27.0^{ab}	1920.8^{a}	3570.80
Rec.NPK+Zn+Cu+Fe+Mn	105.03^{ab}	40.33^{a}	1780	9267	80.93^{a}	29.6^{a}	1367.6^{ab}	3808.30
CV(%)	5.72	5.6	10.16	15.49	4.36	9.63	23.03	21.87
$LSD_{<0.05}$	10.85	3.84	ns	ns	6.14	4.75	581.5	ns

manganese and micronutrients mixture however, grain yield and biomass yield were not significantly affected by the foliar application. At Dodota, the analysis of variance showed that plant height, panicle length and grain yield of tef significantly increased by the foliar application of micronutrient (Table 6). The application of Manganese at Dodota significantly improved plant height and grain yield of tef at p<0.05 level as compared to the NP and NPK control respectively. The application of zinc increased the panicle length significantly at p<0.05 level. However, biomass yield was not significantly influenced by the foliar application of micronutrients.

Generally, the grin yield of tef per ha was found low as compared to its agronomic potential probably duet to rainfall amount and distribution during the study period (Table 1).

In 2015 due to El Nino lower rainfall and higher maximum temperature were recorded in both stations. When compared to the two years rainfall data more than 170mm at Wolenchiti and 300mm at Melkassa, Adulala and Dera between 2014 and 2015 were observed.

In both seasons due to high and low rainfall the tef caused grain yield affected in all test sites caused. High rainfall causes lodging and low rainfall causes early cease of the tef growth before completing panicle exertion (grain filling), due to these two extremes the tef grain yield didn't express agronomic potential.

Partial budget analysis

Melkassa

Partial budget analysis was carried out to identify the rewarding treatment for economic production of tef at Melkassa. Considering results of the economic analysis, the economic gain contributed by the different fertilizer rates did not pass the threshold level of MRR=100, implying that neither the foliar application of micronutrient (1.12kg ha^{-1}) with 41N, 46 P_2O_5 and 60K_2O (kg ha^{-1}) fertilizers nor the application of NPK has shown a significant economic advantage over the NP fertilizers (Table 7). Hence, both the application of NPK with or

Table 7: Partial budget analysis of Micronutrients with and without NPK on tef at Melkassa

Rate (kg ha^{-1})	GY	10%AGY	GFB	TC V	N Benefit	MRR%
41N46P$_2$O$_5$	1166.70	1050.03	16800.48	00000	16800.50	
41N46P$_2$O$_5$60K$_2$O	1200.00	1080.00	17280.00	1500.00	15780.00	D
41N46P$_2$O$_5$60K$_2$O+1.12 Cu	1350.00	1215.00	19440.00	1923.04	17517.00	37.26
41N46P$_2$O$_5$60K$_2$O+1.12Zn	1333.30	1199.97	19199.52	1923.04	17276.50	D
41N46P$_2$O$_5$60K$_2$O+1.12Fe	1266.70	1140.03	18240.48	1923.04	16317.40	D
41N46P$_2$O$_5$60K$_2$O+1,12Mn	1300.00	1170.00	18720.00	1923.04	16797.00	D
41N46P$_2$O$_5$60K$_2$O+0.56(Cu,Zn,Fe,Mn)	1250.00	1125.00	18000.00	2026.04	15974.00	D

Table 8: Partial budget analysis of Micronutrients with and without NPK on tef at Adulala

Rate (kg ha^{-1})	GY	10%AGY	GFB	TC V	N Benefit	MRR%
41N46P$_2$O$_5$	1436.70	1293.03	20688.48	0.000	20,688.5	
41N46P$_2$O$_5$60K$_2$O	1800.00	1620.00	25920.00	1500.00	24,420.0	248.77
41N46P$_2$O$_5$60K$_2$O+1.12 Cu	1991.70	1792.53	28680.48	1923.04	26,757.4	552.53
41N46P$_2$O$_5$60K$_2$O+1.12Zn	1826.70	1644.03	26304.48	1923.04	24,381.4	D
41N46P$_2$O$_5$60K$_2$O+1.12Fe	1753.30	1577.97	25247.52	1923.04	23,324.5	D
41N46P$_2$O$_5$60K$_2$O+1,12Mn	1805.00	1624.50	25992.00	1923.04	24,069.0	D
41N46P$_2$O$_5$60K$_2$O+0.56(Cu,Zn,Fe,Mn)	1738.30	1564.47	25031.52	2026.04	23,005.5	D

Table 9: Partial budget analysis of Micronutrients with and without NPK on tef at Dodota

Rate (kg ha^{-1})	GY	10%AGY	GFB	TC V	N Benefit	MRR%
41N46P$_2$O$_5$	1106.1	995.49	15927.84	0.0000	15,927.80	
41N46P$_2$O$_5$60K$_2$O	1274.8	1147.32	18357.12	1500.00	16,857.10	61.95
41N46P$_2$O$_5$60K$_2$O+1.12 Cu	1577.6	1419.84	22717.44	1923.04	20,794.40	930.71
41N46P$_2$O$_5$60K$_2$O+1.12Zn	1511.4	1360.26	21764.16	1923.04	19,841.10	D
41N46P$_2$O$_5$60K$_2$O+1.12Fe	1179.6	1061.64	16986.24	1923.04	15,063.20	D
41N46P$_2$O$_5$60K$_2$O+1,12Mn	1920.8	1728.72	27659.52	1923.04	25,736.50	2,098.94
41N46P$_2$O$_5$60K$_2$O+0.56(Cu,Zn,Fe,Mn)	1367.6	1230.84	19693.44	2026.04	17,667.40	D

without micronutrients have no meaningful economic advantage over the recommended NP fertilizers in the production of tef at Melkassa.

Adulala

Partial budget analysis at Adulala revealed that foliar application of copper (1.12kg ha^{-1})with 41N, 46 P$_2$O$_5$and 60K$_2$O (kg ha^{-1}) fertilizers provided the highest net benefit (26,757.4ETBha^{-1}) with high marginal rate of return (MRR) of 552.53% which is greater than the minimum acceptable rate of return (MARR) = 100 (CIMMYT, 1988)(Table 8). Hence, for each birr invested in the production of tef, farmers could earn birr 5.52 after recuperating their cost of production at Adulala.

Dodota

Partial budget analysis was carried out for economic production of tef at Dodota. Hence, the foliar application of Mn (1.12kg ha^{-1})with 41N, 46 P$_2$O$_5$and 60 K$_2$O (kg ha-1) fertilizers provided the highest net benefit (25,736.5ETBha^{-1}) with high MRR of 2,098.94 % which is greater than the (MARR) = 100 (CIMMYT, 1988)(Table 9). Hence, for each birr invested in the production of tef, farmers could earn birr 20.98 after recovering their cost of production at Dodota.

CONCLUSION AND RECOMMENDATION

On the basis of present study, it is revealed that tef yield and yield componentsin the central rift valley of Ethiopia, responded well to foliar applications of micronutrients.

Foliar application of copper, manganese and zinc micronutrients significantly increased the tef yield of the testing sites over the control as a result of improved leafmicronutrients status of the tef. Foliar application of micronutrients atconcentration of 1.12 kg $ha^{-1}$with NPK fertilizers improved the tef yield and yield components as compared to the control.

Hence, it is recommended that foliar application of copper and manganese fertilizers at the rate of 1.12kg in 600L of water ha^{-1} at Adulala and Dodota respectively statistically and economically improved the tef grain yield and the farmers of the study area benefited in the production. At Melkassa foliar application of micronutrients have a significant effect in tef production though economically not significant. Furtherresearch for the determination of economic rate ofapplication for the combined use of the deficientmicronutrients is required to improve the tef production.

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REFERENCES

Asgelil Dibabe, Taye Bekele and Yesuf Assen, 2007. The status of micro-nutrients in nitisols, vertisols, cambisols and Fluvisols in major maize, wheat tef and citrus Growing Areas of Ethiopia

Blake G.R. and K.H. Hartge, 1986.Bulk density. In: Klute A, (ed). Methods of soil analysis part 1 Physical and Mineralogical methods. Agronomy Monograph 9. Madison USA p. 363-375

Bouyoucos, G.J., 1962. Hydrometer Method Improvement for Making Particle Size Analysis of Soils. Agron. J., 54: 179-186.

Bremner, J.M., and C.S. Mulvaney, 1982. Nitrogen – total. p.595-642. In A.L. Page et al. (ed.) Methods of soil analysis. Part 2.Chemical and microbiological properties.SSSA, Madison, Wisconsin.

Brennan RF., 1992. The effect of zinc fertilizer in take-all and grain yield of wheat grown on Zn- deficient soil Esperawe Region, Weastern Australia. Fertilizer Research. 31: 215-219

Bruce, R. C., and Rayment, G. E., 1982. Analytical methods and interpretations used by the Agricultural Chemistry Branch for Soil and Land Use Surveys.Queensland Department of Primary Industries. Bulletin QB8 (2004). Indooroopilly, Queensland.

Cakmak, I., 2002. Plant nutrition research: Priorities to meet human needs for food in sustainable ways. Plant and Soil 247:3–24.

Charman, P. E. V., and Roper, M. M., 2007.Soil organic matter. In 'Soils – their properties and management'. 3rd edn.(Eds P. E. V. Charman and B. W. Murphy.) pp. 276–285. (Oxford University Press: Melbourne.)

CIMMYT(International maize and wheat improvement center), 1988. From agronomic data to farmers recommendations.Economics training manual.Completely revised edition. D.F. Mexico.

Clements, B., and McGowen, I., 1994. Strategic fertilizer use on pastures.NSW Agriculture. Agnote Reg. 4/57, Orange, NSW.

CSA (Central Statistics Agency), 2014. Agricultural sample survey 2013/2014 Volume I. Report on area and production of major crops (privet peasant holdings, meher season) Statistical Bulletin 532, Addis Ababa

FAO (Food and Agriculture Organization), 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16, Rome.

Gomez K. A and AA.Gomez, 1984.Statistical Procedures for Agricultural Research.Second Edition. John Wiley &Sons, Inc. USA

Graham, R. D., and R. M. Welch, 1996.Breeding for staple food crops with high micronutrient density. In Worker papers on agricultural strategies for micronutrients, ed. H.D. Bouis, 1–72. Washington, DC: International Food Policy Research Institute.

Havlin, J. L., J. D. Beaton, S. L. Tisdale, and W. L. Nelson, 2005. Soil fertility and fertilizer: An introduction to nutrient management. Upper Saddle River, N.J.: Pearson Education, Inc.

Hazelton, P. and B. Murphy, 2007.Interpreting soil test results: 2nd Edition.CSIRO Publishing. 152p.

Jonesand Jr. Benton, 2003. Agronomic Handbook: Management of Crops, Soils, and Their Fertility. CRC Press LLC, Boca Raton, FL, USA. 482p.

Katyal JC, Randhawa NC, 1983.Micro-nutrients. FAO fertilizer and plant nutrition bulletin No. 7. Rome, Italy.

Korzeniowska J.and E.Stanisławska-Glubiak (2011).The effect of foliar application of copper on content of this element in winter wheat grain. Polish *Journal of Agronomy*4, 3–6

Kumar,R., N.K. Mehrotar, B.D. Nautiyal, P. Kumar and P.K. Singh. 2009. Effect of copper on growth, yield and concentration of Fe, Mn, Zn and Cu in wheat plants (*Triticumaestivum* L.), J. Environ. Biol. 30:485-488.

Mills HA, Jones JB Jr. 1996. Plant analysis handbook II: a practical sampling, preparation, analysis, and interpretation guide. Athens (GA): Micro-Macro Publishing.

Okalebo, J.R., K.W. Gathua, and P.L. Womer, 2002. Laboratory methods of sol and plant analysis: A working manual, 2nd edition. TSBF-CIAT and SACRED Africa, Nairobi, Kenya. 128p.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean, 1954.Estimation of available phosphorus in soils by extraction with sodium carbonate. USDA Circular 939: 1-19.

Pahlavan-Rad M. R. and PessarakliM, 2009. Response of Wheat Plants to Zinc, Iron, and Manganese Applications and Uptake and Concentration of Zinc, Iron, and Manganese in Wheat Grains. *Communications in Soil Science and Plant Analysis, 40: 1322–1332.*

SAS, 2003. Statistical analysis system: version 9.0, SAS Institute Inc, Cary, North Carolina, USA.

Tan, K.H., 1996. Soil Sampling, preparation, and analysis. Marcel Dekker, Inc, New York.

Van Reeuwijk, L.P., 1992. Procedures for Soil Analysis, 3rd Ed. International Soil Reference and Information Center (ISRIC), Wageningen, the Netherlands. 34p.

Walkley A and CA Black, 1934.An examination of the Digestive method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* 37:29-38

Yilmaz A, H Ekiz, I Gultekin, B Torun, S Skaranlik and I Cakmak, 1997.Effect of seed zinc content on grain yield and Zn concentration of wheat grown in zinc-deficient calcareous soils. In:T Ando et al. (Eds.) Plant Nutrition-for Sustainable food Production and Environment. Pp 283-284